TITLE

Prothioconazole Minor Use Registrations Petition for 3 Years Extension of Exclusive Use Data Protection Provided under FIFRA Section 3(c) (1) (F) (ii)

COMPANY PRODUCT CODE

Prothioconazole

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GUIDELINE REFERENCE

None

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No claim of confidentiality is made for any information contained in this study on the basis of its falling within the scope of FIFRA, Section 10(d)(1)(A)(B), or (C) in USA.

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Company: Bayer CropScience AG

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Date: April 30, 2014

The above statement supersedes all other statements of confidentiality that may occur elsewhere in this report.

Good Laboratory Practice Statement

This report does not meet the requirements for EPA FIFRA Good Laboratory Practice Standards, 40 CFR Part 160, and differs in the following way:

(1) This report is not subject to Good Laboratory Practices.

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19.0 Appendices (separate document)

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1.0 Introduction

Bayer CropScience hereby respectfully petitions EPA to extend the period of exclusive data use for Prothioconazole fungicide by 3 years, by applying the provision of FIFRA Section 3(c) (1) (F) (ii).

FIFRA Section 3(c) (1) (F) (ii) states that:

> *The period of exclusive data use provided under clause (i) shall be extended 1 additional year for each 3 minor uses registered after the date of enactment of this clause and within 7 years of the commencement of the exclusive use period, up to a total of 3 additional years for all minor uses registered by the Administrator if the Administrator, in consultation with the Secretary of Agriculture, determines that, based on information provided by an applicant for registration or a registrant, that –*
>
> > *(I) there are insufficient efficacious alternative registered pesticides available for the use;*
> >
> > *(II) the alternatives to the minor use pesticide pose greater risks to the environment or human health;*
> >
> > *(III) the minor use pesticide plays or will play a significant part in managing pest resistance;*
> >
> > *(IV) the minor use pesticide plays or will play a significant part in an integrated pest management program.*

1.1 Prothioconazole Registrations

Prothioconazole technical (EPA Reg. No. 264-824) was first registered by U.S. EPA on March 14, 2007. The formulation of Prothioconazole – Proline 480 SC (EPA Reg. No. 264-825) contains 4 lbs Prothioconazole per gallon and is registered and approved for use in a variety of crops including the following minor use crops detailed in this document: watermelon, summer squash, cucumber, cantaloupe, pumpkin, lowbush blueberry, cranberry, currant, gooseberry, loblolly pine (nursery), slash pine (nursery), longleaf pine (nursery), hardwoods (nursery), chickpea, crambe, buckwheat, and popcorn.[1]

Recent label expansion uses for watermelon, summer squash, cucumber, cantaloupe, pumpkin, lowbush blueberry, cranberry, currant, and gooseberry were approved in December of 2013, within the first seven years of original registration, and were initiated due to the favorable fit with the extension of exclusive use program.

Prothioconazole in its formulated product Proline 480 SC provides control of diseases for which there are few or no effective controls, particularly certain challenging species of *Sclerotinia*, *Sclerotium*, *Cylindrocladium, Cronartium*, *Valdensinia,* and *Fusarium*.

In some instances the active ingredient is already acting commercially as a viable substitute for pesticides or other control measures that pose a greater risk to human safety and/or the environment, including the less desirable and hazardous soil fumigants **methyl bromide, metam sodium, 1,3-dichloropropene** and **chloropicrin**. Proline 480 SC has a minimally restrictive "CAUTION" labeling, a short 12 hour restricted-entry interval for all uses, and flexible a 30 day rotational restriction to crops not on the label.[1]

Prothioconazole has good curative activity so growers may in certain cases wait to see initial signs of disease by scouting before opting to spray. If the disease does not occur this reduces the environmental impact of making an application. It further fits current integrated pest management (IPM) programs because it is not harsh on beneficial organisms when compared to the fumigant uses it replaces. Details of how Prothioconazole meets at least one of the four qualifying criteria in nine or more crops are described in the following sections.

1. **PROLINE 480 SC label 2013.** (Appendix 1)

1.2 <u>Prothioconazole Mode of Action and Pest Resistance and Implications for Pest Resistance Management</u>

Considering that criterion III emphasizes management of pest resistance, the following is a brief description of the mode of action of Prothioconazole.

Prothioconazole is an acropetally systemic fungicide that controls a variety of diseases in both large acreage and small acreage crops. The mode of action of Prothioconazole for fungal control is sterol biosynthesis inhibition (SBI).[1] Within the SBI fungicides, Prothioconazole is a member of SBI class 1, which contains the demethylase-inhibitor fungicides (DMI). The DMI are known to growers as the "Group 3" products as described by the fungicide resistance management action committee (FRAC).

DMI work specifically by inhibiting C^{14}- demethylation of 24 methylene-dihydro-lanosterol during fungal sterol biosynthesis and all are considered to face a medium risk of resistance development.[1,2] Other DMI important to U.S. agriculture include examples: Cyproconazole, Difenoconazole, Metconazole, Myclobutanil, Propiconazole, Tebuconazole, Tetraconazole, Triadimefon, Triadimenol, and Triticonazole.[1]

DMI fungicides play an important *rotational* role in agriculture today. Despite its single site mode of action, resistance to Group 3 fungicides is described as a "medium risk". Resistance is horizontal - it involves multiple genes and is known to develop slowly over time, and as a result, DMI resistance follows a continuous selection over time or "stepwise loss of efficacy."[2] Historically, if selection pressure is lessened, either through the elimination of or a reduction in the number of Group 3 fungicides applied, a partial shift to increased sensitivity has been observed.[2] This contrasts with the other single-site fungicides that growers are strongly reliant upon - the respiration inhibitor fungicides of either Group 7 or Group 11 for which resistance typically develops quickly and does not reverse when fungicide selection pressure is removed or reduced. Agriculture today is highly dependent on single site Group 7, 11, and 3 fungicides as the key alternatives to protectant / multi-site fungicides which may be weak on certain damaging pathogens. Furthermore, the multi-site fungicides typically require much higher (in this case roughly 5x higher) active ingredient use rates and more frequent spray application resulting in higher fuel and time costs due to weathering.

As a DMI, Prothioconazole generally would be expected to be cross-resistant with and only with other DMI fungicides. However, to date the authors know of no field relevant resistance to Prothioconazole with any pathogen in the U.S. With Prothioconazole the available long-term sensitivity monitoring studies give no hint of relevant sensitivity shifts of any studied pathogen of dicot crops. Efficacy is retained even for uses where other DMI provide weakened disease control due to resistance. For example, in peanut, Tebuconazole products, launched in mid-90's, now perform so poorly on the two species of *Cercospora* spp. leafspots that Tebuconazole (numerous brands) must be tankmixed with other fungicides by growers, typically Chlorothalonil, to achieve sufficient foliar disease control. However, Prothioconazole remains an effective tool for exceptional leafspot control. Similarly, in sugarbeet, *Cercospora* spp. resistance to Tetraconazole (Eminent) is widespread and growers have mostly switched to more effective DMI's such as Prothioconazole, which is yet unaffected by the DMI-resistant strains. Why Prothioconazole is not affected by the current mutations was hypothesized by Kuck and Mehl, in 2004.[4] Since then computer modeling and substrate binding studies have indicated that Prothioconazole has a different binding site on the CYP51 enzyme compared with other DMI which may explain why it has retained performance where others are weak or ineffective due to a shift in resistance.[3] As a result, Prothioconazole helps reduce further resistant strain selection to the weakening DMI class by offering a more efficacious rotational treatment within the full spray program.

Prothioconazole enters plant tissues and has good curative effects. It may be effectively applied days after an infection has occurred for many diseases such as leafspots, *Ascochyta* spp., rusts, and others. Curative applications help growers who for IPM and/or economic reasons prefer to scout and wait for visible disease before beginning fungicide applications. Furthermore, despite having a short soil half-life - one early season banded soil application of Proline 480 SC in peanut is widely used early season to reduce initial soil borne disease pressures of *Rhizoctonia* spp. and *Sclerotium* spp. with positive effects for the entire growing season. As a result fewer foliar applications are needed to control these diseases throughout the long 140 day growing season.

The authors know of no field relevant cross resistance of Prothioconazole with any other mode of action fungicide including respiration inhibitor fungicides, protectant fungicides, or any fungicide from any other FRAC Group. As a result, Prothioconazole functions as a significant resistance management tools when used correctly per label in rotation. Furthermore, Prothioconazole can function as a resistance management tool even when weaker DMI are registered for use on a specific crop but compromised due to resistance.

1. **FRAC Code List 2010.** (Appendix 3, page 7)

2. **FRAC webpage**. http://www.frac.info/ See *Working Groups* then *SBI fungicides*.

3. **Mechanism of Binding of Prothioconazole to *Mycosphaerella graminicola* CYP51 Differs from That of Other Azole Antifungals.** Epub 2010. Parker et al. Applied and Environmental Microbiology, Feb. 2011, p. 1460–1465. http://www.ncbi.nlm.nih.gov/pubmed/21169436 (Appendix 37)

4. **Prothioconazole: Sensitivity profile and anti-resistance strategy**. Kuck and Mehl. 2004. Pflanzenschutz-Nachrichten Bayer 57/2004, 2 225-236. (Appendix 2)

1.3 Pest Resistance Management Labeling for Prothioconazole

The Proline 480 SC label (Appendix 1) includes voluntary pesticide resistance management language concerning the use of the product to encourage proper usage by growers. The label displays on the front page the FRAC box designator symbol "Group 3 Fungicide" so growers know what other products have the same mode of action and are therefore not ideal rotational partners with Proline 480 SC. The following precautionary text is also included on the Proline 480 SC label which provides basic tactics to avoid resistance development.

> ***"Resistance Management Statement***
>
> *PROLINE 480 SC FUNGICIDE is a Group 3 fungicide which exhibits no known cross-resistance to other fungicide groups. However, fungal pathogens are known to develop resistance to products with the same mode of action when used repeatedly. Any fungal population may contain or develop individuals that are resistant to PROLINE 480 SC FUNGICIDE and other Group 3 fungicides. If Group 3 fungicides are used repeatedly in the same field or in successive years as the primary method of control for targeted diseases, the resistant isolates may eventually dominate the fungal population. Because resistance development cannot be predicted, the use of this product should conform to resistance management strategies established for the crop and use area. Such strategies may include rotation and /or tank mixing with products having different modes of action or limiting the total number of applications per season. Contact your local extension specialist, certified crop advisor, and/or manufacturer for fungicide resistance management and/or integrated disease management recommendations for specific crops and pathogen populations. Bayer CropScience encourages responsible resistance management to ensure effective long-term control of the fungal diseases on this label."*

2.0 Proposed Minor Use Crop Registrations for Prothioconazole that Qualify for Exclusive Use Data Protection

Table 1 (on the following page) lists the minor use crop registrations detailed in this petition including crop planted acres, corresponding MRID number and PRIA dates, qualifying diseases, and the exclusive use data protection criteria satisfied by Prothioconazole. All of the minor use crop candidates were registered within the requisite seven years period prior to March 14th, 2014. All of the crop candidates are grown on less than 300,000 acres per year, as reported by the USDA-NASS or University experts.

2.1 Table 1: Minor Crop Registrations, Planted Acreage, Diseases Controlled by Prothioconazole, PRIA Date and Exclusive Use Data Protection Criteria Satisfied by Prothioconazole

MINOR CROP REGISTRATION	PLANTED ACRES (YEAR)	PRIA DATE (MRID#)	DISEASE(S) CONTROLLED BY PROTHIOCONAZOLE	CRITERIA SATISFIED[A]
Watermelon (*Citrullus lanatus*)	143,400 (2010)	12/18/2013 (48803303)	Fusarium wilt Southern blight	*I, II, III, IV*
Summer squash (*Cucurbita pepo*)	50,200 (2011)	12/18/2013 (48803303)	Fusarium wilt	*I, II, III, IV*
Cucumber (*Cucumis sativus*)	138,000 (2010)	12/18/2013 (48803303)	Southern blight Fusarium wilt	*III, I*
Cantaloupe (*Cucumis melo*)	77,430 (2010)	12/18/2013 (48803303)	Fusarium wilt	*I, II, III, IV*
Pumpkin (*Cucurbita* spp.)	51,300 (2011)	12/18/2013 (48803303)	Southern blight	*III*
Lowbush blueberry (*Vaccinium angustifolium*)	69,610 (2010)	12/18/2013 (48803301)[B]	Valdensinia leaf spot Mummyberry	*I, III, IV*
Cranberry (*Vaccinium macrocarpon*)	38,500 (2011)	12/18/2013 (48803302)	Valdensinia leaf spot Fruit rots	*I,III*
Currant (*Ribes rubrum* and others)	<300,000	12/18/2013 (48803301)[B]	White pine blister rust	*IV*
Gooseberry (*Ribes hirtellum, R. grossularia*)	<300,000	12/18/2013 (48803301)[B]	White pine blister rust	*IV*

(continued)

2.1 <u>Table 1: Minor Crop Registrations, Planted Acreage, Diseases Controlled by Prothioconazole, PRIA Date and Exclusive Use Data Protection Criteria Satisfied by Prothioconazole (continued)</u>

MINOR CROP REGISTRATION	PLANTED ACRES (YEAR)	PRIA DATE (MRID#)	DISEASE(S) CONTROLLED BY PROTHIOCONAZOLE	CRITERIA SATISFIED[A]
Loblolly pine (*Pinus taeda*)	1327 Nursery (2008)	11/29/11 (48526700 48526701)	Pitch canker Rhizoctonia foliar blight Fusiform rust	*I, II, III, IV*
Slash pine (*Pinus elliottii*)	210 Nursery (2008)	11/29/11 (48526700 48526701)	Pitch canker Rhizoctonia foliar blight Fusiform rust	*I, II, III, IV*
Longleaf pine (*Pinus palustrus*)	82 Nursery (2008)	11/29/11 (48526700 48526701)	Pitch canker Rhizoctonia foliar blight Fusiform rust	*I, II, III, IV*
Hardwoods (over 30 species)	65 Nursery (2008)	11/29/11 (48526700 48526701)	Pitch canker Rhizoctonia foliar blight Fusiform rust	*I, II, III, IV*
Chickpea (*Cicer arietinum*)	146,000 (2010)	03/27/07 (46246221)	Ascochyta blight	*III*
Crambe (*Crambe* spp.)	22,000 (1996)	03/27/07 (46246215 46246224)[C]	White mold	*III*
Buckwheat (*Fagopyrum esculentum*)	24,760 (2007)	05/28/10 (46246218 46246219 46246220 47521901 47521903)[D]	Rhizoctonia seed rot and seedling rot	*IV*
Popcorn (*Zea mays* var. *everta*)	201,623 (2007)	05/28/10 (46246218 46246219 46246220 47521901 47521903)[D]	Gray leaf spot Common rust	*III*

[A.] Criterion

(I) there are insufficient efficacious alternative registered pesticides available for the use.

(II) the alternatives to the minor use pesticide pose greater risks to the environment or human health.

(III) the minor use pesticide plays or will play a significant part in managing pest resistance.

(IV) the minor use pesticide plays or will play a significant part in an integrated pest management program.

[B.] MRID number given for Lowbush blueberry, Currant, and Gooseberry, are for data corresponding to Blueberries (representative crop for Crop Subgroup 13-07B).

[C.] MRID numbers given for Crambe are for data corresponding to Canola, which is a representative crop for Crop Subgroup 20.

[D.] MRID numbers given for Buckwheat and Popcorn are for data corresponding to Wheat, Barley and Corn, which are part of Crop Group 15.

Note: Details of how Prothioconazole meets the exclusivity criteria for each minor use are provided in the following sections using the following format.

1.0 <u>Justification of the Need for Prothioconazole to Control Key Diseases in the *Minor crop(s)*</u>

1.1 <u>*Minor crop(s)* acreage</u>

1.2 <u>Exclusive Use Data Protection Criteria Prothioconazole Satisfies in the *Minor Crop(s)*</u>

1.2.1 Criterion met

1.3 <u>References</u>

Note: When the reference is attached within the separate appendix file this is indicated with (Appendix #).

Note: Some references to websites may be accessed when online by clicking the underlined link and the Ctrl key at the same time. APS, CDMS, and Agrian databases may require log in or new user registration to access the search functions.

3.0 Justification of the Need for Prothioconazole to Control Key Diseases in Watermelon

3.1 Watermelon Acreage

With commercial production in roughly 44 states, watermelon (*Citrullus lanatus*) is an important U.S. crop with larger production primarily centered in the states of Texas, Georgia, Florida, and California. In 2010 the planted acreage was reported by the USDA to be 143,400 acres (Table 1).[1] Watermelon acreage is lower than 300,000 per year and qualifies as a minor use crop.

3.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Watermelon

3.2.1 The Prothioconazole use in watermelon for the control of Fusarium wilt satisfies *Criterion I: There are insufficient efficacious alternative registered pesticides available for the use.*

Fusarium wilt of watermelon caused by *Fusarium oxysporum* f. sp*. niveum* is one of the oldest and most economically serious diseases of watermelon in the U.S. and in the world.[2, 3, 10] Fusarium wilt is a devastating *vascular disease and specifically different* from other Fusarium root rots, Fusarium damping off, Fusarium leaf spots, and other general and non-vascular Fusarium rots.[3]

> *"There are currently no fungicides labeled for Fusarium wilt of watermelon. The $328 million watermelon industry is threatened by Fusarium wilt, for which there are few management options."* - ***Egel and Hoke*** [10]

CDMS lists for Fusarium wilt of watermelon two products - Oxidate (hydrogen dioxide)[8] and two formulations of Telone (1,3-dichloropropene) soil fumigant.[5] Oxidate provides a knock down of surface fungi through oxidation and a claimed short lived-protectant barrier, but this is not sufficient for practical disease control. The authors could find no published efficacy trials on the effectiveness of Oxidate on Fusarium wilt. Further, Oxidate was not included as a positive control in the Fusarium wilt screening program conducted by IR-4. For general non-specific control of *Fusarium* spp. there are also listed some phosphorus acid products, but specifically Fusarium wilt control is not claimed and they are not a viable control measure. Additionally, there are general Fusarium seed treatments however these products only protect seedlings during early emergence against root rots and offer no protection to growing plants against Fusarium wilt. Fusarium wilt is not claimed on these seed treatment product labels. Therefore, there are insufficient efficacious alternative registered pesticides available to control Fusarium wilt in watermelon.

Because Fusarium wilt is so difficult to control and causes growers such high crop losses, the IR-4 project (Interregional Research Project No.4) conducted a major research program in 2008 and 2009 to screen fungicide candidates for Fusarium wilt control in watermelon and other cucurbits. IR-4 project 10813 (Prothioconazole for cucurbit) was requested by project clearance request PCR by B. Tanner of Georgia. Eleven Prothioconazole trials from the project are publicly available for download at the IR-4 website.[4] In these IR-4 coordinated research trials, and in additional trials published since, Proline 480 SC has been highly effective in most of the trials. Proline 480 SC has been the only effective product in some of them including a University of Maryland trial conducted by X.G. Zhou where only treatments with Proline 480 SC controlled the disease.[9]

> "*Fusarium wilt was severe in all plots. In nontreated plots, 78% of plants had wilt symptoms by 1 Aug. On 17 July, plots treated with Proline alone had significantly less wilt incidence than nontreated plots. By 1 Aug, the differences were more pronounced: all plots where Proline was applied alone, or in combination with Actigard and/or Topsin M, had significantly less wilt than nontreated plots as well as plots where Actigard or Topsin M were applied alone or in combination".* **- X. G. Zhou** [9]

> "*Proline applied as drench provided good to excellent efficacy against Fusarium oxysporum f. sp. niveum on watermelon in 3 greenhouse trials. It also provided good control in 4 field trials either applied as drench to the soil immediately after transplanting or through drip irrigation.*" **- Ely Vea** [11]

Additional University Proline 480 SC / Fusarium wilt trials are available and published in the Plant Management Network (PDMR), former F&N tests, which requires subscription to access (40$/year) http://www.plantmanagementnetwork.org/

Fusarium spp. control is an uncommon strength of Prothioconazole as demonstrated for years in cereal crops where it is widely used to reduce vomitoxin / deoxynivalenol (DON) levels in grain to a FDA established target of 1 ppm or less by controlling the pathogen. Proline 480 SC is listed as a manufacturer's objective on the IR-4 website and Bayer CropScience conducted the cucurbit residue trials and obtained registration in December of 2013. The Prothioconazole use in watermelon for the control of Fusarium wilt satisfies Criterion I

3.2.2 The Prothioconazole use in watermelon for the control of Fusarium wilt satisfies *Criterion II: the alternatives to the minor use pesticide pose greater risks to the environment or human health.*

As mentioned in 3.2.1, two soil fumigants containing 1,3-dichloropropene (Telone EC and Telone II) are registered for use on Fusarium wilt for watermelon. This widely used fumigant is a broad spectrum biocide and restricted use pesticide that has the potential to cause more harm to the environment and human health than does Prothioconazole. Proline 480 SC carries a "Caution" label, while Telone EC caries a "Warning" label with the following human safety text:

> "*Do not swallow any of this product. May be fatal if swallowed. Do not get in eyes. Causes substantial, but temporary eye injury. Do not get on skin. may be fatal if absorbed through the skin. Do not breathe vapor. May be fatal if inhaled."* **- Telone EC label** [5]

Telone EC carries a groundwater advisory, requires special posting, has limitations on distance from occupied housing, and requires special PPE and applicator licensing and training since it a restricted use pesticide. In contrast, Proline 480 SC with a has a short half-life, moves very little through the soil profile, and provides effective control of Fusarium wilt in watermelon and will replace some Telone fumigant use, particularly at locations where disease is not already well established at the site and severe in pressure. The other Fusarium wilt labeled product Oxidate also poses a greater risk to human health and caries a “Danger” label and the following precautionary text.

> *“DANGER: Corrosive. Concentrate causes irreversible eye damage. Concentrate may be fatal if swallowed or absorbed through skin. Concentrate causes skin burns or temporary discoloration on exposed skin. Do not breathe vapor of concentrate. Do not get concentrate in eyes, on skin, or on clothing. Wear protective eye-wear such as goggles or face shield.”* - **Oxidate label** [8]

Prothioconazole poses a less risk to the environment and human health than Oxidate or the Telone fumigants which are commonly used and so satisfies Criterion II.

3.2.3 The Prothioconazole use in watermelon for the control of Fusarium wilt satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Currently there are no effective conventional fungicides approved for Fusarium wilt control in watermelon. The “high resistance risk” QoI (such as Azoxystrobin) and Topsin (Thiophanate-methyl) occasionally performed sufficiently well in the IR-4 trials but no manufacturer has since labeled the use. The new generation SDHI fungicides Fluopyram, Fluxapyroxad, and Penthiopyrad were recently approved on certain crops, but are also single site fungicides. They vary in their disease control spectrum and systemicity and might offer an alternative if vascular wilt efficacy is determined to be adequate. To date there are no SDHI fungicides approved for Fusarium wilt control that the authors were able to find. In the future as additional fungicides are registered approved for use in watermelon, Prothioconazole will offer an excellent rotational or premix mode of action especially for any of the non-DMI fungicide and therefore satisfies Criterion III.

3.2.4 The Prothioconazole use in watermelon for the control of Fusarium wilt satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

According to an American Phytopathological Society article by Purdue researchers.

> “*Fusarium wilts are difficult to manage without durably resistant cultivars*”, “*With the exception of host resistance, it is likely that no one technique will result in the complete control of Fusarium wilt of watermelon. However, by combining several different options, adequate control may be achieved.*” **- Egel and Martyn** [2]

Proline 480 SC, paired with the more resistant cultivars, will take the place of some applications of 1,3-dichloropropene which is broad spectrum biocide that destroys beneficial soil microbes such as beneficial mycorrhizae and actinomycetes, beneficial entomopathogens, and other beneficials which improve nutrient uptake, plant health and control damaging insect populations naturally. Proline 480 SC is more targeted in spectrum than 1,3-dichloropropene and is not known to affect any beneficial microbial populations or reduce beneficial insect populations when used according to label directions. Studies indicated Prothioconazole to be “practically non-toxic” to bees.

Proline 480 SC is highly active on two other major diseases that are also extremely difficult for watermelon growers to control including Gummy stem blight (*Didymella bryoniae*) and Southern blight (*Sclerotium rolfsii*), and as a result - applications of Proline 480 SC for one disease can have added benefit of preventing or controlling the other two diseases which further reduces input costs to that grower. The Prothioconazole use in watermelon for the control of Fusarium wilt satisfies Criterion IV

3.2.5 The Prothioconazole use in watermelon for the control of Southern blight satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Southern blight caused by *Sclerotium rolfsii* is a common disease on a wide variety of vegetables including watermelon.[6] The fungus can attack both the watermelon fruit and the lower trunk of the plant near the soil line. Proline 480 SC is registered and highly effective on this watermelon disease and is a standard treatment in peanut for this pathogen. According to CDMS there is one recently registered conventional fungicide available - OSO (Polyoxin D), and there are three organic fungicides registered for the control of Southern blight. The OSO label recommends avoiding consecutive use of OSO to prevent resistance. The organic options are a neem oil product and two are biological control agents that claim general control of *Sclerotium* spp. for all crops on the label. These products are Debug Turbo (neem oil), Soilgard 12G (*Gliocladium* spp.), and Tenet WP (*Trichoderma* spp.). These three products are approved for use as organic options but not widely used by growers due to the low level of activity they provide as indicated by sales and efficacy trial results. Therefore, the Prothioconazole use in watermelon for the control of Southern blight satisfies Criterion III as an excellent rotational partner with OSO (Polyoxin D) for control of Southern blight.

3.3 References

[1.] **USDA Vegetables 2011 Summary.** ISSN: 0884-6413. January 2012. Page 42. http://usda01.library.cornell.edu/usda/current/VegeSumm/VegeSumm-01-26-2012.pdf (Appendix 4)

[2.] **Fusarium wilt of watermelon and other cucurbits.** D. S. Egel and R. D. Martyn. 2007. Fusarium wilt of watermelon and other cucurbits. The Plant Health Instructor. DOI: 10.1094/PHI-I-2007-0122-01. http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Pages/FusariumWatermelon.aspx

[3.] **Compendium of Cucurbit Diseases.** T. A. Zitter, D. L. Hopkins, and C. E. Thomas, eds. APS Press, St. Paul, MN. 1996.

[4.] **IR-4 website.** Project request. PCR and efficacy trial results with Proline 480 SC. http://www.ir4.rutgers.edu/FoodUse/performancedmp1.cfm?prnum=10813

[5.] **CDMS.** http://www.cdms.net/ Telone EC label (Appendix 5).

[6.] **An IPM Scouting Guide for Common Problems of Cucurbit Crops in Kentucky. ID-91**. 2009. page 17. http://www.ca.uky.edu/agc/pubs/id/id91/id91.pdf (Appendix 6)

[8.] **Oxidate label** (Appendix 30)

[9.] **Zhou Watermelon Fusarium trial.** Field evaluation of fungicides applied through drip tape for control of Fusarium wilt of watermelon. X. G. Zhou, M. Hochmuth, and K. L. Everts University of Maryland. 2009. (Appendix 31)

[10.] **Managing Fusarium Wilt of Watermelon with Fungicide Drenches and Seed Treatments.** Dan Egel and Sara Hoke, Department of Botany and Plant Pathology, Purdue University. 2007. http://ir4.rutgers.edu/FoodUse/PerfData/1953.pdf (Appendix 32)

[11.] **IR-4 Ornamental Horticulture Program: Fusarium Efficacy: A Literature Review**. Ely Vea and Cristi Palmer. June 27, 2012. http://ir4.rutgers.edu/ir4_pdf/default.aspx?pdf=http://ir4.rutgers.edu/Ornamental/SummaryReports/FusariumDataSummary2012.pdf (Appendix 38)

4.0 Justification of the Need for Prothioconazole to Control Key Diseases in Summer Squash

4.1 Summer Squash Acreage

The two most common examples of summer squash are zucchini and yellow crookneck. Summer squash (*Cucurbita pepo*) is an important U.S. crop with larger production primarily centered in the states of California, Georgia, and New York. In 2011 the U.S acreage for summer squash was reported by the USDA to be 50,200 planted acres and summer squash production is lower than 300,000 acres per year.[1] (Table 1)

4.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Summer Squash

4.2.1 The Prothioconazole use in summer squash for the control of Fusarium wilt satisfies *Criterion I: There are insufficient efficacious alternative registered pesticides available for the use.*

Fusarium wilt of summer squash such as zucchini and yellow crookneck squash is caused by the same pathogen that causes losses in watermelon and citron melon - *Fusarium oxysporum* f. sp. *niveum.*[2, 10] Fusarium wilt is a devastating *vascular disease and specifically different* from Fusarium root rots, Fusarium leaf spots, and other general and non-vascular Fusarium rots.[3]

CDMS lists for Fusarium wilt of squash three products - Oxidate (hydrogen dioxide)[8] and three formulations of Telone (1,3-dichloropropene) soil fumigant.[5] Oxidate provides a knock down of surface fungi through oxidation and a short lived protectant barrier, but this is not sufficient for practical disease control. It was not included as a positive control in the Fusarium wilt screening program conducted by IR-4. For general non-specific control of *Fusarium* spp. there are also listed some phosphorus acid products, but specifically Fusarium wilt control is not claimed and they are not a viable control measure. Additionally, there are general Fusarium seed treatments however these products only protect during early emergence root rots and offer no protection to growing plants. Fusarium wilt is not claimed on these labels.

Because Fusarium wilt is so difficult to control and causes growers such high crop losses, the IR-4 project (Interregional Research Project No.4) conducted a major research program in 2008 and 2009 to screen fungicide candidates for Fusarium wilt control in watermelon and other cucurbits including squash. IR-4 project 10813 (Prothioconazole for cucurbit) was requested by PCR by B. Tanner of Georgia and eleven Prothioconazole trials from the project are publicly available at the IR-4 website.[4] In these IR-4 coordinated research trials, and in additional published trials, Proline 480 SC has been effective in most of the trials. Proline 480 SC has been the only effective product in some of them.[9] There are insufficient efficacious alternative registered pesticides available to control Fusarium wilt in summer squash and the Prothioconazole use satisfies Criterion I.

4.2.2 The Prothioconazole use in summer squash for the control of Fusarium wilt. satisfies *Criterion II: the alternatives to the minor use pesticide pose greater risks to the environment or human health*.

As mentioned in 4.2.1, two soil fumigants containing 1,3-dichloropropene (Telone EC and Telone II) are registered for use on Fusarium wilt for summer squash. These fumigants are broad spectrum biocides that are believed to cause more harm to the environment and human health than does Prothioconazole. As an example, Proline 480 SC carries a “Caution” label, while Telone EC caries a “Warning” label with the following human safety text:

> “*Do not swallow any of this product. May be fatal if swallowed. Do not get in eyes. Causes substantial, but temporary eye injury. Do not get on skin. may be fatal if absorbed through the skin. Do not breathe vapor. May be fatal if inhaled.”* **- Telone EC label [5]**

Telone EC carries a groundwater advisory, requires special posting, has limitations on distance from occupied housing, and requires special PPE and applicator licensing and training. Proline 480 SC with a has a short half-life, moves very little through the soil profile, and provides effective suppression of Fusarium wilt in watermelon and will replace some Telone fumigant use, particularly at locations where disease is not already well established at the site and severe in pressure.

The other labeled product Oxidate poses a greater risk to human health and caries a “Danger” label and the following precautionary text.

> *“DANGER: Corrosive. Concentrate causes irreversible eye damage. Concentrate may be fatal if swallowed or absorbed through skin. Concentrate causes skin burns or temporary discoloration on exposed skin. Do not breathe vapor of concentrate. Do not get concentrate in eyes, on skin, or on clothing. Wear protective eye-wear such as goggles or face shield.”* – **Oxidate label** [8]

Prothioconazole poses a lower risk to the environment and human health than Oxidate or the Telone fumigants which are commonly used and therefore satisfies Criterion II.

4.2.3 The Prothioconazole use in summer squash for the control of Fusarium wilt satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Currently there are no effective conventional fungicides approved for Fusarium wilt control in summer squash. The QoI (Azoxystrobin) and Topsin (Thiophanate-methyl) occasionally performed sufficiently well in the IR-4 trials but no manufacturer has since added the use. The new SDHI fungicides (Fluopyram, Fluxapyroxad, and Penthiopyrad registrations were recently approved on certain crops) vary in their spectrum and could offer an alternative if efficacy is determined to be sufficient, however to date there are no SDHI fungicides approved for Fusarium wilt control that the authors could find. In the future as additional fungicides are registered approved for use in watermelon Prothioconazole will offer an excellent rotational mode of action especially for any of the non-DMI fungicide at that time.

4.2.4 The Prothioconazole use in summer squash for the control of Fusarium wilt satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

According to an American Phytopathological Society (APS) article by Purdue researchers control requires multiple tools.

> "*Fusarium wilts are difficult to manage without durably resistant cultivars" and* "*With the exception of host resistance, it is likely that no one technique will result in the complete control of Fusarium wilt of watermelon. However, by combining several different options, adequate control may be achieved*." **- Egel and Martyn[6]**

For summer squash growers with a history of losses by Fusarium wilt, Proline 480 SC fits their IPM programs better than fumigants and can complement the control measures detailed by the authors; including disease-free transplants and seed, host resistance, crop rotations, soil solarization, grafting, and biological control and play significant roles in integrated pest management.[6, 2] Proline 480 when used for Fusarium wilt control will take the place of some use of 1,3-dichloropropene which is a broad spectrum biocide that destroys beneficial soil microbes such as beneficial mycorrhizae, actinomycetes, and entomopathogens. Proline 480 SC fungicide is more targeted in spectrum and not known to affect any beneficial microbial or insect populations when used according to the label. Prothioconazole studies indicated it to be "practically non-toxic" to bees. Proline 480 SC is also active on other diseases that are difficult for summer squash growers to control including Southern blight (*Sclerotium rolfsii*). Applications in summer squash made to control Fusarium wilt early season will also reduce later season Southern blight. Evidence of this can be found in the fact that peanut growers apply Proline 480 SC near seedling emergence which reduces *Sclerotium rolfsii* damage season long via eradication. Proline 480 SC for these reasons fit summer squash IPM programs well and satisfy Criterion IV.

4.3 References

1. **USDA Vegetables 2011 Summary.** January 2012. ISSN: 0884-6413. Page 38. http://usda01.library.cornell.edu/usda/current/VegeSumm/VegeSumm-01-26-2012.pdf (Appendix 4).

[2.] **RPD No. 904 - Fusarium Wilt of Watermelon and Muskmelon.** October 1988 http://ipm.illinois.edu/diseases/series900/rpd904/index.html

[3.] **Compendium of Cucurbit Diseases.** T. A. Zitter, D. L. Hopkins, and C. E. Thomas, eds. APS Press, St. Paul, MN. 1996.

[4.] **IR-4 website.** Project request. PCR and efficacy trial results with Proline 480 SC. http://www.ir4.rutgers.edu/FoodUse/performancedmp1.cfm?prnum=10813

[5.] **CDMS.** http://www.cdms.net/ (Telone EC label Appendix 5)

[6.] **Fusarium wilt of watermelon and other cucurbits.** D. S. Egel and R. D. Martyn. 2007. Fusarium wilt of watermelon and other cucurbits. The Plant Health Instructor. DOI: 10.1094/PHI-I-2007-0122-01. http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Pages/FusariumWatermelon.aspx

[8.] **Oxidate label** (Appendix 30)

[9.] **Zhou Watermelon Fusarium trial.** Field evaluation of fungicides applied through drip tape for control of Fusarium wilt of watermelon. X. G. Zhou, M. Hochmuth, and K. L. Everts. University of Maryland. 2009. (Appendix 31)

[10.] **Fusarium Wilt of Cucurbits ANR-872.** Alabama A&M and Auburn Universities. Plant Disease Notes. June 2004. (Appendix 7)

5.0 Justification of the Need for Prothioconazole to Control Key Diseases in Cucumber

5.1 Cucumber Acreage

Cucumber (*Cucumis sativus*) is an important U.S. crop with production primarily centered in the states of Michigan, Florida, Ohio, Texas, North and South Carolina, California, and Wisconsin depending on the type grown. In 2010 the planted acreage was reported by to be 138,000 acres (processing/pickles 92,000 plus fresh 46,000). [1] Cucumber production is lower than 300,000 acres per year. (Table 1)

5.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Cucumber

5.2.1 The Prothioconazole use in cucumber for the control of Southern blight satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Southern blight caused by *Sclerotium rolfsii* is a common fruit disease on a wide variety of vegetables including cucumber.[2, 3, 7] The fungus primarily attacks both the cucumber fruit and the trunk of the plant near the soil line. According to CDMS there is only one chemical fungicide product registered for the control of Southern blight on cucumber.[4]

The OSO (Polyoxin D) label recommends avoiding consecutive use of OSO to prevent resistance and therefore needs a rotational partner such as Proline 480 SC. CDMS does list two biological control agents that do claim general control of *Sclerotium* spp. for all crops on the label. These products are Soilgard 12G (*Gliocladium* spp.) and Tenet WP (*Trichoderma* spp.). A neem oil based organic fungicide is also available Debug Turbo. Growers have not widely adopted these products for disease control due to the low efficacy they obtain with them. No other conventional products are listed for the control of Southern blight (*Sclerotium rolfsii)* that the authors could find. Recently registered, Proline 480 SC is highly effective and labeled on Southern blight of cucumber fruit and is already used as one of the most effective grower standard in peanuts for the same pathogen which establishes in the soil and affects both crops. Proline 480 SC will be an excellent rotational treatment with OSO and satisfies criterion III.

5.2.2 The Prothioconazole use in cucumber for the control of Fusarium wilt satisfies *Criterion I: There are insufficient efficacious alternative registered pesticides available for the use.*

Fusarium wilt of cucumber, caused by *Fusarium oxysporum* f. sp*. cucumerinum*, occasionally infects cucumber as a minor disease.[3] Fusarium wilt is specifically different from Fusarium root rots, Fusarium leaf spots, and other Fusarium rots.[3, 8]

> "*The Cucurbitaceae plant family is affected by several vascular wilt diseases caused by different formae speciales of the fungus Fusarium oxysporum, which are morphologically similar, but generally host-specific. The most economically important of these attack watermelon, muskmelon, or cucumber*." **- Egel and Martyn[8]**

CDMS lists two products for Fusarium wilt of cucumber - Oxidate (hydrogen dioxide) and two Telone soil fumigants.[4] For general control of *Fusarium* spp. there are also listed some phosphorus acid products, but Fusarium wilt control is not claimed. Additionally, there are general Fusarium seed treatments however these products only protect during early emergence root rots and offer no protection to growing plants and Fusarium wilt is also not claimed on the labels. Therefore, there are insufficient efficacious alternative control measures for Fusarium wilt in cucumber.

Because of the strong demand for new control options, IR-4 conducted a major research project in 2008 and 2009 screening fungicides for Fusarium wilt control in watermelon and cucurbits. IR-4 project 10813 was requested by PCR by B. Tanner of Georgia, and eleven trials are publicly available at the IR-4 website.[5] In these research trials Proline 480 SC was effective in most of the trials, and Proline 480 SC was the only effective product in some of them. Proline 480 SC is listed as a manufacturer's objective and Bayer CropScience has conducted the residue trials and received registration in December of 2013.

5.3 References

[1.] **USDA Vegetables 2011 Summary.** January 2012. ISSN: 0884-6413. Pages 8 and 70. http://usda01.library.cornell.edu/usda/current/VegeSumm/VegeSumm-01-26-2012.pdf (Appendix 4)

[2.] **An IPM Scouting Guide for Common Problems of Cucurbit Crops in Kentucky. ID-91**. 2009. page 17. http://www.ca.uky.edu/agc/pubs/id/id91/id91.pdf (Appendix 6)

[3.] **Compendium of Cucurbit Diseases.** T. A. Zitter, D. L. Hopkins, and C. E. Thomas, eds. APS Press, St. Paul, MN. 1996.

[4.] **CDMS.** http://www.cdms.net/

[5.] **IR-4 website.** Project request. PCR and efficacy trial results with Proline 480 SC. http://www.ir4.rutgers.edu/FoodUse/performancedmp1.cfm?prnum=10813

[7.] ***Sclerotium rolfsii* Sacc. : 'Kudzu of the Fungal World'** Elizabeth J. Fichtner. NC State University. http://www.cals.ncsu.edu/course/pp728/Sclerotium/Srolfsii.html

[8.] **Fusarium wilt of watermelon and other cucurbits.** D. S. Egel and R. D. Martyn. 2007. Fusarium wilt of watermelon and other cucurbits. The Plant Health Instructor. DOI: 10.1094/PHI-I-2007-0122-01. http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Pages/FusariumWatermelon.aspx

6.0 Justification of the Need for Prothioconazole to Control Key Diseases in Cantaloupe

6.1 Cantaloupe Acreage

Cantaloupe (*Cucumis melo*) is a popular type of melon crop grown primarily in the states California, Texas, Georgia, and Arizona. In 2010 the planted acreage was reported by the USDA to be 77,430 acres.[1] Cantaloupe production is lower than 300,000 acres per year. (Table 1)

6.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Cantaloupe

6.2.1 The Prothioconazole use in Cantaloupe for the control of Fusarium wilt satisfies *Criterion I: There are insufficient efficacious alternative registered pesticides available for the use.*

Melons and muskmelons including cantaloupe are susceptible to Fusarium wilt caused by *Fusarium oxysporum* f. sp. *melonis*. Fusarium wilt is an economically serious disease of melons and muskmelons in the U.S.[2, 3, 4, 9] Fusarium wilt is a devastating *vascular disease and specifically different* from Fusarium root rots, Fusarium leaf spots, and other Fusarium rots.[3, 4, 9]

> "*The Cucurbitaceae plant family is affected by several vascular wilt diseases caused by different formae speciales of the fungus Fusarium oxysporum, which are morphologically similar, but generally host-specific. The most economically important of these attack watermelon, muskmelon, or cucumber*." **- Egel and Martyn**[9]

CDMS only lists for Fusarium wilt of cantaloupe Oxidate (hydrogen dioxide) and Telone soil fumigant.[6] For general control of *Fusarium* spp. there are also listed some phosphorus acid products, but Fusarium wilt control is not claimed. Additionally, there are general Fusarium seed treatments however these products only protect during early emergence root rots and offer no protection to growing plants and Fusarium wilt is also not claimed on the labels. There are insufficient efficacious alternative registered pesticides available for the control of Fusarium wilt in cantaloupe.

IR-4 conducted a major research project in 2008 and 2009 screening fungicides for Fusarium wilt control in cucurbits. IR-4 project 10813 was requested by B. Tanner of Georgia, and eleven trials are publicly available at the IR-4 website.[5] In these research trials Proline 480 SC was effective in most of the trials, and Proline 480 SC was the only effective product in some of them. Prothioconazole is listed as a manufacturer's objective on the IR-4 website and Bayer CropScience conducted the residue trials and obtained EPA registration in December of 2013.

6.2.2 The Prothioconazole use in cantaloupe for the control of Fusarium wilt satisfies *Criterion II: the alternatives to the minor use pesticide pose greater risks to the environment or human health.*

Soil fumigant 1,3-dichloropropene (available as Telone EC and Telone II) is registered for use on Fusarium wilt for cantaloupe but potentially cause more harm to the environment and human health than Prothioconazole. Telone EC caries a "Warning" label and has the following text.

> "*Do not breathe vapor. May be fatal if inhaled."* **- Telone EC label** [6]

Telone EC carries a groundwater advisory, requires special posting, has limitations on distance from occupied housing, and requires special PPE and applicator licensing and training. Proline 480 SC with a "Caution" label has a short half-life, moves little through soil profile, and when applied as a drench or drip will replace some soil fumigant use, particularly at locations where disease is not already well established at the site and severe in pressure.

The other labeled product Oxidate poses a greater risk to human health and caries a "Danger" label and the following precautionary text.

> *"DANGER: Corrosive. Concentrate causes irreversible eye damage. Concentrate may be fatal if swallowed or absorbed through skin. Concentrate causes skin burns or temporary discoloration on exposed skin. Do not breathe vapor of concentrate. Do not get concentrate in eyes, on skin, or on clothing. Wear protective eye-wear such as goggles or face shield."* – **Oxidate label** [10]

Prothioconazole poses a less risk to the environment and human health than 1,3-dichloropropene fumigant which is commonly used (and Oxidate) and therefore satisfies criterion II.

6.2.3 The Prothioconazole use in cantaloupe for the control of Fusarium wilt satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Currently there are no effective fungicides approved for Fusarium wilt control in cantaloupe. The single site fungicides QoI (Azoxystrobin) and Topsin (Thiophanate-methyl) occasionally performed well in the IR-4 trials but no manufacturer has since added the use to their label. The new SDHI fungicides (Fluopyram, Fluxapyroxad, and Penthiopyrad registrations were recently approved on certain crops) vary in their spectrum and could offer an alternative if efficacy is determined to be sufficient, however to date there are no SDHI fungicides approved for Fusarium wilt control. In the future as additional fungicides are registered approved for use in watermelon Prothioconazole will offer an excellent rotational or premix mode of action especially for any of the non-DMI fungicide.

6.2.4. The Prothioconazole use in cantaloupe for the control of Fusarium wilt satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

According to American Phytopathological Society article.

> "*Fusarium wilts are difficult to manage without durably resistant cultivars*" and "*With the exception of host resistance, it is likely that no one technique will result in the complete control of Fusarium wilt of watermelon. However, by combining several different options, adequate control may be achieved*." **- Egel and Martyn [7]**

Proline 480 SC has a good fit in cantaloupe from an IPM perspective because unlike the biocide fumigant currently used it is not known to destroy beneficial microbial populations. Proline 480 SC use can complement the control measures listed by the authors when the measures do not provide sufficient disease control. These include disease-free transplants and seed, host resistance, crop rotations, soil fumigation, soil solarization, grafting, and biological control which play significant roles in integrated pest management.[7] For this disease a grower with a history of light Fusarium wilt damage could apply Proline 480 SC preventatively in place of fumigants. Under extreme pressure it may complement current IPM practices including the use of fumigants and other measures listed. Proline 480 SC is also active on other diseases that are difficult for cantaloupe growers to control including Southern blight (*Sclerotium rolfsii*).

6.3 <u>References</u>

[1.] **USDA Vegetables 2011 Summary** January 2012. ISSN: 0884-6413. Pages 8. http://usda01.library.cornell.edu/usda/current/VegeSumm/VegeSumm-01-26-2012.pdf (Appendix 4)

[2.] **UC IPM Pest Management Guidelines:** Cucurbits Fusarium Wilt (Cantaloupe) Pathogen: *Fusarium oxysporum* f. sp. *melonis* Cucurbits, UC ANR Publication 3445 , R. M. Davis et.al. http://www.ipm.ucdavis.edu/PMG/r116101011.html

[3.] **Fusarium Wilt of Cucurbits ANR-872** Alabama A&M and Auburn Universities. Plant Disease Notes. June 2014. (Appendix 7)

[4.] **Compendium of Cucurbit Diseases.** T. A. Zitter, D. L. Hopkins, and C. E. Thomas, eds. APS Press, St. Paul, MN. 1996.

[5.] **IR-4 website.** Project request. PCR and efficacy trial results with Proline 480 SC. http://www.ir4.rutgers.edu/FoodUse/performancedmp1.cfm?prnum=10813

[6.] **CDMS.** http://www.cdms.net/ (Telone EC label Appendix 5)

[7.] **Fusarium wilt of watermelon and other cucurbits.** D. S. Egel and R. D. Martyn. 2007. The Plant Health Instructor. DOI: 10.1094/PHI-I-2007-0122-01. http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Pages/FusariumWatermelon.aspx

[9.] **Fusarium wilt of watermelon and other cucurbits.** D. S. Egel and R. D. Martyn. 2007. Fusarium wilt of watermelon and other cucurbits. The Plant Health Instructor. DOI: 10.1094/PHI-I-2007-0122-01. http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Pages/FusariumWatermelon.aspx

[10.] **Oxidate label** (Appendix 30)

7.0 Justification of the Need for Prothioconazole to Control Key Diseases in Pumpkin

7.1 Pumpkin Acreage

Top pumpkin (several *Cucurbita* spp.) production states are Illinois, California, New York, Ohio, Pennsylvania and Michigan. According to the University of Illinois, 496 million pounds of pumpkins were produced in Illinois in 2008. In 2011, pumpkins were estimated at 51,300 planted acres. [1] Pumpkin production is lower than 300,000 acres per year. (Table 1)

7.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Pumpkin

7.2.1 The Prothioconazole use in pumpkin for the control of Southern blight satisfies *Criterion II: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Southern blight caused by *Sclerotium rolfsii* is a common fruit disease on a wide variety of vegetables including pumpkin.[2, 3, 4, 7, 8, 9.]

> "*Southern blight, also known as southern stem blight, is a serious disease of many vegetable crops, causing an almost certain death of affected plants*." **- Steve Bost** [8]

According to CDMS there is only one chemical product registered for the control of Southern blight - OSO.[5] The active ingredient in OSO is the antibiotic Polyoxin D and the manufacturer recommends on their label to avoid consecutive use of the product to delay resistance development. CDMS does list one biological control agent that does claim general control of *Sclerotium* spp. for all crops on the label. This product is Tenet WP. There are no conventional fungicides listed for control of Southern blight or *Sclerotium rolfsii* that the authors could find.

Proline 480 SC is highly effective and labeled on this disease and is commonly used as a grower standard on peanut to control this pathogen. Some growers will specifically apply Proline 480 SC to control Southern blight, but it will be more commonly be applied to pumpkins to control Gummy stem blight (*Didymella bryoniae*) which is most often more devastating than Southern blight. These applications will reduce Southern blight losses as an added benefit to that grower.

7.3 References

1. **USDA Vegetables 2011 Summary.** January 2012. ISSN: 0884-6413. Pages 8. http://usda01.library.cornell.edu/usda/current/VegeSumm/VegeSumm-01-26-2012.pdf (Appendix 4)

2. **An IPM Scouting Guide for Common Problems of Cucurbit Crops in Kentucky. ID-91**. 2009. page 17. http://www.ca.uky.edu/agc/pubs/id/id91/id91.pdf (Appendix 6)

3. **Fruit Rots of Cucurbits PPFS-VG-07.** Plant pathology fact sheet. Univ. of Kentucky cooperative extension service. Nov 2010. page 4 (Appendix 8)

4. **Compendium of Cucurbit Diseases.** T. A. Zitter, D. L. Hopkins, and C. E. Thomas, eds. APS Press, St. Paul, MN. 1996.

5. **CDMS.** http://www.cdms.net/

7. **Late Season Disease Management for Pumpkin.** Dr. Kathryne Everts, Extension Vegetable Plant Pathologist, University of Maryland Extension. http://carroll.umd.edu/ag/files/Pumpkin/2010/3%20-%20Late%20Season%20Pumpkin%20Disease%20Mgt%20-%20EVERTS.pdf

8. **EPP266-Southern Blight of Vegetables**. Steve Bost, Professor, Entomology and Plant Pathology, University of Tennessee. 2006. http://eppserver.ag.utk.edu/Extension/PUBS/EPP266-Southern-blight.pdf (Appendix 33)

9. ***Sclerotium rolfsii* Sacc. : 'Kudzu of the Fungal World'** Elizabeth J. Fichtner. NC State University. http://www.cals.ncsu.edu/course/pp728/Sclerotium/Srolfsii.html

8.0 Justification of the Need for Prothioconazole to Control Key Diseases in Lowbush Blueberry

8.1 Lowbush Blueberry Acreage

Blueberries are grown in states such as Michigan, Oregon, Washington, New Jersey, and Georgia. In 2010 USDA NASS reports 69,610 planted acres for all blueberry types which include lowbush (*Vaccinium angustifolium*), highbush, and rabbiteye blueberries.[1] Lowbush blueberry production is lower than 300,000 acres per year. (Table 1)

8.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Lowbush Blueberry

8.2.1 The Prothioconazole use in lowbush blueberry production for the control of Valdensinia leaf spot satisfies *Criterion I: There are insufficient efficacious alternative registered pesticides available for the use.*

Valdensinia leaf spot caused by *Valdensinia heterodoxa* is a major disease of blueberry in Canada and has spread to the U.S. entering Maine in July of 2009.[2,11]

> *"Valdensinia leaf spot, caused by the fungus Valdensinia heterodoxa, has become a serious disease of lowbush blueberry in the last few years. It was first observed in 1997 and has since spread to numerous fields throughout Nova Scotia, New Brunswick, Prince Edward Island and with new observations occurring in Quebec and Maine in 2009."*- **Hildebrand and Renderos** [9]

The pathogen can "cause early leaf drop and in pruned fields can result in total leaf defoliation". As a result, no flower buds are produced by infected stems significantly reducing production. There are no fungicides labeled in U.S. to control this disease, and occurrence has been increasing.[3, 4] In order to prevent further spread of this invasive pathogen, infected fields in Maine were burned in order to stop spread from field to field.[4] Proline 480 SC is labeled and highly effective on this pathogen as demonstrated by researchers in field trials.[10, 12]

8.2.2 The Prothioconazole use in lowbush blueberry for the control of Valdensinia leaf spot satisfies *Criterion III. The minor use pesticide plays or will play a significant part in managing pest resistance.*

Proline 480 SC is the only product registered in U.S. to control this disease as far as the authors have been able to determine, however if/when other modes of action are also registered, such as with the at risk single site SDHI (Group 7) or QoI (Group 11) fungicides then Proline 480 SC (Group 3) will serve as an alternation partner during the Valdensinia spray timings. For example, when Fluopyram, a single site SDHI by Bayer, is approved for use in lowbush blueberry then Proline 480 SC will serve either as a rotational treatment or as a premix fungicide with Fluopyram (Propulse) for built in resistance management for this disease. Proline 480 SC also will serve as excellent rotation option for this disease with Penthiopyrad available as Fontelis or the Canadian version Lance (not yet registered but according to Dr. David Percival is in progress for use in Canada).[10]

> "*Dr. Percival's research is examining more than 15 products for application in the sprout year. He says fungicides have different windows for effectiveness, with Proline, particularly on sprouts, offering excellent suppression in the sprout year for septoria and rust. Bravo and Proline work well on leaf retention and there were more flower buds, he says. Bravo and Proline also work very well together against valdensinia. "We think there is a larger window of protection with these two fungicides in a tank mix," he says. Dr. Percival also recommends using Proline in a tank mix with Bravo to avoid resistance problems. Good suppression can also be achieved with just one application. He feels Proline is the best way to go with leaf diseases in the future. "You have to stay on top of these leaf diseases," he advises. "You have to keep going out to the field, even after harvest, to keep these leaf diseases at bay." Protect the plant canopy in the crop year for excellent fruit retention, he says. As for future fungicides, Fontelis has excellent potential and BASF is developing a new product, under the trade name Lance, Dr. Percival says*." – **Dan Wooley [10]**

8.2.3 The Prothioconazole use in lowbush blueberry for the control of Valdensinia leaf spot satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

Currently sanitation, pruning, and burning are cultural controls used to combat Valdensinia leaf spot.[2, 4] As of December 2013 Proline 480 SC is the only labeled option in lowbush blueberry.[3] Proline 480 SC is highly active on the economically important pathogens of the Fruit rot complex which causes losses on this crop. When used along with the cultural methods of sanitation, pruning and burning the use of Proline 480 SC can play an important role in integrated management of Valdensinia leaf spot disease on lowbush blueberry and satisfies Criterion IV.

8.2.4 The Prothioconazole use in lowbush blueberry for the control of Mummyberry satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

Without fungicide use, Mummyberry in Maine and Michigan blueberry has been estimated to lead to 50% crop loss. There are various fungicides labeled for the control of Mummyberry of lowbush blueberry (*Monilinia vaccinii-corymbosi*) however there is still a need expressed by University and extension agents for additional variety of products.[5, 6.] Because growers often first monitor for disease (one detect) before spraying, Proline 480 SC with its curative efficacy and expected pattern of horizontal resistance will fit this IPM program. Below is a comment from David Percival on the use of Proline as a curative treatment on another key disease of blueberry.

> *"Therefore, from disease suppression perspective, the use of Proline™ 480SC provides the opportunity to wait until the initial early symptoms of Septoria are present, also provide suppression of rust (which will is infecting the plant in July), and provide for more judicious use of fungicide inputs (and have less of an environmental impact)."* - **David Percival** [8]

Dr. Pscheidt, of OSU conducted the listed Mummyberry performance trial and Proline 480 SC was significantly better for percent fruit rot ratings than the grower standard DMI product Indar (which at this writing does not appear in CDMS).[6] Despite the availability of another DMI fungicide labeled for Mummyberry control, Florida and Michigan researchers requested via Project Clearance Request (PCR) that Prothioconazole become an IR-4 project demonstrating the need for additional products in this crop to control Mummyberry. IR-4 project 10456 can be found on IR-4 website and is listed as manufactures objective.[6] Bayer has conducted the necessary residue program and obtained registration in December of 2013, and Proline 480 SC will be an important part of an IPM program with its broad-spectrum control.

8.3 References

[1.] **NASS blueberry**. Blueberry acres. (Appendix 9)

[2.] **Valdensinia leaf spot, NEW Disease in Maine Blueberry Fields.** Annis et al. University of Maine. Cooperative Extension: Maine's native wild blueberries. 2009. http://umaine.edu/blueberries/factsheets/disease/valdensinia-leaf-spot-disease/

[3.] **CDMS.** http://www.cdms.net/

[4.] **Maine's wild blueberry crop imperiled by leaf spot fungus.** Bangor Daily News. July 27, 2009
http://bangordailynews.com/2009/07/27/news/mainersquos-wild-blueberry-crop-imperiled-by-leaf-spot-fungus/

[5.] **Integrated Pest Management for Blueberries. A Guide to Sampling and Decision Making for Key Blueberry Pests in Northwest Washington.** WSU Whatcom County Extension.
http://whatcom.wsu.edu/ag/comhort/nooksack/ipmweb/blue/mummyberry.html

[6.] **IR-4 website.** Project request. PCR and efficacy trial results with Proline 480 SC; Prothioconazole request for blueberry.
http://www.ir4.rutgers.edu/FoodUse/food_Use2.cfm?PRnum=10456

[8.] **Rationale for Using Proline in Blueberry.** Use Wild Blueberry Research Program. David Percival, Department of Environmental Sciences, Nova Scotia Agricultural College. 2009. (Appendix 29)

[9.] **Valdensinia leaf spot of lowbush blueberry**. Hildebrand and Renderos. Agriculture and Agri-Food Canada. March 2010.
http://www.gov.pe.ca/photos/original/af_fact_Valden.pdf
(Appendix 34)

[10.] **Blueberry Research Continuing At NSAC.** Dan Woolley. Fruit and Vegetable Magazine - January 2012.
http://www.mydigitalpublication.com/display_article.php?id=936995

[11.] **Wild blueberry newsletter.** August 2011. University of Maine Cooperative Extension. (Appendix 35)

[12.] **Valdensinia Leaf Spot Suppression Research Update.** D. Percival, H. Hines and R.Burlakoti. Department of Environmental Sciences Nova Scotia Agricultural College, Truro, NS Wild Blueberry Producers Association of Nova Scotia Annual Meeting.

November 21, 2009. (Appendix 35 - Trial results with Proline 480 SC and Proline 480 SC in tankmixes)

9.0 Justification of the Need for Prothioconazole to Control Key Diseases in Cranberry

9.1 Cranberry Acreage

Cranberry (primarily *Vaccinium macrocarpon*) production can be found in Massachusetts, New Jersey, Oregon, Washington, and Wisconsin. According to USDA NASS data, 2008-2010 planted acres were generally around 38,000 per year. There were 38,500 planted acres in 2011.[1] Cranberry production is lower than 300,000 acres per year. (Table 1)

9.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Cranberry

9.2.1 The Prothioconazole use in cranberry production for the control of Valdensinia leaf spot satisfies *Criterion I: There are insufficient efficacious alternative registered pesticides available for the use.*

Valdensinia leaf spot caused by *Valdensinia heterodoxa* is a major disease of blueberry in several provinces of Canada and has spread to the U.S. entering Maine in 2009.[2] The pathogen also can attack cranberry but has not yet spread to any US cranberry growing locations.[5] There are no fungicides labeled in cranberry to control this disease, and occurrence has been increasing.[2, 3, 4] To eradicate this disease in infected blueberry in Maine fields were burned to prevent spread from field to field.[2] Valdensinia leaf spot has not been reported in the U.S. in cranberry, but the significant threat exists according to key researchers at Univ. of Wisconsin.

> "*Other diseases such as Valdensinia leaf spot have not yet been reported on cranberry but represent a significant threat….*
>
> *As stakeholders in the cranberry industry we need to be aware of the micro-organisms that travel with our crop and take precautions not to introduce novel pathogens into areas where they do not currently exist. Valdensinia leaf spot is a prime example of such a disease*." **– Peter Oudemans [5]**

Prothioconazole as Proline 480 SC is highly effective on Valdensinia leaf spot as demonstrated in research trials. The product is available in the market on the shelf for cranberry growers beginning December 2013 and also labeled for other economically important diseases such as Fruit rot control (caused by a large number of different fungal species) and will be an important tool should the pathogen spread into any of the cranberry producing states. Proline 480 SC use for Valdensinia leaf spot satisfies Criterion I.

9.2.2 The Prothioconazole use in cranberry for the control of Fruit rot satisfies *Criterion III. The minor use pesticide plays or will play a significant part in managing pest resistance.*

Cranberry Fruit rot is considered a complex caused potentially by any of at least 11 of different fungal species. There are many fungicides labeled for cranberry fruit rot, however there are significant limitations to most of the products labeled. The products and limitations are described on page 2 of Cranberry Diseases and Fruit Rot Control.[5]

> "*Of that yield there was an average of 24% fruit rot which amounted to 9000 bbl. This result demonstrated that the management strategies were not working and required significant revision*." **– Peter Oudemans [5]**

Currently growers use Chlorothalonil, Azoxystrobin and some DMI fungicides including Fenbuconazole (Indar) which has a narrow and incomplete spectrum.[3, 5, 6, 7]

> "*Both of these registered materials (Indar and Abound) have limited spectra of action and gaps in activity have been observed*. **- Peter Oudemans** [7]

In addition to filling gaps in control of the eleven species, the consistently high efficacy of Proline 480 SC may reduce further resistance development by reducing the number of Indar applications required per season. Researchers in NJ and MA submitted a PCR for Prothioconazole for control of Fruit rot and Fairy ring; PR# 10078 despite the fact that Indar, also a DMI, was already registered at the time for the disease complex of Fruit rot.[6] Five trials are available on the IR-4 website in the performance data section of the Prothioconazole Cranberry request.[6] In the trials Proline 480 SC performed very well on Fruit rot and storage rot diseases.[8] University specialists are pleased that Bayer moved forward with the Proline 480 SC cranberry registration for Fruit rot control (*personal communications*) which was initiated primarily due to the potential fit within the minor use exclusivity program. First cranberry use is expected in 2014 and will lessen selection pressure on Fenbuconazole and provide growers with improved broader spectrum Fruit rot control which University, grower and IR-4 interest indicate was needed.

9.3 References

1. **Cranberry acres NASS** (Appendix 10)

2. **Valdensinia leaf spot, NEW Disease in Maine Blueberry Fields.** Annis et al. University of Maine. Cooperative Extension: Maine's native wild blueberries. http://umaine.edu/blueberries/factsheets/disease/valdensinia-leaf-spot-disease/

3. **CDMS.** http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=

4. **Maine's wild blueberry crop imperiled by leaf spot fungus.** Bangor Daily News. July 27, 2009 http://bangordailynews.com/2009/07/27/news/mainersquos-wild-blueberry-crop-imperiled-by-leaf-spot-fungus/

5. **Cranberry Diseases and Fruit Rot Control**. Peter Oudemans, Ph.D., Specialist in Plant Pathology and Patricia McManus, Ph.D., Professor of Plant Pathology, University of Wisconsin. April 2011. http://njaes.rutgers.edu/pubs/plantandpestadvisory/2011/cb041411.pdf (Appendix 11).

6. **IR-4 PCR request for Prothioconazole use for fruit rot control.**

http://www.ir4.rutgers.edu/FoodUse/food_Use2.cfm?PRnum=10078

7. **2009 Annual Summer Meeting of the American Cranberry Growers Association.** 2009 page 12. (Appendix 12)

8. **Caruso Cranberry. Evaluation of fungicides for control of field and storage rot of cranberries, 2010**. F.L Caruso. Univ of Mass Cranberry Station. (Appendix 13)

10.0 Justification of the Need for Prothioconazole to Control Key Diseases in Currant

10.1 Currant Acreage

Currants (*Ribes* spp.) are cultivated for their berries which are often sold dried similar to raisins. Production is less than 300,000 acres in the U.S. and therefore qualifies as a minor crop. No official NASS figure for currants was found. (Table 1)

10.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Currant

10.2.1 The Prothioconazole use in currant production for the control of White pine blister rust satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

Currants and other *Ribes* spp. are the required alternate hosts for the pathogen *Cronartium ribicola*. White pine blister rust is a devastating disease of pine (*Pinus* spp.) within the pathogens lifecycle. It is too difficult from a practical perspective to control diseases directly in forest crops with fungicide applications. One means of reducing disease in pine is to reduce disease that occurs locally on the alternate hosts such as *Ribes* spp. Therefore, since the early 1900's some of the more highly susceptible varieties of *Ribes* spp. have been illegal to grow due to the larger threat to pine forests. The federal government lifted the ban in 1966. According to Roper et.al.[2] "Separating currant and gooseberry from white pine by at least 1,000 feet can reduce infections but is often not practical". According to CDMS there is only one other fungicide Rally (Myclobutanil) labeled to control White pine blister rust. Its only other labeled use on Currants is for Powdery mildews.[1] Proline 480 SC use for White pine blister rust control is labeled .[1]

Currant growers have more economically important pests to control than White pine blister rust, which causes a relatively minor loss to their yield.[3, 4] Growers may not typically have a business need to control the Rust disease. When a grower does not have Powdery mildew he will likely have no reason to apply Rally. Proline 480 SC, however, will be broadly labeled for many important pests that do occur on and cause economic losses to in currants, such as Anthracnose, Powdery mildew, Septoria leaf spot, Botrytis, Fruit rots and others. Both *Septoria* and *Botrytis* (strengths of Proline 480 SC) cause economic losses in currants, but neither are controlled by Rally and so the currently available options are insufficient.[3] Proline 480 SC when applied for control of economically important currant diseases such as *Botrytis* and *Septoria* will, when timed correctly in spring, summer, and fall, and used with more resistant cultivars provide the side benefit of preventative control of White pine blister rust reducing the inoculum source that would then cause greater damage in pine.

10.3 References

1. **CDMS.** http://www.cdms.net/

2. **White Pine Blister Rust on Currants and Gooseberries.** Michael A. Ellis and Leona Horst. Department of Plant Pathology. Ohio State University. 2010. http://ohioline.osu.edu/hyg-fact/3000/pdf/3205.pdf (Appendix 14)

3. **Growing Currants, Gooseberries, and Elderberries in Wisconsin**. Roper et.al. University of Wisconsin Extension, Cooperative Extension. 1998. http://learningstore.uwex.edu/assets/pdfs/A1960.PDF (Appendix 15)

4. **Gooseberries and Currants.**. The Mid-Atlantic Berry Guide for Commercial Growers. PSU. Chapter 9. 2010-2011. page 221-222. http://pubs.cas.psu.edu/freepubs/MABerryGuide.htm (Appendix 16)

5. **PROLINE 480 SC label 2013.** (Appendix 1)

11.0 Justification of the Need for Prothioconazole to Control Key Diseases in Gooseberry

11.1 Gooseberry Acreage

Gooseberries are grown in the U.S for their berries which are similar in size to blueberries. No official acreage estimates could be found, however Gooseberry (*Ribes grossularia* var. *uva-crispa* and *R. hirtellum*.) production is less than 300,000 planted acres in the U.S. and therefore qualifies as a minor crop. (Table 1)

11.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Gooseberry

11.2.1 The Prothioconazole use in gooseberry production for the control of White pine blister rust satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

White pine blister rust is a devastating disease of pine forests (*Pinus* spp.). Gooseberries and other *Ribes* spp. are the required alternate hosts for the pathogen *Cronartium ribicola*. It is too difficult from a practical perspective to control diseases directly in forest crops with fungicide applications. However, one means of reducing disease in pine is to reduce disease that occurs locally on the alternate hosts such as *Ribes* spp. Since the early 1900's some of the more highly susceptible varieties of *Ribes* spp. have been illegal to grow due to the threat to pine. The federal government lifted the ban in 1966. According to Roper et.al.[2] "Separating currant and gooseberry from white pine by at least 1,000 feet can reduce infections but is often not practical" According to CDMS there is only one other fungicide Rally (Myclobutanil) labeled to control White pine blister rust, Anthracnose, and Powdery mildew on berries.[1] Proline 480 SC use for White pine blister rust control is labeled along with many other diseases.[5]

Gooseberry growers have more economically important diseases to control than White pine blister rust, which causes a relatively minor loss to fruit yield.[3, 4] Gooseberry growers may not typically have a business need to control the White pine blister rust disease. Proline 480 SC, however, will be broadly labeled for many important pests that do occur on and cause losses to in gooseberry, such Septoria leaf spot, Botrytis, Fruit rots and others.[5] Unlike with Proline 480 SC, neither *Septoria* nor *Botrytis* are controlled by Rally and so there is a need for additional fungicide option that do have the side benefit of protection against White pine blister rust when used for *Septoria, Botrytis,* and fruit rots each of which cause economic losses in gooseberry.[3] Proline 480 SC when applied for control of these economically important gooseberry diseases will, when timed correctly in spring, summer, and fall, and used with more resistant cultivars provide the side benefit of preventative control of White pine blister rust reducing the inoculum source that would then cause damage in pine.

11.3 References

1. **CDMS.** http://www.cdms.net/

2. **White Pine Blister Rust on Currants and Gooseberries.** Michael A. Ellis and Leona Horst Department of Plant Pathology. Ohio State University. 2010. http://ohioline.osu.edu/hyg-fact/3000/pdf/3205.pdf (Appendix 14)

3. **Growing Currants, Gooseberries, and Elderberries in Wisconsin**. Roper et.al. University of Wisconsin Extension, Cooperative Extension. 1998. http://learningstore.uwex.edu/assets/pdfs/A1960.PDF (Appendix 15)

4. **Gooseberries and Currants.** The Mid-Atlantic Berry Guide for Commercial Growers. PSU. Chapter 9. 2010-2011. page 221-222. http://pubs.cas.psu.edu/freepubs/MABerryGuide.htm (Appendix 16)

5. **PROLINE 480 SC label 2013.** (Appendix 1)

12.0 Justification of the Need for Prothioconazole to Control Key Diseases in Pine and Hardwood Nurseries

12.1 Pine and Hardwood Nurseries Acreage

The U.S. pine nursery industry produces nursery-grown bare root seedlings used for reforestation. Prothioconazole is registered and commercially available to the forestry nursery industry as Proline 480 SC. The label specifies “not for forest plantings” It is labeled and used in the production of the conifers and hardwoods to control several key diseases in the southern United States which generates 80% of the national forest seedlings.

There are 38 different pine and fir tree species listed in CDMS.[1] Common name examples of these species include: Loblolly, Longleaf, Slash, Shortleaf, Sand, Scotch, Virginia, White, Black, Monterey, Alpine fir, and Ponderosa pine. In *Forest Nursery Practices in the South*, Boyer and South list in Table 3 various pine species of seedlings grown in the southeast.[2] According to Tom Starkey estimated nursery acreage in U.S. in 2008 breaks out as follows:

- 75% of the pine seedlings produced are loblolly pine (*Pinus taeda*)
- 19% are slash pine (*Pinus elliottii*)
- 2% longleaf pine (*Pinus palustrus*)
- 4% are other miscellaneous pine types.[3]

Although the nurseries supply the U.S. with one billion seedlings each year, the production is **highly concentrated** on the minor nursery acres where Proline 480 SC is registered. According to Scott Enebak Director and Professor, Southern Forest Nursery Management Cooperative, School of Forestry and Wildlife Sciences the total U.S. pine nursery acreage is approximately 2500 acres (Practices for Forest Nursery Seeds and Seedlings: Predation Potential by Birds/Mammals and Risk to Non-Target Organisms see page 14)[4] and therefore less than 300,000 acres. (Table 1)

In addition to the conifer uses Proline 480 SC is approved for use for nursery production of hardwood trees. There were estimated 65 acres of hardwood nursery acres in the South in 2008 and hardwood species are primarily within the Genera of *Quercus, Carya, Liquidambar, Populus, Plantanus,* and *Fraxinu.* There are approximately 30 to 40 various types of hardwood species grown for planting stock throughout the southern U.S.[3] These hardwood species are typically produced by state run nurseries and used for ecosystem restoration, wildlife planting, restoration projects and watershed management.

12.2 <u>Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Pine and Hardwood Nurseries</u>

12.2.1 The Prothioconazole use in pine nursery production for the control of Pitch canker satisfies *Criterion I: There are insufficient efficacious alternative registered pesticides available for the use.*

Besides Proline 480 SC there are no fungicides registered for the control of Pitch canker caused by *Fusarium circinatum* in nurseries.[4, 5, 7] The following is an excerpt from a letter from Russell Pohl of the GA Forestry Commission to the GA Department of Agriculture.[5] It demonstrates the importance of Prothioconazole for pitch canker and supports Prothioconazole satisfying Criteria I.

> "*Forest tree nurseries have faced the loss of a number of fungicides that make growing tree seedlings increasingly difficult. Proline 480 SC is a broad spectrum fungicide that can ameliorate a number of significant nursery diseases including two of the most important – fusiform rust and pitch canker. Fusiform rust is the most important disease in the southern pines and <u>there are no currently registered fungicides for pitch canker control in nurseries.</u> Proline 480 SC would be a valuable tool in a nursery manager's arsenal. The product has been thoroughly researched by the*

> *Auburn University Nursery Management Cooperative and has proven to be effective." -* **Russell Pohl** ***[5]***

12.2.2 The Prothioconazole use in pine nursery production for the control of Rhizoctonia foliar blight and for Fusiform rust satisfies *Criterion II: the alternatives to the minor use pesticide pose greater risks to the environment or human health.*

There are products registered for use in Pine to control two other key nursery diseases; Rhizoctonia foliar blight (*Rhizoctonia* spp.) and Fusiform rust (*Cronartium* spp.). For Fusiform rust control these are based on active ingredients Tridimefon, Ziram and Myclobutanil. However, according to the industry for the nurseries none of the alternatives in practice have been sufficiently effective as proven in numerous research trials conducted at Auburn University.[3]

> *"The currently available fungicide do not provide efficacious control of Rhizoctonia Foliar Blight". -* **Tom Starkey** ***[7]***

Poor performance with the currently available fungicides leaves nurseries with the more effective option to apply labeled fumigants such as <u>methyl bromide</u>[1], <u>Telone</u> [1, 6] (1,3-dichloropropene and chloropicrin) and <u>Nutrapic</u>[1] (chloropicrin) which may pose a greater risk to human health and to the environment. For example, methyl bromide depletes the ozone layer and finding alternatives to it in agricultural production has been a major U.S. research focus for the past 20 years. Also used is Telone C-17 and its label caries a "Danger" classification and carries the following text:

> "*This fumigant has the capacity to cause marked irritation to the upper respiratory tract. A strong lachrymator (tear-producing eye irritant). Low concentrations are capable of causing painful eye irritation. The effect may be so powerful that a person may become temporarily blinded and panic-stricken. That, in turn, may lead to accidents."* **- Telone C-17 label [6]**

Proline 480 SC, on the other hand, caries a "Caution" classification and the reentry interval is only 12 hours. Proline 480 SC does not deplete the ozone and has proven to be exceptionally effective on both Rhizoctonia foliar blight and Fusiform rust. As more nurseries adopt the use, Proline 480 SC will take the place of some fumigant use. Other currently available fungicides have not been able to do so due to poor performance. Prothioconazole therefore satisfies Criterion II: the alternatives to the minor use pesticide pose greater risks to the environment or human health.

12.2.3 The Prothioconazole use in Pine for the control of Fusiform rust satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

One of the most important stem diseases on conifers is Fusiform rust caused by the obligate pathogen *Cronartium* spp. There are few products labeled for this disease. Proline 480 SC will play a significant part in managing pest resistance according to Dr. Scott Enebak Director & Professor Southern Forest Nursery Management Cooperative, School of Forestry and Wildlife Sciences.

> *"Proline will play a significant part in managing pest resistance (especially with the obligate fungal pathogen fusiform rust*)" page 3 **- Scott Enebak [4]**

12.2.4 The Prothioconazole use in Pine for the control of soil-borne diseases satisfies *Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.*

Proline 480 SC is labeled and effective on the three key pine diseases as either as a foliar or seed-applied treatment. The option to apply product effectively in a highly targeted manner as a seed treatment for some of the pine diseases reduces tractor/fuel input requirements. Effectiveness of this application method will vary by nursery and depend on disease pressures. Whichever application method is used by the grower the treatment is a better fit from an IPM strategies perspective because it supports a replacement of fumigant use and is not known to be harmful on beneficial organisms. Methyl bromide, 1,3-dichloropropene, and chloropicrin pose a greater risk to human health and to the environment, and they destroy a wide range beneficial microbial populations desired in an IPM program.

> "*Proline will play a significant part in an integrated pest management program in forest tree nurseries as the soil fumigant MBr is being phased out and soil-borne fungi become more of an issue*." page 3 **- Scott Enebak [4]**

Furthermore, Prothioconazole will also serve as a tool to control additional diseases, such as *Cylindrocladium* spp., which also cause losses in pine nursery production. The only fungicide labeled for this currently is a *Trichoderma* based product. Prothioconazole is used in peanut in furrow at plant by growers with a history of disease as the standard preventative treatment to control both soil-borne *Rhizoctonia* spp. and *Cylindrocladium* spp. Sufficient *Cylindrocladium* spp. control in peanut is provided by Proline 480 SC and this allows some grower in NC/VA to avoid having to apply fumigant Vapam (Metam sodium) each year which has become more difficult. Bayer plans to add this additional pest to the pine and hardwoods label once field trials have confirmed effectiveness in pine further reducing dependence on fumigants.

Summary: (1) there are no other viable Pitch canker options for the multiple pine and hardwoods tree species grown in the U.S. for reforestation purposes. (2) no other sufficiently effective options for Rhizoctonia foliar blight and Fusiform rust except fumigants which are more harmful to the environment and pose greater worker safety concerns. (3) Prothioconazole is a viable resistance management tool when used in a rotation in a crop with few available fungicides approved for use. (4) Prothioconazole improves integrated management approaches because it may be applied as a seed treatment or foliar treatment and will help provide a more environmentally favorable option to soil fumigants which may be more harmful to the environment, worker, and beneficial organisms.

12.3 References

1. **CDMS.** http://www.cdms.net/

2. **Forest Nursery Practices in the South.** James N. Boyer and David South. Southern Journal of Applied Forestry. (Appendix 17)

3. **Personal communication, Tom Starkey.** Research Fellow. Southern Forest Nursery Management Cooperative. Auburn University, School of Forestry & Wildlife Sciences. 334-844-8069. starkte@auburn.edu

4. **Practices for Forest Nursery Seeds and Seedlings: Predation Potential by Birds/Mammals and Risk to Non-Target Organisms.** Dr. Scott A. Enebak; Director & Professor, Southern Forest Nursery Management Cooperative School of Forestry and Wildlife Sciences, Auburn University, AL. (minor use crop description on page 3). (Appendix 18)

5. **Letter from Georgia Forestry Commission.** (Appendix 19)

6. **Telone C-17 label.** (Appendix 20)

7. **Proline 24-C request.** page 2 and page 8 (Appendix 21)

13.0 Justification of the Need for Prothioconazole to Control Key Diseases in Chickpea

13.1 Chickpea Acreage

Chickpea (*Cicer arietinum*) also known as the garbanzo bean is a cool season legume grown in California, the Pacific Northwest, and in the northern plains states. There were estimated to be 146,000 planted acres in 2010 by USDA NASS. Production is lower than 300,000 acres per year and therefore qualifies as a minor use crop. (Table 1)

13.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Chickpea

13.2.1 The Prothioconazole use in chickpea for the control of Ascochyta blight satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Ascochyta blight caused by *Ascochyta rabiei* is a major disease of chickpea. Growers may need to make 3 to 5 applications per season to control the disease. For the past decade, quinone-outside inhibitor (QoI) fungicides (FRAC Group 11) along with protectants have been the mainstay of control for this disease, however overuse of the single-site QoI products Azoxystrobin (Quadris) and Pyraclostrobin (Headline) have resulted in widespread and increasing resistance and loss of efficacy with these products.[1, 2, 3, 8] University researchers advised that **no Group 11 be used to control this disease due to the resistance**.[3]

> "*Ascochyta blight is the most problematic disease of chickpea in North Dakota and a severe disease in most chickpea growing regions of the world. Complete yield loss to Ascochyta has been recorded, and the disease can reduce seed quality significantly. In 2005, the Ascochyta pathogen developed resistance to FRAC Group 11 fungicides (Headline*

> *and Quadris), rendering the most frequently applied fungicides ineffective in North Dakota."*
>
> *"…fungicides in FRAC group 11 are not recommended*." ***- PP-1362*** [3]
>
> "*DO NOT USE STROBILURIN (QoI/FRAC 11) FUNGICIDES such as Headline and Quadris: Ascochyta rabiei has developed resistance to these fungicides, and they no longer work*." - **Michael Wunsch**

Approach (Picoxystrobin) is a recently registered QoI fungicide that would fall into same group as Headline and Quadris and would not be recommended for the same reason.

For the control of *Ascochyta* spp. CDMS[4] and Agrian[5] searches list the following non-QoI containing fungicides: Chlorothalonil (a protectant), Maneb (a protectant, labeled via 2ee), Boscalid (SDHI, FRAC Group 7), and Prothioconazole (FRAC Group 3) as Proline/Propulse. The two protectants - Chlorothalonil and Maneb provide acceptable control if applied preventively. However, for financial reasons growers are not always willing or able to apply preventively. From an IPM perspective they may not choose to apply preventatively believing that the disease may not occur.

Endura (Boscalid) is a fungicide from the succinate dehydrogenase inhibitor mode of action SDHI (FRAC Group 7) and at high risk in this crop. Group 7 fungicides have a single site mode of action and resistance strains are already well documented in other pests/crops such as *Alternaria alternata* of almond, pistachio, and other tree nuts, *Didymella bryoniae* Gummy stem blight of cucurbits, various species of Powdery mildews such as *Podosphaera xanthii* of cucurbits, *Botrytis cinerea* Grey mold of grape and strawberries, and other important pathogens. Globally there are already eleven examples of resistance known with Boscalid. [6] Resistance management for SDHI is particularly required if used for at risk pathogens such as *Ascochyta rabiei*.[2] Proline 480 SC is the ideal rotational option for the SDHI in chickpea.

Difenoconazole (FRAC Group 3) is approved and available as Quadris Top in mixture with Azoxystrobin. The Azoxystrobin component is no longer recommended due to spreading resistant strains. Use of premixes where one component has an increasing resistant population is not ideal, and not recommended by some researchers. There are concerns about using Quadris Top because the QoI component may or may not be contributing to the disease control depending on the *local sensitivity to the QoI component*. This may lead to uncertainty and use of a rate of Difenoconazole that is insufficient to control the disease. Use of low rates is a risk factor in the selection of resistance strains. Quadris Top is not included in the 2012 recommendation from NDSU pathologist Michael Wunsch. Priaxor (SDHI, FRAC Group 7 and 11) was labeled however it also contains a QoI - Pyraclostrobin.

Proline 480 SC is the only solo DMI fungicide (FRAC Group 3) available for use against Ascochyta blight of chickpea. With curative efficacy it is excellent on this disease, may be rotated with and serves as good resistance management for Boscalid (and other new SDHI fungicides), which have a single site mode of action and are at high risk of resistance development. Further, unlike Bravo and Maneb the grower can wait for disease to appear before spraying.

The authors believe that Proline 480 SC satisfies Criteria III by providing a viable and much needed alternative mode of action tool in chickpea to control Ascochyta blight. Chickpea is a crop requiring multiple applications and at significant risk due to fungicide resistance and effective alternatives and variety of options will slow resistance. Proline 480 SC will help to prevent overuse of the few options they have and delay the eventual loss of the single site SDHI Group 7 fungicides as has already happened in chickpea with the QoI Group 11.

13.3 References

1. **Resistance to QoI Fungicides in *Ascochyta rabiei* from Chickpea in the Northern Great Plains.** Wise, K. A., Bradley, C. A., Pasche, J. S., and Gudmestad, N. C. 2009. Plant Dis. 93:528-536. (Appendix 22)

2. **Baseline Sensitivity of *Ascochyta rabiei* to Azoxystrobin, Pyraclostrobin, and Boscalid.** Wise, K. A., Bradley, C. A., Pasche, J. S., Gudmestad, N. C., Dugan, F. M., and Chen, W. 2008. Plant Dis. 92:295-300. (Appendix 23)

3. **Ascochyta Blight of Chickpea.** PP-1362. NDSU Extension Service, N.D. Agricultural Experiment Station. June 2008. (Appendix 24)

4. **CDMS.** http://www.cdms.net/

5. **Agrian** *www.agrian.com*

6. **List of SDHI resistant species.** SDHI Working Group. FRAC. www.frac.info (Appendix 25).

7. **Resistance and Mixtures Jan 2010.** FRAC recommendations for fungicide mixtures designed to delay resistance evolution. FRAC January 2010. (Appendix 39)

8. **Chickpea Ascochyta 2012.** Management of Ascochyta blight of chickpea. Michael Wunsch, Plant Pathologist, NDSU Carrington Research Extension Center. 2012. (Appendix 40)

14.0 Justification of the Need for Prothioconazole to Control Key Diseases in Crambe

14.1 Crambe Acreage

Crambe (*Crambe* spp.), are brassicas grown in U.S. for its seed oil which is used for a variety of industrial purposes, is susceptible to White mold, caused by *Sclerotinia sclerotiorum.* When excessive rain coincides with bloom significant yield losses can occur.[1] Crambe planted acres in US in 1996 was 22,000 acres. (Economic Research Service, USDA, 1996).[2] Crambe production is lower than 300,000 acres per year. (Table 1)

14.2 <u>Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Crambe</u>

14.2.1 The Prothioconazole use in crambe for the control of *Sclerotinia sclerotiorum* satisfies *Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.*

Sclerotinia sclerotiorum occurs on crambe and is the same pathogen that occurs on major U.S. crops grown geographically where crambe is produced, including potato, canola, and soybean. The pathogen is classified by FRAC as a pathogen with a "medium" risk of resistance development.[3] There are no commercially available crambe varieties with complete resistance.

Three modes of action are currently available to growers for control of Sclerotinia stem rot / white mold caused by *Sclerotinia sclerotiorum* - Endura (Boscalid, FRAC Group 7), Topsin (Thiophanate-methyl, FRAC Group 1), and Proline 480 SC (Prothioconazole, FRAC Group 3).[4] Priaxor (labeled only as suppression) is a newly registered product containing Fluxapyroxad and Pyraclostrobin (a mix of Group 7 and Group 11). The Pyraclostrobin component of this mix adds little to the *Sclerotinia sclerotiorum* control as the QoI products are weak on this pathogen. These products are applied during bloom to protect the flowers from infection. The biocontrol agent Contans only controls very early seedling disease and not the larger yield reducing damages during the season.

Resistance management required, especially if used for at risk pathogens. Over reliance on these modes of action in Crambe such as Thiophanate-methyl or Boscalid and Fluxapyroxad, both SDHI's, can result in resistant populations that could jeopardize production of potato or other crops that are susceptible to the pathogen. There is already resistance reported for *Sclerotinia sclerotiorum* in oilseed rape for SDHI and the mutation is known to be D-H132R.[12] Boscalid and Fluxapyroxad have a single site mode of action and resistance is already well known in eleven other pests/crops such as *Alternaria alternata* of tree nuts, *Alternaria solani* of potato, *Didymella bryoniae* Gummy stem blight of cucurbits, and various species of Powdery mildews. [12]

The resistance risk for Thiophanate–methyl (methyl benzimidazole carbamate or MBC fungicide group) is designated as "high" according to the FRAC guidelines. Resistance is common in many fungal species for this older fungicide. *S. sclerotiorum* isolates resistant to MBC fungicides has been reported in Canada (Gossen, Rimmer & Holley, 2001)[6], China (Zhiqi et al., 2000)[7] and USA (Mueller et al., 2002)[8], thus showing that the potential of developing resistance to MBC's could be realized. Several target site mutations are known, mostly E198A/G/K, F200Y in ß-tubulin gene. The Topsin M 70 WDG label includes the following resistance management text.

> *"RESISTANCE MANAGEMENT: To avoid the development of tolerant or resistant strains of fungi, Topsin M 70WDG should always be tank-mixed with a fungicide of different chemistry, and/or a fungicide of different chemistry should be alternated with Topsin M 70WDG."* **- Topsin M label[9]**

Contans is a biological control agent that does not protect the crambe blossoms from infection Contans is only used to "reduce"/control the disease in the soil prior to or at planting. It does not protect blossoms from infection during the in the season. Activity of Contans will not provide cure to fields that are heavily infested. Since Contans is a slow-growing fungus, it parasitizes sclerotia in field soils slowly (Partridge, Sutton & Jordan, 2006). In addition, the growth, spore germination and mycoparasitic activity of Contans are potentially reduced with increasing temperature and soil moisture (Partridge et al., 2006).[10, 11.]

Prothioconazole (Proline 480 SC), a DMI fungicide belonging to FRAC Group 3, provides a much needed alternative to overuse of the high risk Thiophanate-methyl and the two registered SDHI products where the mutation D-H132R already has been identified. Growers may use Proline 480 SC in alternation or tankmix with either of the other fungicides to delay resistance. Prothioconazole satisfies Criteria III by providing a viable alternative mode of action in crambe in order to prevent overuse and eventual loss of Boscalid and Thiophanate-methyl which could consequently cause huge economic losses to the U.S. potato, canola, and soybean industry.

14.3 References

[1.] **Crambe production.** A-1010. Endres and Schatz. NDSU. 1993. http://www.ag.ndsu.edu/pubs/plantsci/crops/a1010w.htm#disease

[2.] **Crambe acres.** Economic Research Service, USDA; Industrial Uses/IUS-6/September 1996, page 17. Table 4. (Appendix 26)

[3.] **FRAC Pathogen risk List.** Table 2, page 3. (Appendix 27)

[4] **Agrian** *www.agrian.com*

[5.] **CDMS.** http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=

[6.] **First report of resistance to benomyl fungicide in *Sclerotinia sclerotiorum*.** Gossen, B. D., Rimmer, S. R., and Holley, J. D. 2001. First report of resistance to benomyl fungicide in *Sclerotinia sclerotiorum*. Plant Dis. 85:1206.

[7.] **Resistance monitoring of *Sclerotinia sclerotiorum* to carbendazim.** Zhiqi, S., Mingguo, Z., Zhongyin, Y., Jianrong, S., Huaigu, C., and Yuzhong, W. 2000. Resistance monitoring of *Sclerotinia sclerotiorum* to carbendazim. Jiangsu J. Agric. Sci. 16:226-229.

[8.] **Efficacy of fungicides on *Sclerotinia sclerotiorum* and their potential for control of Sclerotinia stem rot on soybean.** Mueller, D. S., Dorrance, A. E., Derksen, R. C., Ozkan, E., Kurle, J. E., Grau, C. R., Gaska, J. M., Hartman, G. L., Bradley, C. A., and Pedersen, W. L. 2002. Efficacy of fungicides on *Sclerotinia sclerotiorum* and their potential for control of Sclerotinia stem rot on soybean. Plant Dis. 86:26-31.

[9.] **Topsin M label.** (Appendix 28)

[10.] **Management of Sclerotinia blight of peanut with the biological control agent *Coniothyrium minitans*.** Partridge, D. E., Sutton, T. B., Jordan, D. L., Curtis, V. L., and Bailey, J. E. 2006. Management of Sclerotinia blight of peanut with the biological control agent *Coniothyrium minitans*. Plant Dis. 90:957-963.

[11.] **Effect of environmental factors and pesticides on mycoparasitism of Sclerotinia minor by *Coniothyrium minitans*.** Partridge, D. E., Sutton, T. B., and Jordan, D. L.

2006. Effect of environmental factors and pesticides on mycoparasitism of Sclerotinia minor by *Coniothyrium minitans*. Plant Dis. 90:1407-1412.

12. **List of SDHI resistant species.** SDHI Working Group. FRAC. www.frac.info (Appendix 25)

15.0 Justification of the Need for Prothioconazole to Control Key Diseases in Buckwheat

15.1 Buckwheat Acreage

Buckwheat (*Fagopyrum esculentum*) has been grown since the colonial days in North America. Buckwheat grain is used to produce flour for human and livestock consumption. Buckwheat is also well suited as a smother crop to control problematic weeds such as Canada thistle, sowthistle, quackgrass, and other weeds and reduce herbicides use.[1] It is also used, because of its prolific flowering, as a source of nectar for pollinators.[2] Finally, buckwheat is used as a rotational crop to condition and rejuvenate low-fertility soils.[2] Recent census' indicates buckwheat acreage in the U.S. has been between 42,641 in 2002 to 24,760 in 2007 (2007 Census of Agriculture), qualifying this as a minor crop. (Table 1)

15.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Buckwheat

15.2.1 The Prothioconazole use in Buckwheat production for the control of *Rhizoctonia* satisfies Criterion IV: The minor use pesticide plays or will play a significant part in an integrated pest management program.

The use of Prothioconazole (Proline 480 SC Fungicide)[5] as a seed treatment on buckwheat will improve its stand and vigor so that it performs better as a quick cover, smother crop, soil conditioner, and nectar source in integrated pest management programs. Proline 480 SC will serve as an alternative mode of action to the Rhizoctonia control provided by Fludioxonil (FRAC group 12) in Maxim. Proline 480 SC seed treatment will improve buckwheat's establishment and performance as a rotational/smother crop in fields rotated to potato. The advantages of buckwheat as a rotational crop in potato, such as improved soil structure and fertility can be offset by increased populations of *Rhizoctonia* in plots planted to potatoes when they follow buckwheat.[3,4] The higher *Rhizoctonia* spp. populations, however, were not associated with increased Rhizoctonia disease in the potatoes. The authors suggested that buckwheat cover crops selected for *Rhizoctonia* strains or species that were nonpathogenic or less pathogenic on potato.[3] Consequently, IPM systems that employ cover crops such as buckwheat to help manage soil diseases, improve soil fertility, and provide pollen sources will benefit by using Prothioconazole-treated (Proline 480 SC) buckwheat seed to establish optimum stand and vigor, and best maintain non-pathogenic strains of *Rhizoctonia* populations in IPM fields such as potato.

15.3 References

1. **Alternative Field Crops Manual. Buckwheat.** Oplinger, E. S., Oelke, E. A., Brinkman, M.A., and Kelling, K. A. 1989. http://www.hort.purdue.edu/newcrop/afcm/buckwheat.html

2. **Managing Cover Crops Profitably.** Sustainable Agricultural Research and Education. 3rd Edition. 2007. http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Printable-Version2

3. **Effects of Crop Rotation on Rhizoctonia Disease of White Potatoes.** Specht, L. P., and Leach, S. S. 1987. Plant Disease 71: 433-437. http://www.apsnet.org/publications/PlantDisease/BackIssues/Documents/1987Articles/PlantDisease71n05_433.pdf

4. **Rotation and Cover Crop Effects on Soilborne Potato Diseases, Tuber Yield, and Soil Microbial Communities.** Larkin, R. P., Griffin, T. S., and Honeycutt, C. W.2010. Plant Disease 94: 1491-1502. http://www.ncaur.usda.gov/research/publications/publications.htm?SEQ_NO_115=220988

5. **PROLINE 480 SC label 2013** (Appendix 1, seed treatment box)

16.0 Justification of the Need for Prothioconazole to Control Key Diseases in Popcorn

16.1 Popcorn Acreage

Popcorn (*Zea mays* var. *everta*) is a specialty type of corn that is sold primarily as either a plain or flavored, popped snack product, or as dried seed for conventional or microwave popping. It is nutritionally one of the best snack foods, providing approximately the same protein, iron, and calcium as an equal amount of beef. Popcorn can be grown under the same conditions that favor dent (field) corn. Consequently, the largest acreages of popcorn, in Nebraska, Iowa, Illinois, Indiana, and Ohio, coincide with areas where large acreages of field corn are grown.[1] Popcorn is subjected to the same diseases as field corn and field corn is thought to provide the inoculum for popcorn diseases.[2] Principle diseases of economic importance to corn in general (including popcorn) include gray leaf spot (*Cercospora zeae-maydis*), and rusts (*Puccinia* spp.). In 2011 a total of 23.4 million acres of corn were treated with fungicides for foliar disease control. Principle products included Headline (8.0 mm acres), Headline AMP (6.2 mm acres), Quilt (3.4 mm acres), and Stratego YLD (2.4 mm acres) (Source: GfK Kynetec). Popcorn acres were 309,879 in 2002 but have come down to 201,623 in 2007 qualifying as a minor crop. (Table 1).

16.2 Exclusive Use Data Protection Criteria Prothioconazole Satisfies in Popcorn

A. The Prothioconazole use in popcorn production for the control of Gray leaf spot and Common rust satisfies Criterion III: The minor use pesticide plays or will play a significant part in managing pest resistance.

Prothioconazole offers a highly active alternative of the DMI FRAC group 3 to commonly used QoI fungicides (FRAC group 11) and older-generation DMI fungicides in order to preserve the effectiveness of both of these groups against common popcorn diseases. Prothioconazole is registered as an in-can with the QoI-fungicide Trifloxystrobin (Stratego YLD). This in-can combination offers two of the highest performing fungicides of their respective FRAC grouping against the major popcorn and corn diseases, and is an accepted way to manage resistance to both FRAC groups.[4] Although other DMI fungicides are registered in combination with strobilurin fungicides on popcorn, Prothioconazole gives the highest level of control compared to Propiconazole, a 1st-generation DMI fungicide, and Metconazole.

Stratego YLD is currently one of the highest performing fungicides registered for use on popcorn, and corn in general. For example, Stratego YLD (Trifloxystrobin + Prothioconazole) applied at V5 and again at R1 on field corn provided significantly higher gray leaf spot (*Cercospora zea-maydis*) and higher common rust (*Puccinia sorghi*) control compared to other QoI + DMI fungicide in-can products such as Headline AMP (Pyraclostrobin + Metconazole) and Quilt (Azoxystrobin + Propiconazole), and the market leader Headline (Pyraclostrobin). Stratego YLD had the highest yield and maintained the highest level of “greenness”, both measures of overall plant health, of any fungicide program tested by the University of Nebraska near Clay Center, NE.[3] Research conducted on popcorn by Real Farm Research in Aurora, NE in 2011 showed that 5 oz of Stratego YLD applied at tassel to hybrid VYP214 provided the greatest yield increase, +929 lbs/acre over the untreated check, compared to any other fungicide plus variety program. Stratego YLD was also the top overall yielding fungicide treatment to the four hybrids tested, averaging 340.5 lbs/acre, compared to Quilt Xcel (169.8 lbs), and Headline AMP (83.2 lbs).[5]

16.3 References

1. **Alternative Field Crops Manual – Popcorn. University of Wisconsin-Extension.** Carter, P. R., Hicks, D. R., Doll, J. D., Schulte, E. E., Schuler, R., and Holmes, B. 1989 (updated 2012). 10 pp. http://www.hort.purdue.edu/newcrop/afcm/popcorn.html

2. **Popcorn Pest Management Strategic plan for the North Central Region.** 2002. Workshop March 2002. 83 pp. http://www.ipmcenters.org/pmsp/pdf/ncrpopcorn.pdf

3. **Efficacy evaluation of foliar fungicide application timing on diseases of field corn in Nebraska.** 2011. Schleicher, C.M, and Jackson, T.A. 2011. Plant Disease Management Reports 6: FC016. http://www.plantmanagementnetwork.org/pub/trial/pdmr/reports/2012/FC016.pdf

4. **Field Crop Fungicides for the North Central United States.** Mueller, D.S., and Bradley, C.A. http://www.ncipmc.org/resources/Fungicide%20Manual4.pdf

5. **Real Farm Research.** 2011. http://www.realfarmresearch.com

17.0 <u>Qualification for Extension of Exclusive Data Use</u>

FIFRA Section 3(c) (1) (F) (ii) allows for the extension of the period of exclusive data use by one additional year for each three minor uses registered within seven years of the initial registration up to a total of three additional years provided that:

> *(I) there are insufficient efficacious alternative registered pesticides available for the use;*
>
> *(II) the alternatives to the minor use pesticide pose greater risks to the environment or human health;*
>
> *(III) the minor use pesticide plays or will play a significant part in managing pest resistance;*
>
> *(IV) the minor use pesticide plays or will play a significant part in an integrated pest management program.*

The minor crops on which Prothioconazole was registered during the first seven years after initial registration March 14, 2007 is summarized in *Table 1: Minor Crop Registrations, Planted Acreage, Diseases Controlled by Prothioconazole, PRIA Date and Exclusive Use Data Protection Criteria Satisfied by Prothioconazole.* These uses meet requirements for extension as follows.

(I) there are insufficient efficacious alternative registered pesticides available for the use.

> A review of Table 1 shows that many of the minor uses qualify in part because current options to growers are limited or non-existent. Cucurbit (watermelon, summer squash, cucumber, and cantaloupe) growers currently rely on restricted use broad spectrum biocide fumigants to reduce Fusarium wilt losses because of the lack of effective conventional fungicides. The need for non-fumigant fungicide options in cucurbits was supported by requests to IR-4 from grower/extension agencies, which led to the major investment of a large scale testing program directed by IR-4 which identified Prothioconazole as a highly effective control measure. In addition to Fusarium wilt, in some cucurbits like watermelon, pumpkin, and cucumber there are limited approved controls for Southern blight which causes stem and fruit rot damages in some geographies. In pine and hardwood nurseries there were no effective non-fumigant options available to the forestry industry for Pitch canker prior to the registration of Prothioconazole. In cranberry and lowbush blueberry there are no approved fungicides except Prothioconazole registered to control Valdensinia leaf spot disease which has recently been identified in Maine and has potential to cause losses already occurring in Canada. As indicated by the public use requests and explained in this document, there are insufficient efficacious alternative registered pesticides available to control the target pests on these crops. Therefore, the authors believe these uses qualify towards extension of exclusive data use.

(II) the alternatives to the minor use pesticide pose greater risks to the environment or human health.

Several of the minor use candidates qualify because Prothioconazole will replace or has replaced some commercial use of a control measure, restricted use fumigants, which pose a greater risk to the environment or human health. In the crops watermelon, summer squash, and cantaloupe and in nursery production of pine and hardwood seedlings, Prothioconazole takes the place of some use of the biocide fumigant active ingredients methyl bromide, metam sodium, 1,3-dichloropropene, and chloropicrin. All four of these fumigants are potentially dangerous, sometimes fatal products to humans and their effects on the ozone, environment, and beneficial organisms are more damaging than the use of Prothioconazole. In some of these crops Oxidate (Hydrogen Dioxide) is labeled but it too has a Danger label and can cause irreversible eye damage. In peanut (which does not qualify as a minor use) a premixture of Prothioconazole and Fluopyram has been described in numerous public meetings as being a "*Vapam replacement*" by a prominent University researcher (Dr. Patrick Phipps, retired Virginia Tech). Registration of this Prothioconazole containing premix (Propulse) in furrow uses is in progress. Therefore, the authors believe these uses qualify for extensions of exclusive data use based on criterion II.

(III) the minor use pesticide plays or will play a significant part in managing pest resistance.

Many of the minor uses qualify in part because Prothioconazole will play a significant part in managing pest / disease resistance, especially for resistance-prone pests. Prothioconazole functions as significant resistance management tool when used correctly in rotation with the other fungicide classes. Furthermore, it can function as a resistance management tool even where weaker DMI are registered for use. For example, in chickpea *Ascochyta* spp. resistance threatens the industry and key QoI products are no longer effective in part because of over use and lack of alternative modes of action through the past decade. When there are few available products there is an increase in the selection pressure on the few that are available. Prothioconazole rotated into the growers spray program slows the pace of the resistance developing or worsening in crops such as cucurbits for both Fusarium wilt and *Sclerotium rolfsii* control. According to University researchers, in pine Prothioconazole plays a significant part in managing pest resistance especially for *Cronartium* spp. which causes Fusiform rust. In cranberry, growers and University researchers requested Prothioconazole via IR-4 for the highly varied complex of Fruit rot pathogens. One of the two products they use is a high risk QoI, and neither registered product covers all disease control gaps for this complex of disease. Crambe is a crop grown in rotation with major crops of potato, soybean, and canola and it shares a common disease but without the fungicide options of the larger acreage crops increasing the overall threat of resistance in the larger crops. Prothioconazole provides an alternative mode of action in crambe. There are numerous minor uses of Prothioconazole that will result in better management of pest resistance. Therefore, these uses qualify for extensions of exclusive data use.

(IV) the minor use pesticide plays or will play a significant part in an integrated pest management program.

> Many of the minor uses qualify in part because Prothioconazole plays or will play a significant part in an integrated pest management program. For example, growers of *Ribes* spp. currant and gooseberry growers when treating for various economically important diseases may also obtain control of a disease that may not even threaten them directly economically - White pine blister rust, which is historically devastating to forests. Because Prothioconazole is a systemic fungicide also with excellent curative properties, growers have an option to wait and not spray until they see disease when scouting. Because Prothioconazole is active on Fusarium wilt disease of watermelon, summer squash, and cantaloupe and the key diseases of pine and hardwoods it will provide these growers with an alternative to applications of liquid and gaseous fumigants which are more harmful to the humans and the environment and destroy the beneficial organisms which are important contributors to a successful IPM program. The use of Prothioconazole as a seed treatment on buckwheat will improve its stand and vigor so that it performs better as a quick cover, smother crop, soil conditioner, and nectar source in integrated pest management programs. Therefore, the authors believe these uses qualify for extensions of exclusive data use.

18.0 Conclusions

In conclusion, this document demonstrates that the registration of Prothioconazole on nine or more minor crops meets the criteria for granting a 3 year extension of the exclusive data use period. Prothioconazole controls important diseases for which effective control products are either not available or are available on a limited basis. Development of certain described uses on minor crops was initiated by Bayer following requests made to IR-4 (which originate from growers, grower organizations and researchers) which demonstrate that there are few or no effective measures for control of these pests and that there is a need for alternatives. Prothioconazole takes the place of control measures such as fumigants that pose a greater risk to humans and to the environment. Furthermore, when the number of available fungicidal alternative modes of action is limited as it is in the listed crops, the future effectiveness of those and related products are at risk due to resistance which follows overuse as in cucurbits, pine, chickpea, popcorn and crambe. Prothioconazole can reduce risk of resistance by replacing and/or complementing some of these currently over used high resistance risk products, some of which have already shown resistance development. Proline 480 SC, paired with the more resistant cultivars and other IPM tools will take the place of some applications of broad spectrum biocides that destroy beneficial soil microbes such as beneficial mycorrhizae and actinomycetes, beneficial entomopathogens, and other beneficials which improve nutrient uptake and plant health and control damaging insect populations naturally. Proline 480 SC is more targeted in spectrum than fumigants and is not known to affect any beneficial microbial populations or reduce beneficial insect populations when used according to label directions. Proline 480 SC in these crops is highly active on additional diseases and has curative efficacy and therefore further reduces input costs to that grower by reducing applications in an integrated program.

19.0 Appendices

The file **Appendix to Prothioconazole.pdf** has been bookmarked. Clicking on bookmarks (left side of page) in Adobe reader will jump to correct page.

PROLINE®

480 SC Fungicide

Net Contents:

2.5 Gallons

GROUP 3 FUNGICIDE

For control of specified diseases on listed crops.

ACTIVE INGREDIENT:
Prothioconazole, 2-[2-(1-Chlorocyclopropyl)-3-(2-chlorophenyl)-2-hydroxypropyl]-1,2-dihydro-3*H*-1,2,4-triazole-3-thione **41.0%**
INERT INGREDIENTS: **59.0%**
100.0%

Contains 4 pounds Prothioconazole per gallon

EPA Reg. No. 264-825

STOP - Read the label before use

KEEP OUT OF REACH OF CHILDREN

CAUTION

FOR ADDITIONAL PRECAUTIONARY STATEMENTS: See Inside Booklet.

For **MEDICAL** And **TRANSPORTATION** Emergencies **ONLY** Call 24 Hours A Day 1-800-334-7577
For **PRODUCT USE** Information Call 1-866-99BAYER (1-866-992-2937)

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US80977808B

Produced for:
Bayer CropScience LP
P.O. Box 12014, 2 T.W. Alexander Drive
Research Triangle Park, North Carolina 27709
PROLINE is a registered trademark of Bayer.

Product of Germany

FIRST AID

IF SWALLOWED:	• Immediately call a poison control center or doctor for treatment advice. • Have person sip a glass of water if able to swallow. • Do not induce vomiting unless told to do so by a poison control center or doctor. • Do not give anything by mouth to an unconscious person.
IF INHALED:	• Move person to fresh air. • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible. • Call a poison control center or doctor for further treatment advice.
IF ON SKIN OR CLOTHING:	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a poison control center or doctor for treatment advice.
IF IN EYES:	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.
For MEDICAL Emergencies Call 24 Hours A Day 1-800-334-7577. **Have the product container or label with you when calling a poison control center or doctor or going for treatment.**	
NOTE TO PHYSICIAN: No specific antidote. Treat symptomatically.	

PRECAUTIONARY STATEMENTS

HAZARD (TO HUMANS AND DOMESTIC ANIMALS)

CAUTION

Harmful if swallowed or inhaled. Causes moderate eye irritation. Avoid contact with eyes and clothing. Avoid breathing vapor or spray mist. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, or using tobacco. Remove and wash contaminated clothing before reuse.

Personal Protective Equipment

Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Chemical resistant gloves made of any waterproof material
- Shoes plus socks

Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions exist for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

Engineering Control Statements

When handlers use closed systems, enclosed cabs, or aircraft in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides [40 CFR 170.240(d)(4-6)], the handler PPE requirements may be reduced or modified as specified in the WPS.

User Safety Recommendations

Users should:

- Wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Wash the outside of gloves before removing.

ENVIRONMENTAL HAZARDS

This product is toxic to estuarine/marine invertebrates, and freshwater/estuaries/marine aquatic plants. Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwater or rinsate.

Prothioconazole-desthio (a degradate of prothioconazole) is known to leach through soil into ground water under certain conditions as a result of label use. Use of this chemical in areas where soils are permeable, particularly where the water table is shallow, may result in ground-water contamination.

(continued)

Drift and runoff are hazardous to aquatic organisms in water adjacent to treated areas. This product has a high potential for runoff for several months or more after application. Poorly draining soils and soils with shallow water tables are more prone to produce runoff that contains this product. A level, well maintained vegetative buffer strip between areas to which this product is applied and surface water features such as ponds, streams, and springs will reduce the potential for contamination of water from rainfall-runoff. Runoff of this product will be reduced by avoiding applications when rainfall is forecasted to occur within 48 hours.

DIRECTIONS FOR USE

It is a violation of federal law to use this product in a manner inconsistent with its labeling.

Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your State or Tribe, consult the agency responsible for pesticide regulation.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment (PPE) and restricted-entry interval and notification to workers (as applicable). The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard.

Do not enter or allow worker entry into treated areas during the restricted-entry interval (REI) of 12 hours.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water is:

- Coveralls
- Chemical-resistant gloves made of any waterproof material.
- Shoes plus socks

GENERAL INFORMATION

PROLINE® 480 SC Fungicide is a broad-spectrum systemic fungicide for the control of Ascomycetes, Basidiomycetes and Deuteromycetes diseases in a variety of crops including barley, buckwheat, bushberry subgroup, low growing berry subgroup (except strawberry), canola, corn, crambe, cucurbit vegetables, dry shelled pea and bean crop subgroup, field mustard, Indian rapeseed, millet, oats, peanuts, rapeseed, rye, soybean, sugar beets, triticale, wheat; conifer and hardwood nursery seeds and seedlings. Under conditions conducive to extended infection periods or high disease pressure, additional fungicide applications beyond the number allowed by this label may be needed. Under these conditions use another fungicide registered for the crop/ disease. Equipment must be properly calibrated before use.

Resistance Management Statement

PROLINE 480 SC FUNGICIDE is a Group 3 fungicide, which exhibits no known cross-resistance to other fungicide groups. However, fungal pathogens are known to develop resistance to products with the same mode of action when used repeatedly. Any fungal population may contain or develop individuals that are resistant to PROLINE 480 SC FUNGICIDE and other Group 3 fungicides. If Group 3 fungicides are used repeatedly in the same field or in successive years as the primary method of control for targeted diseases, the resistant isolates may eventually dominate the fungal population. Because resistance development cannot be predicted, the use of this product should conform to resistance management strategies established for the crop and use area. Such strategies may include rotation and /or tank mixing with products having different modes of action or limiting the total number of applications per season. Contact your local extension specialist, certified crop advisor, and/or manufacturer for fungicide resistance management and/ or integrated disease management recommendations for specific crops and pathogen populations. Bayer CropScience encourages responsible resistance management to ensure effective long-term control of the fungal diseases on this label.

Spray Equipment/Volumes

PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial and/or chemigation application equipment. Refer to the USE DIRECTIONS FOR SPECIFIC CROPS section of this label for approved applications for each crop.

Apply in a minimum of 10 gallons of spray solution per acre by ground sprayer. Apply in a minimum of 5 gallons of spray solution per acre by aircraft spray equipment unless stated differently elsewhere in this label. Check equipment calibration frequently. Complete coverage and uniform application are essential for the most effective results, especially when lower spray volumes are applied. If necessary, increase the spray volume per acre for complete crop coverage.

Mixing Procedures
Prepare no more spray mixture than is necessary for the immediate operation. Thoroughly clean spray equipment before using this product. Maintain maximum agitation throughout the spray operation. Do not let the spray mixture stand overnight in the spray tank. Flush the spray equipment thoroughly following each use and apply the rinsate to the previously treated area or dispose of the rinsate according to local regulations.

PROLINE 480 SC FUNGICIDE Alone: Add 1/2 of the required amount of water to the mix tank. With the agitator running, add the PROLINE 480 SC FUNGICIDE to the tank. Continue agitation while adding the remainder of the water. Begin application of the solution after the product has completely and uniformly dispersed into the mix water. Maintain agitation until all of the mixture has been applied.

PROLINE 480 SC FUNGICIDE + Tank-Mix Partners: Add 1/2 of the required amount of water to the mix tank. Start the agitator running before adding any of the tank-mix partners. In general, tank-mix partners should be added in this order: products packaged in water-soluble packaging, wettable powders, wettable granules (dry flowables), liquid flowables, liquids, and emulsifiable concentrates. Always allow each tank-mix partner to become fully and uniformly dispersed before adding the next product. Provide sufficient agitation while adding the remainder of the water. Maintain agitation until all of the mixture has been applied.

When using PROLINE 480 SC FUNGICIDE in tank mixtures, all products in water-soluble packaging should be added to the tank before any other tank-mix partner, including PROLINE 480 SC FUNGICIDE. Allow the water-soluble packaging to completely disperse before adding any other tank-mix partner to the tank.

If using PROLINE 480 SC FUNGICIDE in a tank mixture, observe all directions for use, crop/sites, use rates, dilution ratios, precautions, and limitations; which appear on the tank-mix product label. No label dosage rate must be exceeded, and the most restrictive label precautions and limitations must be followed. This product must not be mixed with any product that prohibits such mixing. Tank mixtures or other applications of products are permitted only in those states in which the products are registered.

PROLINE 480 SC FUNGICIDE is compatible with most insecticide, fungicide, herbicide, and foliar nutrient products. However, the physical compatibility of PROLINE 480 SC FUNGICIDE with tank-mix partners should be tested before use. To determine the physical compatibility of PROLINE 480 SC FUNGICIDE with other products, use a jar test, as described below.

Using a quart jar, add the proportionate amounts of the products to 1 qt. of water. Add wettable powders and water-dispersible granular products first, then liquids, and emulsifiable concentrates last. After thoroughly mixing, let stand for at least 5 minutes. If the combination remains mixed or can be remixed readily, it is physically compatible. Once compatibility has been proven, use the same procedure for adding required ingredients to the spray tank. For further information, contact your local Bayer CropScience representative.

The crop safety of all potential tank mixes including additives and other pesticides on all crops has not been tested. Before applying any tank mixture not specifically recommended on this label, the safety to the target crop should be confirmed. To test for crop safety, apply PROLINE 480 SC FUNGICIDE to the target crop in a small area and in accordance with label instructions for the target crop.

Aerial Application: Avoid application under conditions when uniform coverage cannot be obtained or when excessive spray drift may occur. Do not apply directly to humans or animals.

Chemigation Application: Apply PROLINE 480 SC FUNGICIDE through irrigation equipment only to crops for which chemigation is specified on this label.

PROLINE 480 SC FUNGICIDE alone or in combination with other pesticides, which are registered for application through irrigation systems, may be applied through irrigation systems. Apply this product only through center pivot, solid set, drip, linear, or moving wheel irrigation systems. Do not apply this product through any other type of irrigation system. Illegal pesticide residues in the crop can result from nonuniform distribution of treated water. If you have questions about calibration, you should contact State Extension Service specialists, equipment manufacturers, or other experts. Do not connect an irrigation system (including greenhouse systems) used for pesticide application to a public water system, unless the pesticide label-prescribed safety devices for public water systems are in place. A person knowledgeable of the chemigation system and responsible for its operation, or under the supervision of the responsible person, shall shut the system down and make necessary adjustments should the need arise.

Operating Instructions
1. The system must contain a functional check-valve, vacuum relief valve, and low-pressure drain appropriately located on the irrigation pipeline to prevent water-source contamination from backflow.

2. The pesticide injection pipeline must contain a functional, automatic, quick-closing check-valve to prevent the flow of fluid back toward the injection pump.

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3. The pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.

4. The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops.

5. The irrigation line or water pump must include a functional pressure switch, which will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected.

6. Systems must use a metering pump, such as a positive displacement injection pump (e.g., diaphragm pump), effectively designed, and constructed of materials that are compatible with pesticides and capable of being fitted with a system interlock.

7. Do not apply when wind speed favors drift beyond the area intended.

Center Pivot Irrigation Equipment
Notes: (1) Use only with drive systems, which provide uniform water distribution. (2) Do not use end guns when chemigating PROLINE 480 SC FUNGICIDE through center pivot systems because of non-uniform application.

Determine the size of the area to be treated. Determine the time required to apply 1/8-1/2 inch of water over the area to be treated when the system and injection equipment are operated at normal pressures as recommended by the equipment manufacturer. When applying PROLINE 480 SC FUNGICIDE through irrigation equipment use the lowest obtainable water volume while maintaining uniform distribution. Run the system at 80-95% of the manufacturer's rated capacity. Using water, determine the injection pump output when operated at normal line pressure. Determine the amount of PROLINE 480 SC FUNGICIDE required to treat the area covered by the irrigation system. Add the required amount of PROLINE 480 SC FUNGICIDE and sufficient water to meet the injection time requirements to the solution tank. Make sure the system is fully charged with water before starting injection of the PROLINE 480 SC FUNGICIDE solution. Time the injection to last at least as long as it takes to bring the system to full pressure. Maintain constant solution tank agitation during the injection period. Continue to operate the system until the PROLINE 480 SC FUNGICIDE solution has cleared the sprinkler head.

Solid Set and Moving Wheel Irrigation Equipment
When applying PROLINE 480 SC FUNGICIDE through irrigation equipment use the lowest obtainable water volume while maintaining uniform distribution. Determine the amount of PROLINE 480 SC FUNGICIDE required to treat the area covered by the irrigation system. Add the required amount of PROLINE 480 SC FUNGICIDE into the same quantity of water used to calibrate the injection period. Operate the system at the same pressure and time interval established during the calibration. Stop injection equipment after treatment is completed. Continue to operate the system until the PROLINE 480 SC FUNGICIDE solution has cleared the last sprinkler head.

Using Water from Public Water Systems: Public water system means a system for the provision to the public of piped water for human consumption if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. Chemigation systems connected to public water systems must contain a functional, reduced-pressure zone (RPZ), back flow preventer or the functional equivalent in the water supply line upstream from the point of pesticide introduction. As an option to the RPZ, the water from the public water system should be discharged into a reservoir tank prior to pesticide introduction. There shall be a complete physical break (air gap) between the flow outlet end of the fill pipe and the top or overflow rim of the reservoir tank of at least twice the inside diameter of the fill pipe. The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection. The pesticide injection pipeline must contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down. The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops or in cases where there is no water pump, when the water pressure decreases to the point where pesticide distribution is adversely affected. Systems must use a metering pump, such as a positive displacement injection pump (e.g., diaphragm pump) effectively designed and constructed of materials that are compatible with pesticides and capable of being fitted with a system interlock.

Adjuvants: PROLINE 480 SC FUNGICIDE is recommended to be used with a registered non-ionic surfactant at the lowest recommended labeled rate for most crops. Refer to the individual crop recommendations for those specific uses where a surfactant is not recommended.

Recommendations to Avoid Spray Drift
Do not make applications when conditions favor drift beyond the target application area. When drift may be a problem, take measures to reduce drift, including:

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1. Do not spray if wind speeds are or become excessive. Do not spray if wind speed is 15 mph or greater. If non-target crops are located downwind, use caution when spraying if wind is present. Do not spray if winds are gusty.
2. Use caution when conditions are favorable for drift (high temperatures, drought, and low relative humidity).
3. Do not apply when temperature inversion exists. If inversion conditions are suspected, consult with local weather services before making an application.

ROTATIONAL RESTRICTIONS

Treated areas may be replanted with any crop specified on this label as soon as practical after last application. For crops not listed on this label, do not plant back within 30 days of last application.

USE DIRECTIONS FOR SPECIFIC CROPS

PROLINE 480 SC FUNGICIDE provides control or suppression of many important diseases of barley, buckwheat, bushberry subgroup, low growing berry subgroup (except strawberry), canola, corn, crambe, cucurbit vegetables, dry shelled pea and bean crop subgroup, field mustard, Indian rapeseed, millet, oats, peanuts, rapeseed, rye, soybean, sugar beets, triticale, wheat; conifer and hardwood nursery seeds and seedlings. When reference is made to disease suppression, suppression can mean either erratic control from good to fair or consistent control at a level below that obtained with the best commercial disease control products.

<table>
<tr><th colspan="3">APPLICATION DIRECTIONS</th></tr>
<tr><th>CROP</th><th>DISEASE CONTROLLED</th><th>RATE OF PROLINE 480 SC FUNGICIDE</th></tr>
<tr><td rowspan="3">Barley</td><td>Fusarium Head Blight (Fusarium spp.)
(Suppression Only)</td><td>5.0 to 5.7 fl oz per acre</td></tr>
<tr><td>Leaf and Stem Diseases
Net Blotch (Pyrenophora teres)
Powdery Mildew (Blumeria graminis f. sp. hordei)
Rusts (Puccinia spp.)
Scald (Rhynchosporium secalis)
Spot Blotch (Cochliobolus sativus)</td><td>2.8 to 4.3 fl oz per acre</td></tr>
<tr><td colspan="2">PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment.
For aerial applications made prior to heading (prior to Feekes Growth Stage 10.5), apply a minimum of 2 gpa spray solution. For aerial applications made at the heading growth stage or later, apply in a minimum of 5 gpa spray solution. Chemigation use is allowed only for applications made prior to heading.
Fusarium Head Blight (Suppression Only): The optimal time to apply PROLINE 480 SC FUNGICIDE is as a preventative foliar spray when barley heads on the main stem are fully emerged (~ Feekes Growth Stages 10.5). Spray equipment must be set to provide good coverage to barley heads. For thorough coverage of barley head using ground application equipment, it is recommended to use forward and backward mounted nozzles or nozzles that have a two-directional spray. Nozzles should be operated within the spray pressure directions suggested by the manufacturer.
Leaf and Stem Diseases: Apply PROLINE 480 SC FUNGICIDE as a preventive foliar spray when the earliest disease symptoms appear on the leaves or stems. Barley fields should be observed closely for early disease symptoms, particularly when susceptible varieties are planted and/or under prolonged conditions favorable for disease development.</td></tr>
<tr><td colspan="3">Other Requirements: Apply up to two (2) applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications using a 14-day spray interval if conditions remain favorable for continued or increasing disease development. For optimum disease control, the lowest labeled rate of a spray surfactant should be tank mixed with PROLINE 480 SC FUNGICIDE.
A maximum of 9.37 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. Do not apply within 32 days of harvest.</td></tr>
</table>

APPLICATION DIRECTIONS		
CROP	**DISEASES CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Bushberry subgroup: Aronia berry; blueberry (highbush and lowbush); Chilean guava; highbush cranberry; currant (black, buffalo, and red); elderberry; European barberry; gooseberry; edible honeysuckle; huckleberry; jostaberry; juneberry (Saskatoon berry); lingonberry; native currant; salal; sea buckthorn; and cultivars, varieties, and/or hybrids of these.	Septoria leaf spot (*Septoria* spp.) Monilinia blight *(Monilinia vaccinii-corymbosi)* Valdensinia leaf spot *(Valdensinia heterodoxa)* Leaf rust *(Thekopsora minima)* Anthracnose *(Colletotrichum gloeosporioides)* Botrytis blight *(Botrytis cinerea)* Alternaria fruit rot (*Alternaria* spp.) White pine blister rust *(Cronartium ribicola)*	5.7 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground or chemigation application equipment. Apply PROLINE 480 SC FUNGICIDE at the first sign of disease.	
Other Requirements: Apply up to two (2) applications of PROLINE 480 SC per year. Repeat applications as needed using a 7- to 10-day spray interval if conditions remain favorable for continued or increasing disease development. A maximum of 11.4 fl oz of PROLINE 480 SC may be applied per year. Do not apply within 7 days of harvest.		

APPLICATION DIRECTIONS		
CROP	**DISEASES CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Low growing berry subgroup, except strawberry: Bearberry; bilberry; cloudberry; cranberry; muntries; partridgeberry; and cultivars, varieties, and/or hybrids of these	**Fruit rot:** *Coleophoma empetri* *Glomerella cingulata* *Phyllosticta vaccinii* *Physalospora vaccinii* *Allantophomopsis lycopodina* *Allantophomopsis cytisporea* *Fusicoccum putrefaciens* *Penicillium* spp. *Phomopsis vaccinii* *Colletotrichum acutatum* *Botrytis* spp. *Monilinia* spp. Valdensinia leaf spot *(Valdensinia heterodoxa)*	5.0 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground or chemigation application equipment. For best control of fruit rots begin applications at early bloom. Make a second application of PROLINE 480 SC or another approved fungicide 7-10 days later.	
Other Requirements: Apply up to two (2) applications of PROLINE 480 SC per year. Repeat applications as needed using a 7- to 10-day spray interval if conditions remain favorable for continued or increasing disease development. A maximum of 10.0 fl oz of PROLINE 480 SC may be applied per year. Do not apply within 45 days of harvest.		

APPLICATION DIRECTIONS		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Canola	Sclerotinia Stem Rot (*Sclerotinia sclerotiorum*)	4.3 to 5.7 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. Apply PROLINE 480 SC FUNGICIDE when the canola crop is in the 20 - 50% bloom stage. This will be approximately 4-8 days after the canola crop begins to flower. Best protection will be achieved when the fungicide is applied prior to petals beginning to fall, and will allow for the maximum number of petals to be protected. The 4.3 fl oz per acre rate is the recommended rate for most canola crops, however, the higher rate is recommended for fields with a history of heavy disease pressure or for dense crop stands. Good spray coverage of the plants is essential.	
Other Requirements: Apply up to two (2) applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications as needed using a 14-day spray interval if conditions remain favorable for continued or increasing disease development. A maximum of 11.4 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. PROLINE 480 SC FUNGICIDE may be applied until the 50% bloom stage. This will be when the canola crop is at its maximum yellow color, and prior to significant petal fall. Do not apply within 36 days of harvest.		

APPLICATION DIRECTIONS		
CROP	**DISEASES CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Buckwheat **Millet, pearl** **Millet, proso** **Oats** **Rye**	Glume Blotch (*Stagonospora nodorum*) Head Blight or Scab (*Fusarium graminearum*) – Suppression Powdery Mildew (*Erysiphe graminis*) Rusts (*Puccinia* spp.) Scald (*Rynchosporium secalis*) Speckled Blotch (*Septoria avenae; Septoria tritici*) Spot Blotch (*Bipolaris sorokiniana*) Tan Spot or Yellow leaf Spot (*Pyrenophora tritici-repentis*)	5 to 5.7 fl oz per acre
	Apply PROLINE 480 SC as a preventive foliar spray when the earliest disease symptoms appear on the leaves or stems. Fields should be observed closely for early disease symptoms, particularly when susceptible varieties are planted and/or under prolonged conditions favorable for disease development.	
Other Requirements: Apply only one application per year. Applications may be made by ground or aerial spray equipment. A maximum of 5.7 fl oz of PROLINE 480 SC may be applied per acre per year. Do not apply within 30 days of harvest.		

APPLICATION DIRECTIONS			
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**	**APPLICATION TIMING**
Corn (field corn, field corn grown for seed and popcorn)	Anthracnose Leaf Blight *(Colletotrichum graminicola)* Eye spot *(Aureobasidium zeae)* Gray leaf spot *(Cercospora zeae-maydis)* Northern Corn Leaf Blight *(Setosphaeria turcica)** Northern Corn Leaf Spot *(Cochliobolus carbonum)** Rust (*Puccinia* spp.) Southern Corn Leaf Blight *(Cochliobolus heterostrophus)** *The above diseases are also known as Helminthosporium leaf blights	5.7 fl oz per acre	Apply PROLINE 480 SC at the first sign of disease. Repeat applications as needed on a 7 – to 14-day interval if favorable conditions for disease development persist. **Do not** use adjuvants in sprays made between V8 (8 leaf collar) and VT (lowest branch of the tassel is visible but the silks have not yet emerged).
	For the suppression of Fusarium and Gibberella ear rots (*Fusarium spp. and Gibberella spp.*)	5.7 fl oz per acre	For optimum suppression of Fusarium and Gibberella ear rots, apply PROLINE 480 SC Fungicide from the R1 (initial silk emergence) to the R2 (brown silk) corn growth stages. PROLINE 480 SC Fungicide will reduce both disease symptoms and levels of mycotoxin in the grain.

Other requirements: PROLINE 480 SC Fungicide may be applied by either ground, aerial or chemigation application equipment.

For aerial applications, apply PROLINE 480 SC Fungicide using a minimum of 3 gpa spray solution. An adjuvant may be used to improve spray coverage. Refer to the adjuvant product label for specific use directions.

Application of PROLINE 480 SC Fungicide is not recommended at times when corn is under severe environmental stress conditions.

Do not apply more than 22.8 fl oz per acre of PROLINE 480 SC fungicide per acre per crop. For field corn, field corn grown for seed and popcorn, do not apply within 14 days of harvest for grain and fodder. Forage may be harvested the same day of application.

APPLICATION DIRECTIONS		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Chickpea	Ascochyta Blight (*Ascochyta* spp.)	5.0 to 5.7 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. Apply PROLINE 480 SC FUNGICIDE at the first sign of disease. Use the higher use rate when conditions are favorable for severe disease pressure and/or when growing susceptible varieties.	

Other Requirements: Apply up to three (3) applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications as needed using a 10- to 14-day spray interval if conditions remain favorable for continued or increasing disease development. To optimize disease control, the lowest labeled rate of a spray surfactant should be tank-mixed with PROLINE 480 SC FUNGICIDE.

A maximum of 17.1 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. Allow a minimum of 7 days from the last application until cutting or swathing the crop for harvest.

APPLICATION DIRECTIONS		
CROP	**DISEASES CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Cucurbit vegetables: Chayote (fruit); Chinese waxgourd (Chinese preserving melon); citron melon; cucumber; gherkin; edible gourd (includes hyotan, cucuzza, hechima, Chinese okra); *Momordica* spp (includes balsam apple, balsam pear, bittermelon, Chinese cucumber); muskmelon (includes cantaloupe); pumpkin; squash (summer and winter, includes butternut squash, calabaza, hubbard squash, acorn squash, spaghetti squash); watermelon	Fusarium wilt Fusarium blight *(Fusarium oxysporum)* (*Fusarium* spp.) Gummy stem blight (*Didymella* spp.) Southern blight *(Sclerotium roflsii)* Powdery mildew *(Sphaerotheca fuliginea / Podosphaera xanthii)* *(Erysiphe cichoracearum)*	5.7 fl oz per acre (soil) 5.7 fl oz per acre (foliar)
	PROLINE 480 SC FUNGICIDE may be applied by either ground or chemigation application equipment (including drip irrigation). Do not use in water used for hand transplanting. Not for use in greenhouse/transplant house.	
Other Requirements: Apply up to one (1) soil application and two (2) foliar applications of PROLINE 480 SC per year. Repeat applications as needed using a 5- to 10-day spray interval if conditions remain favorable for continued or increasing disease development. A maximum of 17.1 fl oz of PROLINE 480 SC may be applied per year. Do not apply within 7 days of harvest.		

APPLICATION DIRECTIONS		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Dried Shelled Peas and Beans Subgroup (except soybeans) *Lupinus* spp. (Grain, Sweet, White and White Sweet lupins) *Phaseolus* spp .(Field, Kidney, Dry lima, Navy, Pinto and Tepary beans) *Vigna* spp. (Adzuki bean, Blackeyed pea, Catjang, Cowpea, Crowder pea, Moth bean, Mung bean, Rice bean, Southern pea and Urd bean) Dry broad bean Guar Lablab bean *Pisum* spp. [Pea (including Field pea) and Pigeon pea]	Ascochyta Blight *(Ascochyta pinodes)* Rust (*Uromyces appendiculatus*) White Mold (*Sclerotinia sclerotiorum*)	5.7 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. For ground applications, apply in a minimum of 20 gpa. For rust control, apply PROLINE 480 SC FUNGICIDE at the first sign of disease. For white mold control, apply PROLINE 480 SC FUNGICIDE at 25% flower.	
Other Requirements: Apply up to three (3) applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications as needed using a 5- to 14-day spray interval if conditions remain favorable for continued or increasing disease development. To optimize disease control, the lowest labeled rate of a spray surfactant should be tank-mixed with PROLINE 480 SC FUNGICIDE. A maximum of 17.1 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. Allow a minimum of 7 days from the last application until cutting or swathing the crop for harvest.		

APPLICATION DIRECTIONS		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Lentils	Ascochyta Blight (*Ascochyta* spp.)	4.3 to 5.7 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. Apply PROLINE 480 SC FUNGICIDE at early flower or at the first sign of disease. Use the higher use rate when conditions are favorable for severe disease pressure and/or when growing less disease resistant varieties.	
Other Requirements: Apply up to three (3) applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications as needed using a 10- to 14-day spray interval if conditions remain favorable for continued or increasing disease development. To optimize disease control, the lowest labeled rate of a spray surfactant should be tank-mixed with PROLINE 480 SC FUNGICIDE. A maximum of 17.1 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. Allow a minimum of 7 days from the last application until cutting or swathing the crop for harvest.		

APPLICATION DIRECTIONS		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Rapeseed **Indian rapeseed** **Field mustard** **Crambe**	Sclerotinia Stem Rot (*Sclerotinia sclerotiorum*)	4.3 to 5.7 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. Apply PROLINE 480 SC FUNGICIDE when the crop is in the 20 - 50% bloom stage. Utilize the higher rate for fields with a history of heavy disease pressure or for dense crop stands. Good spray coverage of the plants is essential.	
Other Requirements: Apply up to two (2) applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications as needed using a 14-day spray interval if conditions remain favorable for continued or increasing disease development. A maximum of 11.4 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. PROLINE 480 SC FUNGICIDE may be applied until the 50% bloom stage. Do not apply within 36 days of harvest.		

APPLICATION DIRECTIONS		
CROP	**DISEASE SUPPRESSED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Peanut	**In-furrow** Cylindrocladium Black Rot (*Cylindrocladium crotalariae*) (Suppression Only) **Banded** Sclerotium Rot White Mold Southern Blight Southern Stem rot *(Sclerotium rolfsii)* Rhizoctonia Limb Rot *(Rhizoctonia solani)* Early Leaf Spot *(Cercospora arachidicola)* Late Leaf Spot *(Cercosporidium personatum)*	0.4 fl oz per 1000 row feet (5.7 fl oz per acre)

(continued)

Peanut (cont.)	**In-furrow and Banded Spray Program:** Apply 5.7 fl oz per acre (0.4 fl oz. per 1000 row feet if on 36 inch row spacing) in the furrow at planting. PROLINE 480 SC FUNGICIDE may also be applied in a 4- to 6- inch band over the row at or near emergence. Bayer CropScience recommends a minimum application volume of 20 gpa.
Other Requirements: Apply up to four (4) applications of PROLINE 480 SC FUNGICIDE per year, including the in-furrow and banded applications. A maximum of 22.8 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. PROLINE 480 SC FUNGICIDE may be applied up to 14 days before harvest. Do not feed hay or threshings or allow livestock to graze in treated areas.	

APPLICATION DIRECTIONS		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Soybean	Asian Soybean Rust *(Phakopsora pachyrhizi)* Frog Eye Leaf Spot *(Cercospora sojina)* Powdery Mildew *(Microsphaera diffusa)* Brown Spot *(Septoria glycines)*	2.5 – 3.0 fl oz per acre
	Sclerotinia Stem Rot also known as White Mold *(Sclerotinia sclerotiorum)* (Suppression Only)	3.0 – 5.0 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. For aerial application, apply in a minimum spray volume of 2 gpa. Apply PROLINE 480 SC FUNGICIDE as a broadcast, preventative foliar spray or at first visible symptoms of the disease. Repeat applications on a 10- to 21-day spray interval if environmental conditions are favorable for continued disease development. Use of the higher rate and shorter spray intervals are recommended when disease pressure is severe. **Sclerotinia Stem Rot (Suppression Only):** Apply PROLINE 480 SC FUNGICIDE as a broadcast foliar spray at R1 (beginning bloom) when conditions are favorable for disease development. A sequential treatment of PROLINE 480 SC FUNGICIDE or Stratego YLD Fungicide may be made at R3 – R4 (beginning to full pod). PROLINE 480 SC FUNGICIDE may be applied by ground or air. Apply in a minimum of 10 gallons of spray solution per acre by ground sprayer or in a minimum of 5 gallons of spray solution per acre by aircraft spray equipment.	
Other Requirements: Applications may not be made within 21 days of harvest. Do not apply more than 3 applications per season. Do not apply more than 12.9 fl oz of PROLINE 480 SC FUNGICIDE per acre per use season.		

APPLICATION DIRECTIONS

CROP	DISEASE CONTROLLED	RATE OF PROLINE 480 SC FUNGICIDE
Sugar beets	**Foliar Diseases** Cercospora Leaf Spot *(Cercospora beticola)* Powdery Mildew *(Erysiphe polygoni)*	5.0 to 5.7 fl oz per acre
	Soil-borne diseases Rhizoctonia Stem Canker, Root Rot, Crown Rot *(Rhizoctonia solani)*	5.7 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. **Foliar disease control:** Apply PROLINE 480 SC FUNGICIDE at the first sign of disease. Use the higher use rate and shorter intervals when conditions are favorable for severe disease pressure and/or when growing less disease resistant varieties. **Soil-borne disease control:** Apply PROLINE 480 SC FUNGICIDE in a seven-inch band at the 4-leaf to row closure growth stage.	
Other Requirements: Apply up to 3 applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications as needed using a 14- to 21-day spray interval depending on disease pressure. Use a 14-day spray interval under normal to heavy disease pressure and a 21-day spray interval under light disease pressure. To optimize disease control, the lowest labeled rate of a spray surfactant may be tank-mixed with PROLINE 480 SC FUNGICIDE. A maximum of 17.1 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per crop year. Allow a minimum of 7 days from the last application before harvesting. PROLINE 480 SC FUNGICIDE is a Group 3 fungicide. To limit the potential for development of disease resistance: • Alternate every application of PROLINE 480 SC FUNGICIDE with a non-Group 3 fungicide.		

APPLICATION DIRECTIONS

CROP	DISEASE CONTROLLED	RATE OF PROLINE 480 SC FUNGICIDE
Wheat (spring, durum and winter) **Triticale**	Fusarium Head Blight (*Fusarium* spp.) (Suppression Only)	5.0 to 5.7 fl oz per acre
	Leaf and Stem Diseases Powdery Mildew (*Blumeria graminis* f. sp. *tritici*) Rusts (*Puccinia* spp.) Septoria Leaf and Glume Blotch (*Septoria tritici*) Stagonospora Blotch (*Stagonospora nodorum*) Tan Spot (*Pyrenophora tritici-repentis*)	4.3 to 5.0 fl oz per acre
	PROLINE 480 SC FUNGICIDE may be applied by either ground, aerial or chemigation application equipment. For aerial application made prior to early flower (prior to Feekes Growth Stage 10.51, apply a minimum of 2 gpa spray solution. For aerial applications made at the early flower growth stage or later, apply in a minimum of 5 gpa spray solution. Chemigation use is allowed only for applications made prior to early flower.	

(continued)

Wheat (spring, durum and winter) **Triticale (cont.)**	**Fusarium Head Blight (Suppression Only):** The optimal time to apply PROLINE 480 SC FUNGICIDE is as a preventative foliar spray at early flower (Feekes Growth Stage 10.51). Spray equipment must be set to provide good coverage to wheat heads. For thorough coverage of the wheat head using ground application equipment, use forward and backward mounted nozzles or nozzles that have a two-directional spray. Operate nozzles within the spray pressure directions suggested by the manufacturer. **Leaf and Stem Diseases:** Apply PROLINE 480 SC FUNGICIDE as a preventive foliar spray when the earliest disease symptoms appear on the leaves or stems. Wheat fields should be observed closely for early disease symptoms, particularly when susceptible varieties are planted and/or under prolonged conditions favorable for disease development.
Other Requirements: Apply up to two (2) applications of PROLINE 480 SC FUNGICIDE per year. Repeat applications using a 14-day spray interval if conditions remain favorable for continued or increasing disease development. For optimum disease control, the lowest labeled rate of a spray surfactant should be tank mixed with PROLINE 480 SC FUNGICIDE. A maximum of 9.37 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per year. Do not apply within 30 days of harvest.	

APPLICATION DIRECTIONS FOR SEED TREATMENT		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Buckwheat	Seed rot, pre-emergence damping-off and seedling blight caused by soilborne *Rhizoctonia solani, Fusarium, Cochliobolus* Common root rot, foot rot, and crown rot (early season suppression)	0.16 - 0.8 fl oz per 100 lbs seed (5 - 25 g ai per 100 kg seed)

APPLICATION DIRECTIONS		
CROP	**DISEASE CONTROLLED**	**RATE OF PROLINE 480 SC FUNGICIDE**
Nursery seedlings of Shortleaf, Loblolly, Slash, Longleaf and other pines and other Conifers and Hardwoods	Fusiform rust *(Cronartium quercum* f.sp. *fusiforme)* Pitch canker *(Fusarium* spp.*)* Rhizoctonia foliar blight *(Rhizoctonia* spp.*)*	5.0 fl oz per acre
Nursery seeds of Shortleaf, Loblolly, Slash, Longleaf and other pines and other Conifers and Hardwoods	Fusiform rust (*Cronartium quercum* f.sp. *fusiforme)* Pitch canker *(Fusarium* spp.*)*	10 fl oz per 50 lbs seed
Not intended for use in forest planting or established woodlands. The crop safety and mix compatibility on all tree species and in tank-mixes with other products (spray surfactants, fertilizers, insecticides, etc.) has not been confirmed. Bayer CropScience recommends small scale testing with your planned use pattern. The user assumes all risks with the use of this product on trees.		

(continued)

Tree Seedling Application Directions: Foliar disease control: Apply PROLINE 480 SC FUNGICIDE preventatively or at the first sign of disease using ground equipment only. Repeat applications as needed using a 14- to 21-day spray interval depending on your region. Consult your local extension agent on locally recommended spray intervals. Use shorter intervals when conditions are favorable for severe disease pressure and/or when growing less disease resistant varieties. To optimize disease control, the lowest labeled rate of a spray surfactant may be tank-mixed with PROLINE 480 SC FUNGICIDE. A maximum off 25 fl oz of PROLINE 480 SC FUNGICIDE may be applied per acre per crop year.

Tree Seed Treatment Directions: Apply specified dosage to seed in a commercial treater or other suitable tumbler apparatus. Allow to mix for at least 10 minutes. Thoroughly air dry before sowing. Do not use treated seed for food or feed purposes. Seed that has been treated with this product that is then packaged or bagged for future use must contain the following labeling on the outside of the seed package or bag: “Treated Seed – Do not Use for Food, Feed, or Oil Purposes. When opening this bag or loading/pouring the treated seed, wear a long sleeved shirt, long pants, shoes, socks, and chemical resistant gloves. After the seeds have been planted, do not enter or allow worker entry into treated areas during the restricted-entry interval (REI) of 12 hours. Exception: Once the seeds are planted in soil or other planting media, the Worker Protection Standard allows workers to enter the treated area without restriction if there will be no worker contact with the treated seeds in the soil or planting media.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

Pesticide Storage: Store in a cool, dry place and in such a manner as to prevent cross contamination with other pesticides, fertilizers, food, and feed. Store in original container and out of the reach of children, preferably in a locked storage area.

Handle and open container in a manner as to prevent spillage. If container is leaking, invert to prevent leakage. If the container is leaking or material is spilled for any reason or cause, carefully dam up spilled material to prevent runoff. Refer to Precautionary Statements on label for hazards associated with the handling of this material. Do not walk through spilled material. Absorb spilled material with absorbing type compounds and dispose of as directed for pesticides below. In spill or leak incidents, keep unauthorized people away. You may contact the Bayer CropScience Emergency Response Team for decontamination procedures or any other assistance that may be necessary. The Bayer CropScience Emergency Response Telephone No. is 1-800-334-7577.

Pesticide Disposal: Wastes resulting from the use of this product must be disposed of on-site or at an approved waste disposal facility.

Container Disposal: Non-refillable container. Do not reuse or refill this container. Triple rinse or pressure rinse container (or equivalent) promptly after emptying.

Triple rinse as follows: Empty the remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container 1/4 full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times.

Pressure rinse as follows: Empty the remaining contents into application equipment or a mix tank and continue to drain for 10 seconds after the flow begins to drip. Hold container upside down over application equipment or mix tank or collect rinsate for later use or disposal. Insert pressure-rinsing nozzle in the side of the container, and rinse at about 40 PSI for at least 30 seconds. Drain for 10 seconds after the flow begins to drip.

Offer for recycling, if available. If not recycled, then puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

IMPORTANT: READ BEFORE USE

Read the entire Directions for Use, Conditions, Disclaimer of Warranties and Limitations of Liability before using this product. If terms are not acceptable, return the unopened product container at once.

By using this product, user or buyer accepts the following Conditions, Disclaimer of Warranties and Limitations of Liability.

CONDITIONS: The directions for use of this product are believed to be adequate and must be followed carefully. However, it is impossible to eliminate all risks associated with the use of this product. Crop injury, ineffectiveness or other unintended consequences may result because of such factors as weather conditions, presence of other materials, or the manner of use or application, all of which are beyond the control of Bayer CropScience. To the extent consistent with applicable law, all such risks shall be assumed by the user or buyer.

DISCLAIMER OF WARRANTIES: TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, BAYER CROPSCIENCE MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, OF MERCHANTABILITY OR OF FITNESS FOR A PARTICULAR PURPOSE OR OTHERWISE, THAT EXTEND BEYOND THE STATEMENTS MADE ON THIS LABEL. No agent of Bayer CropScience is authorized to make any warranties beyond those contained herein or to modify the warranties contained herein. TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, BAYER CROPSCIENCE DISCLAIMS ANY LIABILITY WHATSOEVER FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES RESULTING FROM THE USE OR HANDLING OF THIS PRODUCT.

LIMITATIONS OF LIABILITY: TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, THE EXCLUSIVE REMEDY OF THE USER OR BUYER FOR ANY AND ALL LOSSES, INJURIES OR DAMAGES RESULTING FROM THE USE OR HANDLING OF THIS PRODUCT, WHETHER IN CONTRACT, WARRANTY, TORT, NEGLIGENCE, STRICT LIABILITY OR OTHERWISE, SHALL NOT EXCEED THE PURCHASE PRICE PAID, OR AT BAYER CROPSCIENCE'S ELECTION, THE REPLACEMENT OF PRODUCT.

NET CONTENTS: 2 1/2 GALLONS

PROLINE® 480 SC **Fungicide**
For control of specified diseases on listed crops.

GROUP 3 FUNGICIDE

ACTIVE INGREDIENT: Prothioconazole, 2-[2-(1-Chlorocyclopropyl)-3-(2-chlorophenyl)-2-hydroxypropyl]-1,2-dihydro-3*H*-1,2,4-triazole-3-thione . . . **41.0%**
INERT INGREDIENTS: . . . **59.0%**
Contains 4 pounds Prothioconazole per gallon **100.0%**

EPA Reg. No. 264-825

STOP - Read the label before use
KEEP OUT OF REACH OF CHILDREN
CAUTION

FOR ADDITIONAL PRECAUTIONARY STATEMENTS: See Attached Booklet.

For **MEDICAL** And **TRANSPORTATION** Emergencies **ONLY** Call 24 Hours A Day 1-800-334-7577
For **PRODUCT USE** Information Call 1-866-99BAYER (1-866-992-2937)

FIRST AID

IF SWALLOWED:	• Immediately call a poison control center or doctor for treatment advice. • Have person sip a glass of water if able to swallow. • Do not induce vomiting unless told to do so by a poison control center or doctor. • Do not give anything by mouth to an unconscious person.
IF INHALED:	• Move person to fresh air. • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible. • Call a poison control center or doctor for further treatment advice.
IF ON SKIN OR CLOTHING:	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a poison control center or doctor for treatment advice.
IF IN EYES:	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.

For MEDICAL Emergencies Call 24 Hours A Day 1-800-334-7577.
Have the product container or label with you when calling a poison control center or doctor or going for treatment.

NOTE TO PHYSICIAN: No specific antidote. Treat symptomatically.

PRECAUTIONARY STATEMENTS

HAZARD (TO HUMANS AND DOMESTIC ANIMALS)
CAUTION

Harmful if swallowed or inhaled. Causes moderate eye irritation. Avoid contact with eyes and clothing. Avoid breathing vapor or spray mist. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, or using tobacco. Remove and wash contaminated clothing before reuse.

FOR ADDITIONAL PRECAUTIONARY STATEMENTS: See attached label booklet: Personal Protective Equipment, User Safety Recommendations, and Environmental Hazards

DIRECTIONS FOR USE: See attached booklet.
It is a violation of federal law to use this product in a manner inconsistent with its labeling.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

Pesticide Storage: Store in a cool, dry place and in such a manner as to prevent cross contamination with other pesticides, fertilizers, food, and feed. Store in original container and out of the reach of children, preferably in a locked storage area.

For complete Pesticide Storage instructions, see attached booklet.

Pesticide Disposal: Wastes resulting from the use of this product must be disposed of on-site or at an approved waste disposal facility.

Container Disposal: Non-refillable container. Do not reuse or refill this container. Triple rinse or pressure rinse container (or equivalent) promptly after emptying.

Triple rinse as follows: Empty the remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container 1/4 full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times.

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Offer for recycling, if available. If not recycled, then puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

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Prothioconazole: Sensitivity profile and anti-resistance strategy

K.-H. Kuck and A. Mehl

1 The DMI fungicide group – Mode of action and resistance

The new Bayer fungicide prothioconazole (JAU 6476) is, chemically, a triazole-3-thione analogue. Its mode of action has been shown to rely on the inhibition of the C14 demethylation of 24 methylene-dihydro-lanosterol during fungal sterol biosynthesis. Fungicides inhibiting this target site are commonly denominated as demethylation inhibitors or DMIs.

The first DMI fungicides were already being marketed in the seventies well before the marketing of prothioconazole. All together, more than 30 DMI fungicides have in the meantime been introduced (Kuck et al., 1995).

Since the early eighties pathogens such as *Erysiphe graminis*, *Mycosphaerella fijiensis*, *Venturia inaequalis* and *Uncinula necator* have been reported as being resistant to DMI fungicides. In most cases, although the initial level of activity can no longer be detected, DMIs are still highly effective tools for the control of plant diseases and are widely used on almost every crop world wide.

From a multitude of publications that are available on the resistance mechanism of DMI fungicides it is obvious that resistance against DMI fungicides is mostly based on the accumulation of several independent mutations. Some resistance mechanisms are known as for example the target site mutation Y136F, amplification of ABC transporters and cell membrane alterations.

The mutation of one single gene can lead to a disruptive selection type as it is known from benzimidazoles and strobilurins. In contrast, the accumulation of several mutations as it is typically found in DMI resistance is the reason for a “continuous selection” type that often has been decribed as “shifting” of fungicide sensitivity.

Extensive experience is now available on the consequences of DMI resistance under field conditions and on effective tools in the resistance management for DMIs (Kuck, 2002).

If resistance occurs with DMI fungicides it is typically developing stepwise after several years of intensive use. DMI resistance is characterised by a gradual loss of efficacy under field conditions. A total loss of control is very rare. If the selection pressure is decreasing even a partial back-shift to more sensitive pathogen populations has been observed in several cases (Kuck, 2002).

This relatively slow development of resistance gives good opportunities for an effective resistance management. Whereas numerous resistance cases have been reported in the eighties and in the early nineties a relatively stable situation has been reached since the middle of the

nineties and the importance of DMI fungicides for the market has not declined considerably (Kuck, 2002). Overall, the resistance risk of DMI fungicides is usually classified as “medium” or “moderate” (Brent and Hollomon, 1998).
In addition to the specific risk of each fungicidal mode of action the inherent risk of the target pathogens is a second factor that determines the overall resistance risk of a fungicide.
From 25 years of intensive DMI use in practise good information is available on the relative resistance risk of certain pathogens with DMIs.
With high risk pathogens first resistance signs were often reported within about 5 years of intensive DMI use. Medium risk pathogens are characterised by the observation that a decrease in field performance occurred mostly only after prolonged periods of 10 years or more of intensive use. With low risk pathogens no resistance has been reported with DMIs after more than 20 years of agricultural use.

Table 1: Pathogen-associated risk for pathogens that are important indications for DMI fungicides (Kuck, 2002; partly supplemented)

High	Medium	Low
Blumeria graminis	*Pyrenophora teres*	*Alternaria solani*
Mycosphaerella fijiensis	*Rhynchosporium secalis*	*Stagonospora nodorum*
Sphaerotheca fuliginea	*Mycosphaerella graminicola*	*Podosphaera leucotricha*
Uncinula necator	*(Septoria tritici)*	*Rhizoctonia solani*
Venturia inaequalis	*Tapesia acuformis*	*Tilletia spec.*
	Tapesia yallundae	*Ustilago spec.*

1.1 Cross resistance between DMI fungicides

As shown in Table 2 DMI fungicides are a member of the Sterol Biosynthesis Inhibitor (SBI) fungicide group. This huge group covers several classes with different biochemical targets that are all used in agricultural praxis.
Whereas it is clear that DMI fungicides show no cross resistance to other SBI classes the cross resistance relationships amongst DMI fungicides have often been a matter of debate.
Nevertheless, all DMI fungicides are grouped in group 3 of the FRAC Mode of action list (www.frac.info/publications) which describes the cross-resistance pattern as follows: "(It is) Generally wise to accept that cross resistance is present between fungicides active against the same fungus."
Indirectly this characterisation explains that cross resistance among DMI fungicides is mostly only a partial one for a given pathogen. With some pathogens even no cross resistance could be found at all. In this context, the most intensively studied pathogen/fungicide interaction are those of eyespots towards the imidazole compound prochloraz and some triazole compounds. (Leroux, 2003)

Table 2: Classes of the SBI group of fungicides

SBI fungicide classes			
	Class I	Class II	Class III
class name	DMI	“morpholines” or “amines”	hydroxyanilides
target in fungal sterol biosynthesis	C14 demethylase	Δ^{14}-reductase $\Delta^{8}\rightarrow\Delta^{7}$-isomerase a.o.	C3 keto-reductase
chemistry	triazoles triazolin-thiones imidazoles pyrimidines etc.	morpholines piperidines spiroketalamines	hydroxyanilides
compounds (examples)	triadimenol prochloraz fenarimol	fenpropimorph fenpropidin spiroxamine	fenhexamide

2 Baseline profile and cross resistance relationships of Prothioconazole

As prothioconazole is not the first DMI fungicide in the market, it is clear that a true (= wild type) baseline situation no longer exists in most crops with an intensive use of modern fungicides.
In order to generate a sensitivity profile for prothioconazole before the marketing a series of sensitivity monitoring studies was carried out over the last years. These monitoring efforts cover – for example – the cereal powdery mildews in wheat and barley, wheat brown rust, *Mycosphaerella graminicola* (anamorph: *Septoria tritici*) and the eyespot pathogens *Tapesia yallundae* (syn. *Pseudocercosporella herpotrichoides* Type W) and *T. acuformis* (syn. *Pseudocercosporella herpotrichoides* Type R).
This report tries to characterize the specific profile of prothioconazole with the aid of some selected examples.

Another DMI fungicide, tebuconazole, will mostly serve as a general reference point. Tebuconazole has been on the market since 1989 and based on its world-wide and multi crop-use numerous monitoring data have been generated since then.

2.1 Wheat powdery mildew: Cross-resistance analysis between Prothioconazole and tebuconazole

The cross-resistance relations of prothioconazole and tebuconazole towards wheat powdery mildew can serve as a first marker for the characterization of prothioconazole.
It is known that tebuconazole shows a positive cross-resistance to other DMI fungicides such as triadimenol, epoxiconazole and cyproconazole (Brent and Hollomon, 1998).
Based on publications of F. G. Felsenstein it is also known, that tebuconazole shows significantly lower Mean Resis-

tance Factors (MRFs) than first generation DMI fungicides such as triadimenol. In Figure 1 MRFs of prothioconazole and of tebuconazole are compared in the year 1998 and from 2000 to 2003 in several European countries. It is obvious that with wheat powdery mildew tebuconazole shows typically MRF values that are in a range of about 11 to 33. The corresponding values for prothioconazole are significantly lower and vary only between 2.7 and 8.5 at the maximum.

For tebuconazole (as for other DMI fungicides) significant fluctuations of the MRF values can be found over the years and – less pronounced – over the regions. Also with other DMI fungicides this typical "up and down" fluctuation can be regularly found with nearly every pathogen. Based on many years of experience MRF fluctuations of about a factor 2 to 3 have mostly no significant influence on the field control level, only stable trends over several years are normally considered to be of practical relevance.

Figure 1 shows clearly that prothioconazole follows roughly the same trends as tebuconazole but with a much smoother fluctuation pattern. Nevertheless, the MRF's of prothioconazole are lower than those of tebuconazole, but they are not zero, which demonstrates a positive cross resistance of prothioconazole to tebuconazole – and to other DMI fungicides.

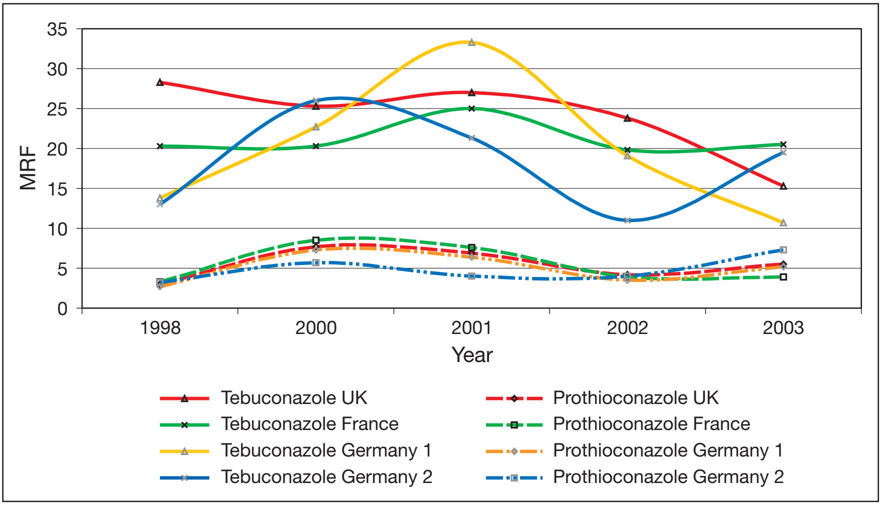

Fig. 1: Mean Resistance Factors (MRFs) of tebuconazole (solid lines) and prothioconazole (dotted lines) with wheat powdery mildew (*Blumeria graminis* f.sp. *tritici*) in different European region in the years 1998 to 2003. Data: F. G. Felsenstein

2.2 Barley powdery mildew

2.2.1 MRFs of Prothioconazole

Reduced sensitivity of barley powdery mildew to DMI fungicides was described for the first time in the early eighties (Wolfe and Fletcher, 1981).
Nowadays resistance factors of about 30 to 90 (compared to fully sensitive reference isolates) for tebuconazole can be found in all investigated regions in Europe with the exception of Northern Italy and Spain. As tebuconazole is not used intensively on barley the MRFs for tebuconazole reflect mostly the selection process by other DMIs that are regularly used in barley.
As shown in Fig. 2, the MRFs for prothioconazole are significantly lower than those known for tebuconazole as they vary only between about 8 and 14. Over the years, the MRFs for prothioconazole remain always within a narrow range and are very uniform in 2003.

2.2.2 Sensitivity level *Erysiphe graminis* f.sp. *hordei*

In 2001 the mean EC_{50}-values (MEC_{50}s) of all the barley powdery mildew samples analysed towards prothioconazole ranged from 0.86 mg/L to 1.02 mg/L. The originally sensitive standard isolates have a MEC_{50} of 0.08 mg/L. Compared with the standard isolates, higher MEC_{50} level are found across North-western Europe similar to the wheat powdery mildew situation. No striking regional differences were detected. The current sensitivity situation is obviously reflecting the positive cross-resistance behaviour of the barley powdery mildew pathogen towards DMI fungicides.

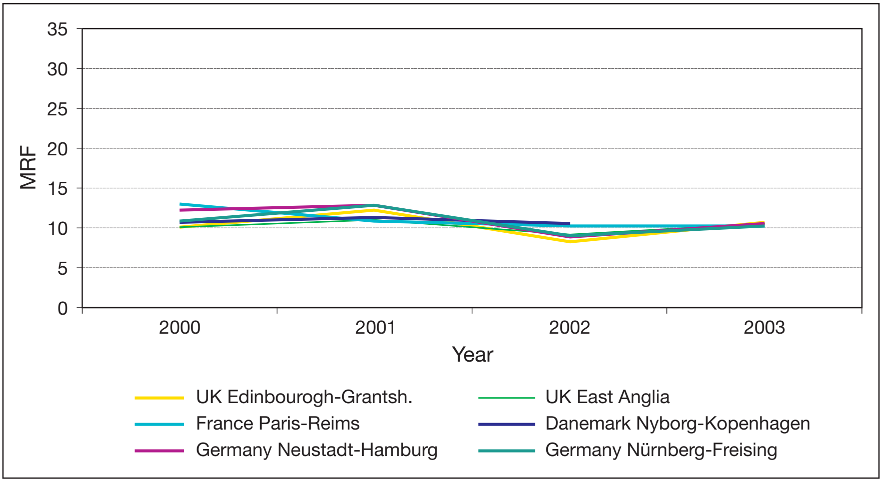

Fig. 2: Changes of Mean Resistance Factors (MRFs) of prothioconazole with barley powdery mildew in the years 2000 to 2003 in different European Regions. Data: F.G. Felsenstein

The EC_{50}s within the individual samples and of all the examined isolates for prothioconazole ranged from 7.8 mg/L to 19.0 mg/L. The EC_{50}max is close to that obtained for wheat powdery mildew. No isolate has been detected which showed a sensitivity close to the standards (RF ≤ 3).

2.3 *Septoria tritici*

2.3.1 Cross resistance analysis

The fungal samples analysed used in this cross resistance study originate from Bayer CropScience trials in 3 French departments in which untreated and tebuconazole-treated plots were analysed in summer 2001 with the microtitre plate method (Suty and Kuck, 1996).

A cross resistance analysis was made by correlating the sensitivity of 111 isolates of prothioconazole and of tebuconazole in a double logarithmic graph.

Figure 3 shows that the sensitivities of the least sensitive and the most sensitive isolates correlate quite reasonably. The majority of isolates showing lower sensitivity to prothioconazole simultaneously show lower sensitivity to tebuconazole and vice versa. This classical indication of a positive cross resistance is con-

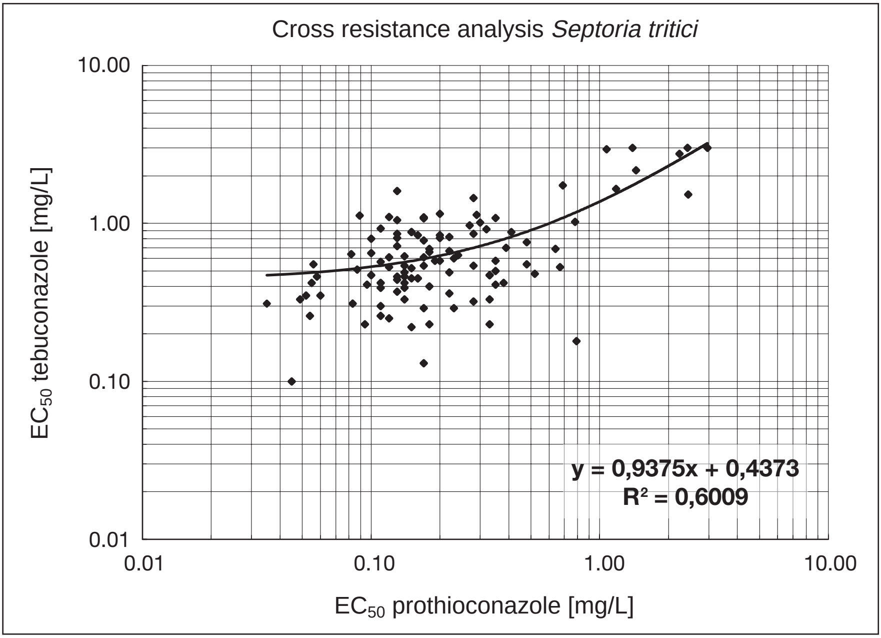

Fig. 3: Cross resistance analysis between tebuconazole and prothioconazole with *Septoria tritici*

firmed by the calculation of the regression coefficient (R^2) which has the value $R^2 = 0.6009$. With DMI fungicides regression coefficients around 0.6 are quite typical.

2.3.2 "Baseline" information

A microtitre plate test was run in parallel with prothioconazole and tebuconazole with 189 French isolates in 2001.
A direct comparison is given in Table 3. From this comparison it becomes evident that prothioconazole has a higher intrinsic potential than the *Septoria* standard tebuconazole if the EC_{50} values are compared. The corresponding MRF's of prothioconazole are similar to those of tebuconazole.

2.4 Eyespot (*Tapesia yallundae / Tapesia acuformis*)

Resistance of *Tapesia acuformis* to prochloraz has been described earlier (Leroux, 2003, Gaujard and Russell, 2002). Resistance factors of >1000 have been detected frequently in these studies (mainly R-types).
A systematic monitoring programme with more than 600 isolates of *T. yallundae* and *T. acuformis* failed so far to demonstrate a positive cross resistance of prothioconazole to either triazoles or prochloraz.
Table 4 shows a trial using 4 reference strains delivered and classified by Pierre Leroux (INRA Versailles). As it becomes clear from the table, all four isolates (characterized to be sensitive (Tri S) or resistant (Tri R) to triazoles, respectively sensitive (Pro S) or resistant (Pro R) to prochloraz show very similar EC_{50} values.
Independent from the actual study, also the INRA group obviously came to similar findings in a first study (P. Leroux, personal communication).
Surprisingly, in the case of the eyespot pathogens prothioconazole seems to have

Table 3: Comparison of sensitivity of prothioconazole and tebuconazole with 189 Septoria isolates from different regions in France, 2001

Region	Isolates	Prothioconazole		Tebuconazole	
	n	MEC_{50} [mg/L]	MRF	MEC_{50} [mg/L]	MRF
Cher	36	0.1	3.9	0.7	3.9
Lot-et-Garonne	40	0.2	7.6	0.5	5.5
Meurthe-et-Moselle	34	0.4	4.0	0.7	5.4
Aube	40	0.6	8.0	0.7	6.8
Somme	39	0.3	4.9	0.8	4.4
Mean		0.3	5.7	0.7	5.2

MEC_{50} = geometric mean of the EC_{50}s of all the analysed isolates within the sample; MRF = mean resistance factor relative to highly sensitive standard isolates

Table 4: Evaluation of the in vitro sensitivity of 2 strains of *Tapesia yallundae* and 2 strains of *T. acuformis* to Prothioconazole on RPMI 1640 [α]. Data: T. Barchietto (BIOTRANSFER)

	Strains	EC_{50} (µm a.i./mL) [β]
Tapesia yallundae	Tri S/2	0.036 ± 0.019 [γ]
	Tri R1/2	0.053 ± 0.015
Tapesia acuformis	Pro S/1	0.044 ± 0.029
	Pro R/1	0.047 ± 0.020

α The liquid medium RPMI 1640 (SIGMA) was adjusted to pH 7.0 and amended with 10 g/L of glucose. Sterilisation by filtration (0.22 µm).

β The EC_{50} was determined after 5 days of incubation on a shaker (150 r.p.m.) at 20 °C in darkness. Mycelial growth was determined by measuring the optical density (OD) of each well of the microtiter plate at 405 nm.

γ EC_{50} are the mean of 6 independant bioassay runs ± standard deviation.

a unique cross resistance profile. Further studies will have to show if this failure is caused by statistical deficiencies or if cross-resistance of prothioconazole to prochloraz and other DMIs is absent in the case of the two eyespot pathogens.

3 Resistance management

3.1 DMI fungicides in general

Over a period of 25 years of DMI use some resistance risk modifiers have been evolved and that have proved to be effective tools in resistance management for this fungicide group and that are meanwhile well accepted on the advisory and on the farmer level.
Generally, the most important resistance management tools are

- limitation of the number of applications per season (using less than the registered number).
- Examples: *Venturia inaequalis* / apples; *Uncinula necator* / grapes: max. 4 applications
- using DMIs in mixture or alternation systems (or both) with fungicide groups showing no cross-resistance to DMIs
- avoiding curative / eradicant use (especially if no warning systems are available)
- using the manufacturer's recommended dose rate
- lowering the disease pressure with all tools of integrated disease management.

3.2 Resistance management intended for Prothioconazole

From the data shown it becomes obvious that usually the resistance factors of prothioconazole are significantly lower than those of tebuconazole which already generally shows lower resistance factors than older triazole standards such as triadimenol.
Nevertheless, it would be negligent to conclude from these findings that the future resistance management for prothioconazole could be less rigid than the

implemented resistance management that has proved to be effective for other DMI fungicides. On the other hand, the results of this study also do not deliver any arguments or need for a more rigid resistance management.
An acceptable resistance risk for prothioconazole is therefore most probably given when the approved resistance management tools that are in use for DMI fungicides are equally implemented for prothioconazole. It seems to be quite probable that the adaptation of these approved rules to prothioconazole will be effective and sufficient.
Bayer CropScience actively participates in the FRAC SBI Working Group. It is clearly intended that all actual FRAC guidelines will automatically be implemented for prothioconazole. The recommendations of the FRAC SBI Working Group for the use of DMI fungicides are yearly updated and published on the internet (www.frac.info/sbi_wg).

4 Summary

Prothioconazole: Sensitivity profile and anti-resistance strategy

The triazolin-thione prothioconazole is, by its mode of action, a member of the DMI fungicide group. As a consequence, prothioconazole generally shows a positive cross-resistance to other DMI fungicides. Sensitivity information and/or cross resistance studies with *Blumeria graminis* f.sp. *tritici*, *Blumeria graminis* f.sp. *hordei*, *Septoria tritici*, *Tapesia yallundae* and *Tapesia acuformis* are presented. Surprisingly until now, with the eyespot pathogens, *Tapesia acuformis* and *Tapesia yallundae*, no cross resistance to prochloraz has been detected.
The resistance management for prothioconazole is orientated at the approved modifiers for other DMIs. Especially the guidelines of the FRAC SBI Working Group for DMI fungicides will be implemented.

Zusammenfassung

Prothioconazole: Sensitivitäts-Profil und Antiresistenz-Strategie

Das Triazolthion Prothioconazole gehört aufgrund seines Wirkungsmechanismus zu den DMI-Fungiziden. Entsprechend besteht generell eine positive Kreuzresistenz zu anderen DMI-Fungiziden. Informationen zur Sensitivität und/oder Kreuzresistenz mit *Blumeria graminis* f.sp. *tritici*, *Blumeria graminis* f.sp. *hordei*, *Septoria tritici*, *Tapesia yallundae* und *Tapesia acuformis* werden vorgestellt. Überraschenderweise konnte in unseren Studien mit den Halmbrucherregern *Tapesia acuformis* und *Tapesia yallundae* bisher keine Kreuzresistenz zu Prochloraz festgestellt werden.
Das Resistenz-Management für Prothioconazole lehnt sich an das anderer DMIs an. Insbesondere werden die Richtlinien der FRAC SBI Arbeitsgruppe implementiert.

Résumé

Prothioconazole: Profile de sensibilité et stratégie anti-résistance

La triazolinthione prothioconazole est, par son mécanisme d’action, un représentant de la classe des fongicides DMI. Par conséquent, le prothioconazole montre, en général, une résistance croisée positive vis-à-vis d’autres fongicides DMI.

Des études de sensibilité et / ou de résistance croisée avec *Blumeria graminis* f.sp. *tritici*, *Blumeria graminis* f.sp. *hordei*, *Septoria tritici*, *Tapesia yallundae* et *Tapesia acuformis* sont présentées. Cependant, contrairement à toute attente, aucune résistance croisée avec le prochloraz n'a pu être mise en évidence détectée pour les organismes pathogènes *Tapesia acuformis* et *Tapesia yallundae*, les agents du piétin verse.
La gestion anti-résistance dans le cas du prothioconazole s'oriente sur celle appliquée aux autres fongicides DMI. Ce sont avant tout les directives du groupe de travail FRAC SBI sur les fongicides DMI qui seront appliquées.

Resumen

Prothioconazole: Perfil de sensibilidad y estrategia anti-resistencia

La triazoltiona prothioconazole por su mecanismo de acción pertenece a los fungicidas DMI. Correspondientemente existe una resistencia cruzada positiva hacia otros fungicidas DMI. Informaciones sobre la sensibilidad y/o resistencia cruzada con *Blumeria graminis* f.sp. *tritici*, *Blumeria graminis* f.sp. *hordei*, *Septoria tritici*, *Tapesia yallundae* y *Tapesia acuformis* se presentan aquí. Sorprendentemente, en nuestros estudios con los patógenos del tallo *Tapesia acuformis* y *Tapesia yallundae* hasta ahora no se pudo detectar una resistencia cruzada a Prochloraz.
El manejo de resistencia para prothioconazole es similar al de otros fungicidas DMI. Especialmente serán implementadas las recomendaciones del grupo de trabajo FRAC SBI.

Резюме

Протиоконазол: профиль сенситивности и стратегия антирезистентности

По своему механизму действия триазолтион протиоконазол относится к ингибиторам широкого спектра действия. Соответственно, принципиально имеется положительная перекрестная резистентность с другими фунгицидами-ингибиторами широкого спектра действия. Приводятся данные о сенситивности и/или перекрестной резистентности с *Blumeria graminis* f.sp. *tritici, Blumeria graminis* f.sp. *hordei, Septoria tritici, Tapesia yallundae* и *Tapesia acuformis*. В наших исследованиях с возбудителями ломкости стеблей *Tapesia acuformis* и *Tapesia yallundae* на удивление до сих пор перекрестной резистентности с прохлоразом не установлено.

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FRAC Code List©*: Fungicides sorted by mode of action (including FRAC Code numbering)

INTRODUCTION

The following table lists commercial fungicides according to their mode of action and resistance risk. The most important bactericides are also included.

The Table headings are defined as:

MOA Code
Different letters (A to I, with added numbers) are used to distinguish fungicide groups according to their biochemical mode of action (MOA) in the biosynthetic pathways of plant pathogens. The grouping was made according to processes in the metabolism starting from nucleic acids synthesis (A) to secondary metabolism, e.g. melanin synthesis (I) at the end of the list, followed by host plant defence inducers (P), recent molecules with an unknown mode of action and unknown resistance risk (U, transient status, mostly not longer than 8 years, until information about mode of action and mechanism of resistance becomes available), and multi-site inhibitors (M).

Target Site and Code
If available, the biochemical mode of action is given. In many cases the precise target site is not known. However, a grouping can be made due to cross resistance profiles within a group or in relation to other groups.

Group Name
The Group Names listed are based on chemical relatedness of structures which are accepted in literature (e.g. The Pesticide Manual). They are based on different sources (chemical structure, site of action, first important representative in group).

Chemical Group
Grouping is based on chemical considerations. Nomenclature is according to IUPAC and Chemical Abstract name.

Common name
BSI/ISO accepted (or proposed) common name for an individual active ingredient expected to appear on the product label as definition of the product.

Comments on Resistance

Details are given for the (molecular) mechanism of resistance and the resistance risk. If field resistance is known to one member of the Group, it is most likely but not exclusively valid that cross resistance to other group members will be present. There is increasing evidence that the degree of cross resistance can differ between group members and pathogen species or even within species. For the latest information on resistance and cross resistance status of a particular pathogen / fungicide combination, it is advised to contact local FRAC representatives, product manufacturer's representatives or crop protection advisors. The intrinsic risk for resistance evolution to a given fungicide group is estimated to be **low, medium or high** according to the principles described in FRAC Monographs 1, 2 and 3. Resistance management is driven by intrinsic risk of fungicide, pathogen risk and agronomic risk (see FRAC pathogen risk list).

Similar classification lists of fungicides have been published by T. Locke on behalf of FRAG – UK (Fungicide Resistance, August 2001), and by P. Leroux (Classification des fongicides agricoles et résistance, Phytoma, La Défense des Végétaux, No. 554, 43-51, November 2002).

FRAC Code

Numbers and letters are used to distinguish the fungicide groups according to their cross resistance behaviour. The numbers were assigned primarily according to the time of product introduction to the market (numbers 1 to 44, status 2008). The letters refer to P = host plant defence inducers, M = multi-site inhibitors, and U = unknown mode of action and unknown resistance risk.

Last update: December 2008

Next update: December 2009

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
A: nucleic acids synthesis	A1: RNA polymerase I	PA – fungicides (PhenylAmides)	acylalanines	benalaxyl furalaxyl metalaxyl metalaxyl-M (=mefenoxam)	Resistance and cross resistance well known in various Oomycetes but mechanism unknown. High risk. See FRAC Phenylamide Guidelines for resistance management	4
			oxazolidinones	oxadixyl		
			butyrolactones	ofurace		
	A2: adenosin-deaminase	hydroxy-(2-amino-) pyrimidines	hydroxy-(2-amino-) pyrimidines	bupirimate dimethirimol ethirimol	Medium risk Resistance and cross resistance known in powdery mildews. Resistance management required.	8
	A3: DNA/RNA synthesis (proposed)	heteroaromatics	isoxazoles	hymexazole	Resistance not known	32
			isothiazolones	octhilinone		
	A4: DNA topoisomerase type II (gyrase)	carboxylic acids	carboxylic acids	oxolinic acid	Bactericide. Resistance known. Risk unknown. Resistance management required.	31
B: mitosis and cell division	B1: ß-tubuline assembly in mitosis	MBC - fungicides (Methyl Benzimidazole Carbamates)	benzimidazoles	benomyl carbendazim fuberidazole thiabendazole	Resistance common in many fungal species. Several target site mutations, mostly E198A/G/K, F200Y in β-tubulin gene Positive cross resistance between the group members. Negative cross resistance to N-Phenylcarbamates High risk. See FRAC Benzimidazole Guidelines for resistance management.	1
			thiophanates	thiophanate thiophanate-methyl		
	B2: ß-tubulin assembly in mitosis	N-phenyl carbamates	N-phenyl carbamates	diethofencarb	Resistance known. Target site mutation E198K. Negative cross resistance to benzimidazoles. High risk. Resistance management required.	10
	B3: ß-tubulin assembly in mitosis	benzamides	toluamides	zoxamide	Low to medium risk. Resistance management required.	22
	B4: cell division (proposed)	phenylureas	phenylureas	pencycuron	Resistance not known	20
	B5: delocalisation of spectrin-like proteins	benzamides	pyridinylmethyl-benzamides	fluopicolide	Resistance not known	43

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
C. respiration	C1: complex I NADH Oxido-reductase	pyrimidinamines	pyrimidinamines	diflumetorim	Resistance not known	39
	C2: complex II: succinate-dehydro-genase	SDHI (Succinate dehydrogenase inhibitors)	phenyl-benzamides	benodanil flutolanil mepronil	Resistance known for several fungal species in field populations and lab mutants. Target site mutations in sdh gene, e.g. H/Y (or H/L) at 257, 267, 272 or P225L, dependent on fungal species. Resistance management required. Medium risk. See FRAC SDHI Guidelines for resistance management.	7
			pyridinyl-ethyl-benzamides	fluopyram		
			furan- carboxamides	fenfuram		
			oxathiin-carboxamides	carboxin oxycarboxin		
			thiazole-carboxamides	thifluzamide		
			pyrazole-carboxamides	furametpyr penthiopyrad bixafen isopyrazam sedaxane		
			pyridine-carboxamides	boscalid		
	C3: complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site *(cyt b gene)*	QoI-fungicides (Quinone outside Inhibitors)	methoxy-acrylates	azoxystrobin enestrobin picoxystrobin	Resistance known in various fungal species. Target site mutations in cyt b gene (G143A, F129L) and additional mechanisms. Cross resistance shown between all members of the QoI group. High risk. See FRAC QoI Guidelines for resistance management.	11
			methoxy-carbamates	pyraclostrobin		
			oximino acetates	kresoxim-methyl trifloxystrobin		
			oximino-acetamides	dimoxystrobin metominostrobin orysastrobin		
			oxazolidine-diones	famoxadone		
			dihydro-dioxazines	fluoxastrobin		
			imidazolinones	fenamidone		
			benzyl-carbamates	pyribencarb		
	C4: complex III: cytochrome bc1(ubiquino-ne reductase) at Qi site	QiI - fungicides (Quinone inside Inhibitors)	cyano- imidazole	cyazofamid	Resistance risk unknown but assumed to be medium to high (mutations at target site known in model organisms). Resistance management required.	21
			sulfamoyl-triazole	amisulbrom		
	C5: uncouplers of oxidative phos-phorylation		dinitrophenyl crotonates	binapacryl meptyldinocap dinocap	Resistance not known. Also acaricidal activity	29
			2,6-dinitro-anilines	fluazinam	Low risk. However, resistance claimed in *Botrytis* in Japan.	
			pyrimidinone-hydrazones	ferimzone	Resistance not known	
	C6: inhibitors of oxidative phos-phorylation, ATP synthase	organo tin compounds	tri phenyl tin compounds	fentin acetate fentin chloride fentin hydroxide	Some resistance cases known. Low to medium risk.	30
	C7: ATP produc-tion (proposed)	thiophene-carboxamides	thiophene-carboxamides	silthiofam	Resistance reported. Risk low	38

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
D: amino acids and protein synthesis	D1: methionine biosynthesis (proposed) *(cgs gene)*	AP - fungicides (Anilino-Pyrimidines)	anilino-pyrimidines	cyprodinil mepanipyrim pyrimethanil	Resistance known in *Botrytis* and *Venturia*, sporadically in *Oculimacula* . Medium risk. See FRAC Anilinopyrimidine Guidelines for resistance management.	9
	D2: protein synthesis	enopyranuronic acid antibiotic	enopyranuronic acid antibiotic	blasticidin-S	Low to medium risk. Resistance management required.	23
	D3: protein synthesis	hexopyranosyl antibiotic	hexopyranosyl antibiotic	kasugamycin	Resistance known in fungal and bacterial (*P. glumae*) pathogens. Medium risk. Resistance management required.	24
	D4: protein synthesis	glucopyranosyl antibiotic	glucopyranosyl antibiotic	streptomycin	Bactericide. Resistance known. High risk. Resistance management required.	25
	D5: protein synthesis	tetracycline antibiotic	tetracycline antibiotic	oxytetracycline	Bactericide. Resistance known. High risk. Resistance management required.	41
E: signal transduction	E1: G-proteins in early cell signalling (proposed)	quinolines	quinolines	quinoxyfen	Resistance known. Medium risk. Resistance management required. Cross resistance to proquinazid in *Erysiphe (Uncinula) necator* but not in *Blumeria graminis*. As a precaution, proquinazid and quinoxyfen should be managed together for resistance management	13
	E2: MAP/Histidine-Kinase in osmotic signal transduction *(os-2, HOG1)*	PP-fungicides (PhenylPyrroles)	phenylpyrroles	fenpiclonil fludioxonil	Resistance found sporadically, mechanism speculative. Low to medium risk. Resistance management required.	12
	E3: MAP/Histidine-Kinase in osmotic signal transduction *(os-1, Daf1)*	dicarboximides	dicarboximides	chlozolinate iprodione procymidone vinclozolin	Resistance common in *Botrytis* and some other pathogens. Several mutations in OS-1, mostly I365S Cross resistance common between the group members. Medium to high risk. See FRAC Dicarboximide Guidelines for resistance management.	2

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
F: lipids and membrane synthesis	F1	formerly dicarboximides				
	F2: phospholipid biosynthesis, methyltrans-ferase	phosphoro-thiolates	phosphoro-thiolates	edifenphos iprobenfos (IBP) pyrazophos	Resistance known for specific fungi. Low to medium risk. Resistance management required if used for risky pathogens.	6
		dithiolanes	dithiolanes	isoprothiolane		
	F3: lipid peroxidation (proposed)	AH-fungicides (Aromatic Hydrocarbons) (chlorophenyls, nitroanilines)	aromatic hydrocarbons	biphenyl chloroneb dicloran quintozene (PCNB) tecnazene (TCNB) tolclofos-methyl	Resistance known to some fungi. Low to medium risk. Cross resistance patterns complex due to different activity spectra.	14
		heteroaromatics	1,2,4-thiadiazoles	etridiazole		
	F4: cell membrane permeability, fatty acids (proposed)	carbamates	carbamates	iodocarb propamocarb prothiocarb	Low to medium risk. Resistance management required.	28
	F5: phospholipid biosynthesis and cell wall deposition (proposed)	CAA-fungicides (Carboxylic Acid Amides)	cinnamic acid amides	dimethomorph flumorph	Resistance known in *Plasmopara viticola* but not in *Phytophthora infestans*. Cross resistance between all members of the CAA group. Low to medium risk. See FRAC CAA Guidelines for resistance management	40
			valinamide carbamates	benthiavalicarb iprovalicarb valifenalate		
			mandelic acid amides	mandipropamid		
	F6: microbial disrupters of pathogen cell membranes	Microbial (*Bacillus* sp.)	*Bacillus subtilis* and the fungicidal lipopeptides they produce	*Bacillus subtilis* strain QST 713	No resistance reported. Assumed to be low risk based on mode of action of non-specific membrane disruption	44

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
G: sterol biosynthesis in membranes	G1: C14- demethylase in sterol biosynthesis *(erg11/cyp51)*	DMI-fungicides (DeMethylation Inhibitors) (SBI: Class I)	piperazines	triforine	There are big differences in the activity spectra of DMI fungicides. Resistance is known in various fungal species. Several resistance mechanisms are known incl. target site mutations in cyp51 (erg 11) gene, e.g. V136A, Y137F, A379G, I381V; cyp51 promotor; ABC transporters and others. Generally wise to accept that cross resistance is present between DMI fungicides active against the same fungus. DMI fungicides are Sterol Biosynthesis Inhibitors (SBIs), but show no cross resistance to other SBI classes. Medium risk. See FRAC SBI Guidelines for resistance management.	3
			pyridines	pyrifenox		
			pyrimidines	fenarimol nuarimol		
			imidazoles	imazalil oxpoconazole pefurazoate prochloraz triflumizole		
			triazoles	azaconazole bitertanol bromuconazole cyproconazole difenoconazole diniconazole epoxiconazole etaconazole fenbuconazole fluquinconazole flusilazole flutriafol hexaconazole imibenconazole ipconazole metconazole myclobutanil penconazole propiconazole prothioconazole simeconazole tebuconazole tetraconazole triadimefon triadimenol triticonazole		
	G2: Δ^{14}-reductase and $\Delta^{8} \rightarrow \Delta^{7}$- isomerase in sterol biosynthesis *(erg24, erg2)*	Amines ("Morpholines") (SBI: Class II)	morpholines	aldimorph dodemorph fenpropimorph tridemorph	Decreased sensitivity for powdery mildews. Cross resistance within the group generally found but not to other SBI classes. Low to medium risk. See FRAC SBI Guidelines for resistance management.	5
			piperidines	fenpropidin piperalin		
			spiroketal-amines	spiroxamine		
	G3: 3-keto reduc-tase, C4- de-methylation *(erg27)*	hydroxyanilides (SBI: Class III)	hydroxyanilides	fenhexamid	Low to medium risk. Resistance management required.	17
	G4: squalene-epoxidase in sterol biosynthesis *(erg1)*	(SBI class IV)	thiocarbamates	pyributicarb	Resistance not known, fungicidal and herbicidal activity	18
			allylamines	naftifine terbinafine	Medical fungicides only	

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
H: glucan synthesis	H3: trehalase and inositol-biosynthesis	glucopyranosyl antibiotic	glucopyranosyl antibiotic	validamycin	Resistance not known	26
	H4: chitin synthase	polyoxins	peptidyl pyrimidine nucleoside	polyoxin	Resistance known. Medium risk. Resistance management required.	19
I: melanin synthesis in cell wall	I1: reductase in melanin biosynthesis	MBI-R (Melanin Biosynthesis Inhibitors – Reductase)	isobenzo-furanone	fthalide	Resistance not known	16.1
			pyrrolo-quinolinone	pyroquilon		
			triazolobenzo-thiazole	tricyclazole		
	I2: dehydratase in melanin biosynthesis	MBI-D (Melanin Biosynthesis Inhibitors – Dehydratase)	cyclopropane-carboxamide	carpropamid	Resistance known. Medium risk. Resistance management required.	16.2
			carboxamide	diclocymet		
			propionamide	fenoxanil		
P: host plant defence induction	P1: salicylic acid pathway	benzo-thiadiazole BTH	benzo-thiadiazole BTH	acibenzolar-S-methyl	Resistance not known	P
	P2	benzisothiazole	benzisothiazole	probenazole (also antibacterial and antifungal activity)	Resistance not known	
	P3	thiadiazole-carboxamide	thiadiazole-carboxamide	tiadinil isotianil	Resistance unknown	
	P4 (proposed)	natural compound		laminarin	Resistance unknown	

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
Unknown mode of action (U numbers not appearing in the list derive from reclassified fungicides)	unknown	cyanoacetamide-oxime	cyanoacetamide-oxime	cymoxanil	Resistance claims described. Low to medium risk. Resistance management required.	27
	unknown	phosphonates	ethyl phosphonates	fosetyl-Al	Few resistance cases reported in few pathogens. Low risk	33
				phophorous acid and salts		
	unknown	phthalamic acids	phthalamic acids	tecloftalam (Bactericide)	Resistance not known	34
	unknown	benzotriazines	benzotriazines	triazoxide	Resistance not known	35
	unknown	benzene-sulfonamides	benzene-sulfonamides	flusulfamide	Resistance not known	36
	unknown	pyridazinones	pyridazinones	diclomezine	Resistance not known	37
	unknown	thiocarbamate	thiocarbamate	methasulfocarb	Resistance not known	42
	microtubule disruption (proposed)	thiazole carboxamide	ethylamino-thiazole carboxamide	ethaboxam	Resistance not known	U5
	unknown	phenyl-acetamide	phenyl-acetamide	cyflufenamid	Resistance in *Sphaerotheca*. Resistance management required	U6
	unknown	quinazolinone	quinazolinone	proquinazid	Resistance known. Medium risk. Resistance management required. Cross resistance to quinoxyfen in *Erysiphe (Uncinula) necator* but not in *Blumeria graminis*. As a precaution, proquinazid and quinoxyfen should be managed together for resistance management	U7
	actin disruption (proposed)	benzophenone	benzophenone	metrafenone	Resistance not known	U8
						U10
						U11
not classified	unknown	diverse	diverse	mineral oils, organic oils, potassium bicarbonate, material of biological origin	Resistance not known	NC

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
Multi-site contact activity	multi-site contact activity	inorganic	inorganic	copper (different salts)	Generally considered as a low risk group without any signs of resistance developing to the fungicides * For dodine, resistance was reported in *Venturia inaequalis* suggesting that dodine may not be a multi-site inhibitor. Resistance management recommended No cross resistance between group members M1 to M9	M1
		inorganic	inorganic	sulphur		M2
		dithiocarbamates and relatives	dithio-carbamates and relatives	ferbam mancozeb maneb metiram propineb thiram zineb ziram		M3
		phthalimides	phthalimides	captan captafol folpet		M4
		chloronitriles (phthalonitriles)	chloronitriles (phthalonitriles)	chlorothalonil		M5
		sulfamides	sulfamides	dichlofluanid tolylfluanid		M6
		guanidines	guanidines	dodine* guazatine iminoctadine		M7
		triazines	triazines	anilazine		M8
		quinones (anthraquinones)	quinones (anthra-quinones)	dithianon		M9

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Vegetables
2011 Summary

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Contents

2011 Fresh Market Vegetable Production Down 2 Percent from 2010

Fresh market vegetable and melon production for the 24 selected crops estimated in 2011 totaled 435 million hundredweight, down 2 percent from last year. Harvested area covered 1.70 million acres, down 1 percent from 2010. Value of the 2011 crop is estimated at 11.1 billion dollars, up 1 percent from a year ago. The three largest crops, in terms of production, are onions, head lettuce, and watermelons, which combined to account for 37 percent of the total production. Tomatoes, head lettuce, and romaine lettuce claim the highest values, accounting for 29 percent of the total value when combined.

For the 24 selected vegetables and melons estimated in 2011, California continues to be the leading fresh market State, accounting for 44 percent of the harvested area, 50 percent of production, and 50 percent of the value.

Leading Fresh Market Vegetable States in 2011

Rank	Area harvested		Production		Value	
	State	Percent of total	State	Percent of total	State	Percent of total
1	California	44.4	California	49.9	California	50.2
2	Florida	10.9	Florida	8.7	Florida	13.0
3	Arizona	6.8	Arizona	7.6	Arizona	10.8
4	Georgia	6.0	Georgia	4.0	Georgia	4.4
5	New York	3.4	Washington	3.8	New York	3.0

Principal Fresh Market Vegetable Area Planted and Harvested by Crop – United States: 2009-2011 (Domestic Units)

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]

Crop	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Artichokes [1]	8,600	7,200	7,400	8,600	7,200	7,400
Asparagus [1]	30,700	29,200	28,900	29,200	28,000	27,300
Beans, snap	96,100	97,100	104,800	91,700	88,500	94,700
Broccoli [1]	127,000	132,300	133,300	126,000	130,200	131,200
Cabbage	69,200	69,800	66,900	65,300	66,700	62,400
Cantaloupes	76,060	77,430	72,590	74,730	74,730	70,950
Carrots	72,300	67,500	75,400	69,400	66,000	72,000
Cauliflower [1]	38,930	38,790	37,680	38,600	38,460	37,430
Celery [1]	28,800	28,800	28,700	28,500	28,000	28,200
Corn, sweet	257,500	269,150	266,700	236,650	250,100	242,450
Cucumbers	49,500	46,000	42,850	46,550	44,200	40,200
Garlic [1]	22,430	23,200	25,650	22,230	22,850	25,150
Honeydews	15,250	16,750	14,750	14,900	16,600	14,400
Lettuce						
Head	137,500	133,500	142,500	135,000	132,000	141,000
Leaf	50,000	52,400	49,500	49,100	51,200	48,800
Romaine	77,300	81,500	81,000	76,100	79,300	79,500
Onions [1]	157,310	155,270	155,930	151,060	149,270	147,630
Peppers, bell [1]	53,200	54,900	56,200	51,700	53,200	54,300
Peppers, chile [1]	28,700	23,550	23,400	27,800	22,400	22,100
Pumpkins [1]	47,700	50,200	51,300	44,100	48,500	47,300
Spinach	38,500	34,400	35,700	36,600	32,300	33,200
Squash [1]	46,000	45,800	50,200	43,900	44,400	47,100
Tomatoes	113,200	107,700	105,400	108,700	103,000	99,710
Watermelons	134,800	143,400	138,600	123,900	134,300	124,900
Total	1,776,580	1,785,840	1,795,350	1,700,320	1,711,410	1,699,320
Strawberries [1]	59,520	58,170	58,660	58,080	56,990	57,470

[1] Includes processing total for dual usage crops.

Principal Fresh Market Vegetable Production and Value by Crop – United States: 2009-2011 (Domestic Units)

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]

Crop	Production			Value of production		
	2009	2010	2011	2009	2010	2011
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Artichokes [1]	1,075	864	962	60,415	43,373	48,485
Asparagus [1]	899	799	840	88,855	90,777	93,474
Beans, snap	5,225	5,062	5,367	282,543	303,889	303,480
Broccoli [1]	19,890	19,289	21,183	794,124	727,463	742,627
Cabbage	22,467	23,238	21,129	341,798	396,432	368,311
Cantaloupes	19,279	19,228	18,840	350,392	319,176	349,725
Carrots	22,163	23,237	22,012	557,670	617,714	729,505
Cauliflower [1]	7,167	7,087	7,169	315,551	295,186	329,716
Celery [1]	20,074	19,923	19,098	404,039	371,153	381,860
Corn, sweet	28,839	29,628	28,089	846,199	759,472	747,026
Cucumbers	9,359	8,385	7,099	239,131	191,752	188,519
Garlic [1]	3,878	3,752	4,204	192,872	266,884	286,820
Honeydews	3,587	3,613	3,216	55,623	55,007	70,681
Lettuce						
Head	50,180	50,120	48,810	1,121,724	1,057,504	1,125,801
Leaf	11,845	13,004	12,296	458,765	499,538	420,741
Romaine	22,355	27,389	24,635	612,716	655,659	795,171
Onions [1]	75,599	73,599	73,924	1,054,227	1,049,704	762,143
Peppers, bell [1]	16,997	16,156	17,618	585,378	649,427	684,941
Peppers, chile [1]	4,790	4,404	4,836	133,878	131,578	146,754
Pumpkins [1]	9,313	10,748	10,713	102,730	117,791	113,178
Spinach	6,821	5,767	6,179	269,424	245,985	250,075
Squash [1]	7,219	6,728	7,437	203,464	208,669	283,244
Tomatoes	33,235	27,961	30,406	1,344,217	1,352,315	1,291,875
Watermelons	38,911	41,736	39,005	450,713	499,800	543,824
Total	441,167	441,717	435,067	10,866,448	10,906,248	11,057,976
Strawberries [1]	28,013	28,532	28,946	2,129,585	2,262,353	2,399,389

[1] Includes processing total for dual usage crops.

Principal Fresh Market Vegetable Area Planted and Harvested by Crop – United States: 2009-2011 (Metric Units)

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]

Crop	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(hectares)	(hectares)	(hectares)	(hectares)	(hectares)	(hectares)
Artichokes [1]	3,480	2,910	2,990	3,480	2,910	2,990
Asparagus [1]	12,420	11,820	11,700	11,820	11,330	11,050
Beans, snap	38,890	39,300	42,410	37,110	35,820	38,320
Broccoli [1]	51,400	53,540	53,950	50,990	52,690	53,100
Cabbage	28,000	28,250	27,070	26,430	26,990	25,250
Cantaloupes	30,780	31,340	29,380	30,240	30,240	28,710
Carrots	29,260	27,320	30,510	28,090	26,710	29,140
Cauliflower [1]	15,750	15,700	15,250	15,620	15,560	15,150
Celery [1]	11,660	11,660	11,610	11,530	11,330	11,410
Corn, sweet	104,210	108,920	107,930	95,770	101,210	98,120
Cucumbers	20,030	18,620	17,340	18,840	17,890	16,270
Garlic [1]	9,080	9,390	10,380	9,000	9,250	10,180
Honeydews	6,170	6,780	5,970	6,030	6,720	5,830
Lettuce						
Head	55,640	54,030	57,670	54,630	53,420	57,060
Leaf	20,230	21,210	20,030	19,870	20,720	19,750
Romaine	31,280	32,980	32,780	30,800	32,090	32,170
Onions [1]	63,660	62,840	63,100	61,130	60,410	59,740
Peppers, bell [1]	21,530	22,220	22,740	20,920	21,530	21,970
Peppers, chile [1]	11,610	9,530	9,470	11,250	9,070	8,940
Pumpkins [1]	19,300	20,320	20,760	17,850	19,630	19,140
Spinach	15,580	13,920	14,450	14,810	13,070	13,440
Squash [1]	18,620	18,530	20,320	17,770	17,970	19,060
Tomatoes	45,810	43,590	42,650	43,990	41,680	40,350
Watermelons	54,550	58,030	56,090	50,140	54,350	50,550
Total [2]	718,960	722,710	726,560	688,100	692,590	687,700
Strawberries [1]	24,090	23,540	23,740	23,500	23,060	23,260

[1] Includes processing total for dual usage crops.
[2] Totals may not add due to rounding.

Principal Fresh Market Vegetable Production by Crop – United States: 2009-2011 (Metric Units)

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]

Crop	Production		
	2009	2010	2011
	(metric tons)	(metric tons)	(metric tons)
Artichokes [1]	48,760	39,190	43,640
Asparagus [1]	40,780	36,240	38,100
Beans, snap	237,000	229,610	243,440
Broccoli [1]	902,190	874,930	960,840
Cabbage	1,019,080	1,054,050	958,390
Cantaloupes	874,480	872,160	854,560
Carrots	1,005,290	1,054,010	998,440
Cauliflower [1]	325,090	321,460	325,180
Celery [1]	910,540	903,690	866,270
Corn, sweet	1,308,110	1,343,900	1,274,090
Cucumbers	424,510	380,340	322,000
Garlic [1]	175,900	170,190	190,690
Honeydews	162,700	163,880	145,870
Lettuce			
Head	2,276,110	2,273,390	2,213,970
Leaf	537,280	589,850	557,730
Romaine	1,014,000	1,242,340	1,117,420
Onions [1]	3,429,100	3,338,380	3,353,120
Peppers, bell [1]	770,970	732,820	799,130
Peppers, chile [1]	217,270	199,760	219,360
Pumpkins [1]	422,430	487,520	485,930
Spinach	309,390	261,590	280,270
Squash [1]	327,450	305,180	337,330
Tomatoes	1,507,510	1,268,280	1,379,190
Watermelons	1,764,960	1,893,100	1,769,230
Total [2]	20,010,890	20,035,840	19,734,200
Strawberries [1]	1,270,640	1,294,180	1,312,960

[1] Includes processing total for dual usage crops.
[2] Totals may not add due to rounding.

Principal Fresh Market Vegetable Area Planted and Harvested – States and United States: 2009-2011

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State. Includes processing total for dual usage crops (asparagus, broccoli, and cauliflower)]

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Alabama	7,000	6,500	6,500	5,300	5,400	5,050
Arizona	115,100	113,600	116,900	113,800	111,900	115,000
Arkansas	2,600	2,600	2,700	2,400	2,400	2,400
California	752,300	756,400	767,600	739,600	742,200	753,700
Colorado	25,600	25,600	24,800	22,400	24,200	23,800
Connecticut	4,500	4,000	4,300	3,900	3,500	3,100
Delaware	6,000	6,000	6,100	6,000	5,800	5,900
Florida	192,600	190,200	204,400	183,100	176,500	185,100
Georgia	117,300	114,300	110,600	110,500	107,900	101,800
Idaho	9,000	9,200	9,400	8,800	9,000	9,200
Illinois	21,600	23,400	24,400	19,600	22,600	22,600
Indiana	17,500	17,500	17,100	16,500	16,800	16,160
Maine	2,000	1,900	1,800	1,500	1,800	1,600
Maryland	11,460	11,430	11,250	10,580	10,630	10,500
Massachusetts	5,400	5,400	5,300	4,700	5,200	4,500
Michigan	57,500	57,500	55,800	54,500	55,200	52,700
Mississippi	2,800	2,900	2,800	2,300	2,500	2,400
Missouri	3,100	3,300	3,000	2,600	3,200	2,900
Nevada	3,930	4,200	4,050	3,930	4,200	4,050
New Hampshire	1,600	1,600	1,500	1,400	1,400	1,300
New Jersey	26,700	26,900	26,500	25,000	25,600	24,400
New Mexico	18,000	15,150	16,100	17,300	14,600	15,400
New York	68,230	69,890	66,080	64,100	67,160	58,530
North Carolina	42,700	42,400	40,800	41,600	39,500	37,900
Ohio	34,510	34,970	34,030	28,610	31,170	31,330
Oklahoma	5,500	5,500	5,400	3,500	5,000	2,300
Oregon	28,500	28,500	28,800	28,300	27,150	28,100
Pennsylvania	26,500	27,500	26,690	24,500	25,300	22,550
Rhode Island	800	750	800	750	700	650
South Carolina	14,700	15,200	15,800	13,200	13,900	14,300
Tennessee	13,700	16,600	17,500	11,600	14,800	15,200
Texas	62,650	66,450	62,750	55,900	59,100	54,000
Utah	1,600	1,600	1,600	1,550	1,600	1,600
Vermont	1,200	1,100	1,000	1,000	1,000	700
Virginia	16,600	16,600	17,100	15,800	15,500	16,200
Washington	42,700	45,700	41,700	42,000	45,000	40,800
Wisconsin	13,100	13,500	12,400	12,200	12,000	11,600
United States	1,776,580	1,785,840	1,795,350	1,700,320	1,711,410	1,699,320

Principal Fresh Market Vegetable Production and Value – States and United States: 2009-2011

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State. Includes processing total for dual usage crops (asparagus, broccoli, and cauliflower)]

State	Production			Value of production		
	2009	2010	2011	2009	2010	2011
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Alabama	893	912	844	19,647	18,916	19,840
Arizona	31,602	31,601	33,222	766,784	900,846	1,193,251
Arkansas	344	525	548	5,712	13,244	18,377
California	214,514	219,733	217,174	5,616,799	5,419,185	5,554,833
Colorado	6,943	7,101	7,107	98,074	119,804	112,178
Connecticut	273	210	155	10,920	8,400	6,665
Delaware	1,358	1,340	1,385	21,658	20,196	23,365
Florida	41,230	34,277	37,898	1,384,921	1,527,289	1,441,675
Georgia	22,727	21,951	17,270	529,620	477,434	483,915
Idaho	6,512	6,840	7,176	80,882	50,025	45,195
Illinois	4,873	4,882	5,713	27,991	32,083	36,692
Indiana	3,630	3,937	4,055	57,013	61,330	69,297
Maine	90	99	96	4,230	4,851	4,800
Maryland	1,199	1,120	1,236	28,247	25,624	29,444
Massachusetts	306	390	315	13,158	17,550	17,325
Michigan	9,100	8,390	7,890	171,540	174,700	178,150
Mississippi	334	450	372	3,407	4,725	4,204
Missouri	858	1,072	957	6,178	8,576	9,666
Nevada	2,537	2,675	2,896	87,905	69,805	73,071
New Hampshire	77	77	85	4,543	4,697	5,185
New Jersey	3,906	3,969	3,945	132,466	122,603	131,411
New Mexico	5,135	5,062	4,746	111,269	132,141	89,833
New York	12,189	14,058	11,258	301,170	374,275	328,470
North Carolina	7,884	6,728	6,835	171,004	124,754	188,020
Ohio	5,668	4,932	5,410	183,108	128,730	155,295
Oklahoma	333	550	230	4,296	5,500	2,553
Oregon	14,159	15,529	15,778	185,991	126,819	113,347
Pennsylvania	2,504	2,711	2,358	78,922	73,984	65,361
Rhode Island	45	49	46	1,800	2,450	2,300
South Carolina	2,710	3,618	4,145	49,205	67,055	86,023
Tennessee	1,677	1,871	1,343	53,964	68,530	47,777
Texas	13,082	13,450	11,604	188,158	316,454	177,947
Utah	698	816	752	6,864	6,690	3,912
Vermont	45	50	28	2,430	2,800	1,484
Virginia	2,074	1,601	1,646	74,731	64,965	61,401
Washington	17,096	17,458	16,404	340,804	302,282	240,696
Wisconsin	2,562	1,683	2,145	41,037	26,936	35,018
United States	441,167	441,717	435,067	10,866,448	10,906,248	11,057,976

Artichokes for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – California: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	8,600	7,200	7,400	8,600	7,200	7,400
State	**Yield per acre**			**Production**		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	125	120	130	1,075	864	962
State	**Price per cwt**			**Value of production**		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	56.20	50.20	50.40	60,415	43,373	48,485

Snap Beans for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	9,800	10,000	9,000	9,600	10,000	9,000
Florida	33,700	36,400	46,000	32,800	32,200	40,000
Georgia	17,000	13,000	12,000	16,000	12,500	11,300
Maryland	1,900	1,800	1,900	1,800	1,800	1,900
Michigan	3,200	3,300	3,000	3,100	3,200	2,900
New Jersey	2,800	2,900	3,100	2,800	2,600	2,700
New York	7,100	6,900	5,600	6,700	6,700	5,300
North Carolina	6,100	6,000	5,900	6,000	4,400	5,300
South Carolina	1,000	500	300	900	400	200
Tennessee	8,000	11,000	12,500	6,800	9,600	10,800
Virginia	5,500	5,300	5,500	5,200	5,100	5,300
United States	96,100	97,100	104,800	91,700	88,500	94,700

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	110	105	110	1,056	1,050	990
Florida	65	60	60	2,132	1,932	2,400
Georgia	45	49	60	720	613	678
Maryland	55	48	54	99	86	103
Michigan	50	45	55	155	144	160
New Jersey	27	30	34	76	78	92
New York	40	70	61	268	469	323
North Carolina	40	23	30	240	101	159
South Carolina	55	45	33	50	18	7
Tennessee	37	42	24	252	403	259
Virginia	34	33	37	177	168	196
United States	57	57	57	5,225	5,062	5,367

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	66.90	67.60	64.40	70,646	70,980	63,756
Florida	52.90	69.90	54.70	112,783	135,047	131,280
Georgia	52.40	33.80	53.70	37,728	20,719	36,409
Maryland	47.00	46.00	44.00	4,653	3,956	4,532
Michigan	40.00	50.00	55.00	6,200	7,200	8,800
New Jersey	67.40	35.40	55.00	5,122	2,761	5,060
New York	88.00	83.60	96.10	23,584	39,208	31,040
North Carolina	31.00	30.00	44.20	7,440	3,030	7,028
South Carolina	43.00	52.00	90.00	2,150	936	630
Tennessee	31.00	36.00	35.00	7,812	14,508	9,065
Virginia	25.00	33.00	30.00	4,425	5,544	5,880
United States	54.10	60.00	56.50	282,543	303,889	303,480

Cabbage for Fresh Market Area Planted and Harvested – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	2,300	2,100	2,500	2,300	2,100	2,500
California	12,700	12,700	13,200	12,500	12,500	13,000
Colorado	3,000	3,100	2,900	2,700	2,900	2,800
Florida	10,100	10,500	8,800	9,500	9,700	8,100
Georgia	6,900	6,200	5,400	6,300	5,700	5,200
Michigan	2,700	3,100	3,400	2,600	3,000	3,300
New Jersey	1,700	1,800	1,500	1,600	1,700	1,400
New York	9,600	10,600	10,900	9,000	10,400	10,700
North Carolina	5,500	5,100	4,900	5,400	5,000	3,900
Ohio	1,100	1,300	1,300	1,000	1,200	1,200
Pennsylvania	1,200	1,200	1,200	1,200	1,200	1,000
Texas	8,700	8,200	7,400	7,500	7,800	6,000
Virginia	500	600	600	500	600	500
Wisconsin	3,200	3,300	2,900	3,200	2,900	2,800
United States	69,200	69,800	66,900	65,300	66,700	62,400

Cabbage for Fresh Market Yield and Production – States and United States: 2009-2011

State	Yield per acre			Production [1]		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	435	515	460	1,000	1,082	1,150
California	395	400	390	4,938	5,000	5,070
Colorado	470	460	460	1,269	1,334	1,288
Florida	385	300	340	3,658	2,910	2,754
Georgia	300	290	230	1,890	1,653	1,196
Michigan	260	280	230	676	840	759
New Jersey	345	280	375	552	476	525
New York	380	430	440	3,420	4,472	4,708
North Carolina	220	270	230	1,188	1,350	897
Ohio	127	280	355	127	336	426
Pennsylvania	220	330	155	264	396	155
Texas	320	320	200	2,400	2,496	1,200
Virginia	250	280	210	125	168	105
Wisconsin	300	250	320	960	725	896
United States	344	348	339	22,467	23,238	21,129

Cabbage for Fresh Market Price and Value – States and United States: 2009-2011

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	19.00	21.30	24.50	19,000	23,047	28,175
California	15.00	14.40	12.90	74,070	72,000	65,403
Colorado	11.00	11.50	13.60	13,959	15,341	17,517
Florida	16.50	24.10	23.60	60,357	70,131	64,994
Georgia	14.80	10.90	17.60	27,972	18,018	21,050
Michigan	15.00	13.00	16.00	10,140	10,920	12,144
New Jersey	15.90	14.50	17.60	8,777	6,902	9,240
New York	18.30	21.20	20.00	55,833	87,980	86,640
North Carolina	12.50	10.50	14.30	14,850	14,175	12,827
Ohio	17.90	25.60	15.70	2,273	8,602	6,688
Pennsylvania	18.90	15.00	20.60	4,990	5,940	3,193
Texas	13.50	20.20	21.00	32,400	50,419	25,200
Virginia	13.00	18.00	18.00	1,625	3,024	1,890
Wisconsin	16.20	13.70	14.90	15,552	9,933	13,350
United States	15.50	17.30	17.70	341,798	396,432	368,311

[1] Includes some quantities of fall storage in New York harvested but not sold because of shrinkage and loss: 2009, 369,000 cwt; 2010, 322,000 cwt; and 2011, 376,000 cwt.

Cantaloupes for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	23,500	21,000	20,200	23,300	20,800	20,000
California	37,000	40,500	36,900	37,000	39,000	36,900
Colorado	2,400	2,300	2,200	2,200	2,200	2,100
Georgia	5,200	5,200	4,500	5,000	5,000	4,000
Indiana	2,400	2,400	2,700	2,200	2,300	2,600
Maryland	660	630	600	530	530	500
Pennsylvania	1,000	1,000	990	900	1,000	950
South Carolina	1,300	1,600	1,600	1,200	1,200	1,400
Texas	2,600	2,800	2,900	2,400	2,700	2,500
United States	76,060	77,430	72,590	74,730	74,730	70,950

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	215	235	240	5,010	4,888	4,800
California	300	290	300	11,100	11,310	11,070
Colorado	270	190	190	594	418	399
Georgia	275	300	260	1,375	1,500	1,040
Indiana	210	170	220	462	391	572
Maryland	85	85	88	45	45	44
Pennsylvania	170	145	195	153	145	185
South Carolina	250	195	325	300	234	455
Texas	100	110	110	240	297	275
United States	258	257	266	19,279	19,228	18,840

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	23.00	19.90	19.60	115,230	97,271	94,080
California	14.20	12.30	16.10	157,620	139,113	178,227
Colorado	21.60	19.10	23.00	12,830	7,984	9,177
Georgia	28.50	34.00	29.90	39,188	51,000	31,096
Indiana	15.00	15.80	22.20	6,930	6,178	12,698
Maryland	30.00	28.00	30.00	1,350	1,260	1,320
Pennsylvania	28.00	24.30	28.10	4,284	3,524	5,199
South Carolina	20.00	15.30	20.00	6,000	3,580	9,100
Texas	29.00	31.20	32.10	6,960	9,266	8,828
United States	18.20	16.60	18.60	350,392	319,176	349,725

Carrots for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	63,500	57,000	66,000	61,000	56,000	63,000
Michigan	2,400	2,100	1,900	2,200	1,900	1,800
Texas	1,300	1,500	1,500	1,200	1,300	1,300
Other States [1]	5,100	6,900	6,000	5,000	6,800	5,900
United States	72,300	67,500	75,400	69,400	66,000	72,000

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	315	350	300	19,215	19,600	18,900
Michigan	270	250	260	594	475	468
Texas	270	260	260	324	338	338
Other States [1]	406	415	391	2,030	2,824	2,306
United States	319	352	306	22,163	23,237	22,012

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	25.70	27.60	34.90	493,826	540,960	659,610
Michigan	21.30	23.00	16.30	12,652	10,925	7,628
Texas	25.60	25.50	25.00	8,294	8,619	8,450
Other States [1]	21.10	20.30	23.30	42,898	57,210	53,817
United States	25.20	26.60	33.10	557,670	617,714	729,505

[1] Other States include Colorado, Georgia, and Washington.

Celery for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	26,800	26,800	26,700	26,600	26,100	26,400
Michigan	2,000	2,000	2,000	1,900	1,900	1,800
United States	28,800	28,800	28,700	28,500	28,000	28,200

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	715	725	690	19,019	18,923	18,216
Michigan	555	525	490	1,055	1,000	882
United States	704	712	677	20,074	19,923	19,098

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	20.50	18.70	20.30	389,141	353,273	368,902
Michigan	14.10	17.90	14.70	14,898	17,880	12,958
United States	20.10	18.60	20.00	404,039	371,153	381,860

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Sweet Corn for Fresh Market Area Planted and Harvested, Yield, Production, Price and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Alabama	2,000	1,800	1,500	1,400	1,300	1,000
California	28,100	32,700	33,200	28,000	32,500	33,000
Colorado	8,000	8,000	7,600	6,800	7,500	7,400
Connecticut	4,500	4,000	4,300	3,900	3,500	3,100
Delaware	3,500	3,300	3,300	3,500	3,100	3,100
Florida	46,900	45,100	50,500	43,100	42,100	43,000
Georgia	26,000	29,000	28,000	25,000	27,000	27,000
Illinois	7,300	8,000	7,000	7,100	7,500	6,700
Indiana	6,400	6,800	6,100	6,100	6,500	5,600
Maine	2,000	1,900	1,800	1,500	1,800	1,600
Maryland	4,300	4,300	4,200	3,900	3,900	3,800
Massachusetts	5,400	5,400	5,300	4,700	5,200	4,500
Michigan	9,700	10,000	10,200	9,100	9,400	9,500
New Hampshire	1,600	1,600	1,500	1,400	1,400	1,300
New Jersey	7,700	8,000	7,400	7,100	7,400	7,000
New York	23,100	23,500	23,300	21,500	22,800	19,600
North Carolina	6,600	7,600	7,200	6,300	6,900	6,700
Ohio	16,500	16,400	15,900	11,400	13,600	15,100
Oregon	5,100	5,200	4,600	4,900	4,100	4,000
Pennsylvania	15,400	16,200	15,200	14,400	14,100	13,000
Rhode Island	800	750	800	750	700	650
Texas	2,800	3,100	3,100	2,400	2,700	2,700
Vermont	1,200	1,100	1,000	1,000	1,000	700
Virginia	3,000	3,500	3,700	2,900	3,100	3,500
Washington	11,700	13,700	12,000	11,500	13,500	11,600
Wisconsin	7,900	8,200	8,000	7,000	7,500	7,300
United States	257,500	269,150	266,700	236,650	250,100	242,450

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Alabama	53	52	56	74	68	56
California	175	165	170	4,900	5,363	5,610
Colorado	160	150	180	1,088	1,125	1,332
Connecticut	70	60	50	273	210	155
Delaware	120	110	108	420	341	335
Florida	155	140	150	6,681	5,894	6,450
Georgia	130	145	100	3,250	3,915	2,700
Illinois	82	81	76	582	608	509
Indiana	69	92	67	421	598	375
Maine	60	55	60	90	99	96
Maryland	67	44	63	261	172	239
Massachusetts	65	75	70	306	390	315
Michigan	110	100	94	1,001	940	893
New Hampshire	55	55	65	77	77	85
New Jersey	110	75	85	781	555	595
New York	100	120	95	2,150	2,736	1,862
North Carolina	110	100	70	693	690	469
Ohio	119	90	115	1,357	1,224	1,737
Oregon	70	70	137	343	287	548
Pennsylvania	68	67	63	979	945	819
Rhode Island	60	70	70	45	49	46
Texas	65	60	53	156	162	143
Vermont	45	50	40	45	50	28
Virginia	35	20	24	102	62	84
Washington	188	180	165	2,162	2,430	1,914
Wisconsin	86	85	95	602	638	694
United States	122	118	116	28,839	29,628	28,089

Sweet Corn for Fresh Market Area Planted and Harvested, Yield, Production, Price and Value – States and United States: 2009-2011 (continued)

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Alabama	30.00	29.50	29.00	2,220	2,006	1,624
California	24.80	18.80	19.20	121,520	100,824	107,712
Colorado	13.70	14.50	16.90	14,906	16,313	22,511
Connecticut	40.00	40.00	43.00	10,920	8,400	6,665
Delaware	27.00	27.00	29.00	11,340	9,207	9,715
Florida	34.00	32.10	27.00	227,154	189,197	174,150
Georgia	26.20	16.70	23.80	85,150	65,381	64,260
Illinois	22.50	27.00	29.00	13,095	16,416	14,761
Indiana	40.00	24.00	47.80	16,840	14,352	17,925
Maine	47.00	49.00	50.00	4,230	4,851	4,800
Maryland	32.00	34.00	36.00	8,352	5,848	8,604
Massachusetts	43.00	45.00	55.00	13,158	17,550	17,325
Michigan	23.60	24.70	23.00	23,624	23,218	20,539
New Hampshire	59.00	61.00	61.00	4,543	4,697	5,185
New Jersey	29.20	27.50	26.60	22,805	15,263	15,827
New York	27.10	26.00	28.80	58,265	71,136	53,626
North Carolina	21.00	17.50	28.00	14,553	12,075	13,132
Ohio	30.40	24.60	25.30	41,253	30,110	43,946
Oregon	27.50	27.50	21.60	9,433	7,893	11,837
Pennsylvania	36.30	28.30	37.30	35,538	26,744	30,549
Rhode Island	40.00	50.00	50.00	1,800	2,450	2,300
Texas	22.00	22.00	23.50	3,432	3,564	3,361
Vermont	54.00	56.00	53.00	2,430	2,800	1,484
Virginia	25.00	20.00	23.00	2,550	1,240	1,932
Washington	37.50	38.80	41.00	81,075	94,284	78,474
Wisconsin	26.60	21.40	21.30	16,013	13,653	14,782
United States	29.30	25.60	26.60	846,199	759,472	747,026

Cucumbers for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	2,600	3,500	3,000	2,600	3,500	3,000
Florida	11,600	12,000	10,000	11,300	11,600	9,500
Georgia	11,500	8,600	9,000	10,000	8,500	8,000
Maryland	500	600	550	450	500	500
Michigan	4,400	4,300	3,800	4,300	4,300	3,700
New Jersey	3,200	3,200	3,300	3,100	3,200	3,100
New York	3,400	3,000	3,000	3,200	2,800	2,900
North Carolina	7,600	6,200	5,500	7,500	6,100	5,300
South Carolina	1,800	1,500	1,800	1,700	1,400	1,700
Texas	1,500	1,800	1,500	1,100	1,100	1,200
Virginia	1,400	1,300	1,400	1,300	1,200	1,300
United States	49,500	46,000	42,850	46,550	44,200	40,200

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	250	210	155	650	735	465
Florida	235	200	250	2,656	2,320	2,375
Georgia	250	250	160	2,500	2,125	1,280
Maryland	55	53	50	25	27	25
Michigan	225	210	190	968	903	703
New Jersey	130	210	160	403	672	496
New York	120	170	160	384	476	464
North Carolina	160	110	140	1,200	671	742
South Carolina	230	180	200	391	252	340
Texas	106	142	125	117	156	150
Virginia	50	40	45	65	48	59
United States	201	190	177	9,359	8,385	7,099

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	29.10	19.50	36.60	18,915	14,333	17,019
Florida	29.60	20.60	21.90	78,618	47,792	52,013
Georgia	23.60	24.00	28.50	59,000	51,000	36,480
Maryland	42.00	40.00	42.00	1,050	1,080	1,050
Michigan	19.20	22.70	23.00	18,586	20,498	16,169
New Jersey	28.00	23.40	31.40	11,284	15,725	15,574
New York	41.80	38.80	40.00	16,051	18,469	18,560
North Carolina	20.00	17.50	23.30	24,000	11,743	17,289
South Carolina	18.00	24.00	26.00	7,038	6,048	8,840
Texas	27.00	26.00	27.00	3,159	4,056	4,050
Virginia	22.00	21.00	25.00	1,430	1,008	1,475
United States	25.60	22.90	26.60	239,131	191,752	188,519

Garlic for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	21,100	22,100	24,500	20,900	21,900	24,000
Nevada	530	500	550	530	500	550
Oregon	800	600	600	800	450	600
United States	22,430	23,200	25,650	22,230	22,850	25,150

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	175	165	170	3,677	3,614	4,080
Nevada	170	170	110	89	85	61
Oregon	140	120	105	112	53	63
United States	174	164	167	3,878	3,752	4,204

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	51.20	71.80	68.60	188,127	259,616	279,927
Nevada	25.00	29.00	36.00	2,225	2,465	2,196
Oregon	22.50	90.60	74.60	2,520	4,803	4,697
United States	49.70	71.10	68.20	192,872	266,884	286,820

Honeydew for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	3,400	3,200	3,600	3,300	3,100	3,500
California	11,200	12,900	10,500	11,000	12,900	10,300
Texas	650	650	650	600	600	600
United States	15,250	16,750	14,750	14,900	16,600	14,400

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	240	200	205	792	620	718
California	235	215	225	2,585	2,774	2,318
Texas	350	365	300	210	219	180
United States	241	218	223	3,587	3,613	3,216

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	20.60	20.30	23.50	16,315	12,586	16,873
California	13.50	13.20	21.00	34,898	36,617	48,678
Texas	21.00	26.50	28.50	4,410	5,804	5,130
United States	15.50	15.20	22.00	55,623	55,007	70,681

Head Lettuce for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	32,500	34,500	36,500	32,000	34,000	36,000
California	105,000	99,000	106,000	103,000	98,000	105,000
United States	137,500	133,500	142,500	135,000	132,000	141,000

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	345	350	335	11,040	11,900	12,060
California	380	390	350	39,140	38,220	36,750
United States	372	380	346	50,180	50,120	48,810

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	22.90	27.20	32.10	252,816	323,680	387,126
California	22.20	19.20	20.10	868,908	733,824	738,675
United States	22.40	21.10	23.10	1,121,724	1,057,504	1,125,801

Leaf Lettuce for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	8,800	7,900	7,500	8,600	7,700	7,400
California	41,200	44,500	42,000	40,500	43,500	41,400
United States	50,000	52,400	49,500	49,100	51,200	48,800

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	200	220	235	1,720	1,694	1,739
California	250	260	255	10,125	11,310	10,557
United States	241	254	252	11,845	13,004	12,296

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	39.50	55.20	66.50	67,940	93,509	115,644
California	38.60	35.90	28.90	390,825	406,029	305,097
United States	38.70	38.40	34.20	458,765	499,538	420,741

Romaine Lettuce for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	16,300	18,500	20,000	16,100	18,300	19,700
California	61,000	63,000	61,000	60,000	61,000	59,800
United States	77,300	81,500	81,000	76,100	79,300	79,500

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	345	330	355	5,555	6,039	6,994
California	280	350	295	16,800	21,350	17,641
United States	294	345	310	22,355	27,389	24,635

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	23.20	31.50	46.60	128,876	190,229	325,920
California	28.80	21.80	26.60	483,840	465,430	469,251
United States	27.40	23.90	32.30	612,716	655,659	795,171

Onions for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price and Value by Season – States and United States: 2009-2011

Season and State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Spring [1]						
Arizona [2]	1,600	(NA)	(NA)	1,600	(NA)	(NA)
California	6,200	6,400	6,500	6,000	6,200	6,300
Georgia	11,800	12,000	13,600	10,800	11,100	12,100
Texas	10,300	10,000	13,000	9,100	8,600	11,200
United States	29,900	28,400	33,100	27,500	25,900	29,600
Summer non-storage [1]						
California	6,600	6,800	6,900	6,400	6,600	6,700
Nevada	3,400	3,700	3,500	3,400	3,700	3,500
New Mexico	5,200	6,000	6,100	5,000	5,900	5,900
Texas	700	600	600	600	500	500
Washington [3]	2,000	2,000	2,200	2,000	2,000	2,200
United States	17,900	19,100	19,300	17,400	18,700	18,800
Summer storage						
California [4]	32,600	30,100	30,600	31,400	29,000	29,500
Colorado	8,000	7,500	7,500	6,600	7,200	6,900
Idaho	9,000	9,200	9,400	8,800	9,000	9,200
Michigan	4,000	4,200	3,900	3,800	4,000	3,400
New York	10,600	10,700	8,100	10,300	9,800	6,200
Oregon						
Malheur	11,200	11,300	11,300	11,200	11,300	11,300
Other	9,100	8,900	9,500	9,100	8,900	9,500
Washington	21,000	22,000	20,000	21,000	22,000	20,000
Wisconsin	2,000	2,000	1,500	2,000	1,600	1,500
Other States [5]	2,010	1,870	1,730	1,960	1,870	1,730
United States	109,510	107,770	103,530	106,160	104,670	99,230
Total summer	127,410	126,870	122,830	123,560	123,370	118,030
Total, spring, and summer	157,310	155,270	155,930	151,060	149,270	147,630
Processed [6]	(X)	(X)	(X)	(X)	(X)	(X)

See footnote(s) at end of table. --continued

Onions for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price and Value by Season – States and United States: 2009-2011 (continued)

Season and State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Spring [1]						
Arizona [2]	360	(NA)	(NA)	576	(NA)	(NA)
California	410	410	400	2,460	2,542	2,520
Georgia	230	205	245	2,484	2,276	2,965
Texas	330	310	300	3,003	2,666	3,360
United States	310	289	299	8,523	7,484	8,845
Summer non-storage [1]						
California	540	490	590	3,456	3,234	3,953
Nevada	720	700	810	2,448	2,590	2,835
New Mexico	550	560	460	2,750	3,304	2,714
Texas	300	350	360	180	175	180
Washington [3]	375	330	350	750	660	770
United States	551	533	556	9,584	9,963	10,452
Summer storage						
California [4]	455	450	440	14,287	13,050	12,980
Colorado	415	400	390	2,739	2,880	2,691
Idaho	740	760	780	6,512	6,840	7,176
Michigan	350	220	240	1,330	880	816
New York	415	315	305	4,275	3,087	1,891
Oregon						
Malheur	700	760	730	7,840	8,588	8,249
Other	600	700	685	5,460	6,230	6,508
Washington	630	610	650	13,230	13,420	13,000
Wisconsin	500	200	370	1,000	320	555
Other States [5]	418	458	440	819	857	761
United States	542	536	551	57,492	56,152	54,627
Total summer	543	536	551	67,076	66,115	65,079
Total, spring, and summer	500	493	501	75,599	73,599	73,924
Processed [6]	(X)	(X)	(X)	10,875	9,389	9,724

See footnote(s) at end of table.

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Onions for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price and Value by Season – States and United States: 2009-2011 (continued)

Season and State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Spring [1]						
Arizona [2]	11.30	(NA)	(NA)	6,509	(NA)	(NA)
California	8.60	18.00	13.50	21,156	45,756	34,020
Georgia	32.90	49.70	31.10	81,724	113,117	92,212
Texas	13.70	50.20	14.70	41,141	133,833	49,392
United States	17.70	39.10	19.90	150,530	292,706	175,624
Summer non-storage [1]						
California	8.60	7.50	5.00	29,722	24,255	19,765
Nevada	35.00	26.00	25.00	85,680	67,340	70,875
New Mexico	19.60	27.40	15.90	53,900	90,530	43,153
Texas	38.20	38.20	38.20	6,876	6,685	6,876
Washington [3]	29.50	50.10	22.80	22,125	33,066	17,556
United States	20.70	22.30	15.10	198,303	221,876	158,225
Summer storage						
California [4]	9.54	9.29	7.88	133,941	118,861	100,285
Colorado	12.60	17.70	13.80	30,731	45,666	32,582
Idaho	13.80	8.70	7.50	80,882	50,025	45,195
Michigan	13.50	14.80	15.40	14,310	10,419	10,056
New York	18.60	19.70	20.80	67,592	53,702	33,051
Oregon						
Malheur	14.30	8.79	7.14	98,670	63,411	49,473
Other	13.50	9.05	7.61	64,800	46,798	42,593
Washington	16.40	11.20	8.90	197,292	135,744	104,130
Wisconsin	10.80	12.50	13.80	9,472	3,350	6,886
Other States [5]	11.30	8.34	5.31	7,704	7,146	4,043
United States	13.50	10.70	8.79	705,394	535,122	428,294
Total summer	14.60	12.60	9.91	903,697	756,998	586,519
Total, spring and summer	15.00	15.60	11.20	1,054,227	1,049,704	762,143
Processed [6]	10.00	8.30	7.50	108,750	77,929	72,930

(NA) Not available.
(X) Not applicable.
[1] Primarily fresh.
[2] Estimates discontinued in 2010.
[3] Includes Walla Walla and other non-storage onions.
[4] Primarily dehydrated and other processing.
[5] Other States include Ohio and Utah.
[6] California only.

Summer Storage Onion Shrinkage and Loss – States and United States: 2009-2011

State	2009	2010	2011
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California [1]	250	250	250
Colorado	300	300	330
Idaho	651	1,090	1,150
Michigan	270	176	163
New York	641	361	302
Oregon			
Malheur	940	1,374	1,320
Other	660	1,059	911
Washington	1,200	1,300	1,300
Wisconsin	123	52	56
Other States [2]	135	150	100
United States	5,170	6,112	5,882

[1] Primarily dehydrated and other processing.
[2] Other States include Ohio and Utah.

Bell Peppers for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	19,900	21,000	23,000	19,800	20,900	22,900
Florida	18,900	18,800	18,700	18,200	17,700	17,600
Georgia	3,700	3,500	3,700	3,500	3,500	3,400
Michigan	1,700	1,700	1,400	1,600	1,600	1,300
New Jersey	3,300	3,300	3,600	3,200	3,300	3,400
North Carolina	3,300	3,500	2,600	3,200	3,400	2,600
Ohio	2,400	3,100	3,200	2,200	2,800	3,100
United States	53,200	54,900	56,200	51,700	53,200	54,300

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	410	390	375	8,118	8,165	8,588
Florida	245	230	250	4,482	4,071	4,400
Georgia	280	250	425	980	875	1,445
Michigan	240	230	270	384	368	351
New Jersey	290	325	305	928	1,073	1,037
North Carolina	400	270	305	1,280	918	793
Ohio	375	245	325	825	686	1,004
United States	329	304	324	16,997	16,156	17,618

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	28.40	29.40	29.40	230,239	239,775	252,129
Florida	44.30	72.60	56.30	198,553	295,555	247,720
Georgia	35.50	25.50	48.70	34,790	22,313	70,372
Michigan	30.00	33.00	36.00	11,520	12,144	12,636
New Jersey	33.80	31.50	29.30	31,366	33,800	30,384
North Carolina	32.00	32.00	38.00	40,960	29,376	30,134
Ohio	46.00	24.00	41.40	37,950	16,464	41,566
United States	34.40	40.20	38.90	585,378	649,427	684,941

Chile Peppers for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

[Chile peppers are defined as all peppers excluding bell peppers. Estimates include both fresh and dry product combined]

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	3,000	3,000	2,600	2,900	2,900	2,400
California	5,400	5,500	6,500	5,300	5,400	6,400
New Mexico	12,800	9,150	10,000	12,300	8,700	9,500
Texas	7,500	5,900	4,300	7,300	5,400	3,800
United States	28,700	23,550	23,400	27,800	22,400	22,100

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	81	72	52	234	210	124
California	360	400	395	1,911	2,160	2,528
New Mexico	195	200	215	2,385	1,758	2,032
Texas	36	51	40	260	276	152
United States	172	197	219	4,790	4,404	4,836

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	44.60	49.40	31.90	10,429	10,369	3,961
California	24.80	27.40	34.00	47,379	59,138	85,923
New Mexico	24.10	23.70	23.00	57,369	41,611	46,680
Texas	71.90	74.10	67.00	18,701	20,460	10,190
United States	27.90	29.90	30.30	133,878	131,578	146,754

Pumpkins for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted 2009	Area planted 2010	Area planted 2011	Area harvested 2009	Area harvested 2010	Area harvested 2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	5,100	6,200	5,900	5,100	6,200	5,800
Illinois	14,300	15,400	17,400	12,500	15,100	15,900
Michigan	7,400	7,400	7,200	6,700	6,800	6,800
New York	6,600	7,100	6,800	6,000	6,800	6,300
Ohio	7,600	7,300	7,100	7,500	6,900	6,800
Pennsylvania	6,700	6,800	6,900	6,300	6,700	5,700
United States	47,700	50,200	51,300	44,100	48,500	47,300

State	Yield per acre 2009	Yield per acre 2010	Yield per acre 2011	Production 2009	Production 2010	Production 2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	290	320	290	1,479	1,984	1,682
Illinois	345	285	325	4,291	4,274	5,204
Michigan	110	140	145	737	952	986
New York	125	215	110	750	1,462	693
Ohio	165	160	165	1,237	1,104	1,122
Pennsylvania	130	145	180	819	972	1,026
United States	211	222	226	9,313	10,748	10,713

State	Price per cwt 2009	Price per cwt 2010	Price per cwt 2011	Value of production 2009	Value of production 2010	Value of production 2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	13.90	10.10	11.70	20,558	20,038	19,679
Illinois	3.47	3.67	4.21	14,896	15,667	21,931
Michigan	14.00	14.50	17.00	10,318	13,804	16,762
New York	29.00	24.00	34.10	21,750	35,088	23,631
Ohio	18.20	15.10	14.80	22,513	16,670	16,606
Pennsylvania	15.50	17.00	14.20	12,695	16,524	14,569
United States	11.00	11.00	10.60	102,730	117,791	113,178

Spinach for Fresh Market Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	6,000	7,600	8,400	6,000	7,500	8,100
California	26,000	20,200	21,100	25,000	18,900	19,600
New Jersey	1,600	1,500	1,400	1,500	1,400	1,200
Texas	1,200	1,200	1,100	600	1,000	700
Other States [1]	3,700	3,900	3,700	3,500	3,500	3,600
United States	38,500	34,400	35,700	36,600	32,300	33,200

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	195	150	210	1,170	1,125	1,701
California	200	210	195	5,000	3,969	3,822
New Jersey	135	85	155	203	119	186
Texas	146	190	154	88	190	108
Other States [1]	103	104	101	360	364	362
United States	186	179	186	6,821	5,767	6,179

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	39.20	40.00	50.40	45,864	45,000	85,730
California	40.10	44.10	36.90	200,500	175,033	141,032
New Jersey	43.20	45.90	45.00	8,770	5,462	8,370
Texas	22.00	23.00	24.40	1,936	4,370	2,635
Other States [1]	34.30	44.30	34.00	12,354	16,120	12,308
United States	39.50	42.70	40.50	269,424	245,985	250,075

[1] Other States include Colorado and Maryland.

Squash for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	5,900	6,800	6,900	5,800	6,700	6,800
Florida	9,100	9,500	12,500	8,800	9,100	11,500
Georgia	5,500	4,100	4,000	5,300	4,000	3,600
Michigan	6,700	6,700	6,500	6,500	6,600	6,400
New Jersey	3,300	3,100	3,100	2,800	3,100	2,700
New York	4,700	4,700	4,900	4,500	4,600	4,400
North Carolina	3,300	3,500	3,400	3,200	3,400	3,300
Ohio	1,600	1,800	1,900	1,500	1,700	1,800
Oregon	2,300	2,500	2,800	2,300	2,400	2,700
South Carolina	1,100	600	1,600	1,000	500	1,500
Tennessee	1,000	700	700	800	600	600
Texas	1,500	1,800	1,900	1,400	1,700	1,800
United States	46,000	45,800	50,200	43,900	44,400	47,100

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	210	200	170	1,218	1,340	1,156
Florida	130	120	150	1,144	1,092	1,725
Georgia	200	120	130	1,060	480	468
Michigan	210	200	190	1,365	1,320	1,216
New Jersey	115	120	150	325	372	405
New York	120	195	190	540	897	836
North Carolina	110	90	130	352	306	429
Ohio	310	160	200	465	272	360
Oregon	175	155	150	404	371	410
South Carolina	140	130	130	141	66	195
Tennessee	81	70	65	65	42	39
Texas	100	100	110	140	170	198
United States	164	152	158	7,219	6,728	7,437

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	26.40	28.50	30.10	32,160	38,205	34,780
Florida	45.00	52.00	55.00	51,480	56,784	94,875
Georgia	28.20	32.00	35.30	29,892	15,360	16,520
Michigan	8.60	9.20	21.00	11,739	12,144	25,536
New Jersey	32.00	27.70	38.20	10,400	10,304	15,471
New York	42.60	41.00	51.30	23,004	36,777	42,887
North Carolina	32.00	30.00	60.00	11,264	9,180	25,740
Ohio	23.00	35.30	26.00	10,695	9,602	9,360
Oregon	26.20	10.50	11.60	10,568	3,914	4,747
South Carolina	32.50	31.60	33.00	4,578	2,083	6,435
Tennessee	19.60	30.00	28.00	1,272	1,260	1,092
Texas	45.80	76.80	29.30	6,412	13,056	5,801
United States	28.20	31.00	38.10	203,464	208,669	283,244

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Tomatoes for Fresh Market Area Planted and Harvested – States and United States: 2009-2011

[Cherry, grape, tomatillo, and greenhouse tomatoes are excluded]

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Alabama	1,400	1,400	1,500	1,300	1,300	1,250
Arkansas	1,100	1,200	1,300	1,000	1,100	1,200
California	39,500	36,500	35,500	39,000	36,000	35,000
Florida	34,600	32,000	32,000	33,600	29,500	31,000
Georgia	4,600	(D)	(D)	4,500	(D)	(D)
Indiana	1,000	1,000	1,000	800	900	760
Michigan	2,100	2,000	2,100	2,000	2,000	2,000
New Jersey	3,100	3,100	3,100	2,900	2,900	2,900
New York	2,700	2,900	3,000	2,500	2,800	2,700
North Carolina	3,400	3,300	3,300	3,300	3,200	3,200
Ohio	4,900	4,800	4,500	4,600	4,700	3,200
Pennsylvania	2,200	2,300	2,400	1,700	2,300	1,900
South Carolina	2,000	2,500	2,700	1,900	2,400	2,500
Tennessee	4,700	4,900	4,300	4,000	4,600	3,800
Texas	900	(D)	(D)	800	(D)	(D)
Virginia	5,000	4,800	4,800	4,800	4,500	4,600
Other States [1]	(X)	5,000	3,900	(X)	4,800	3,700
United States	113,200	107,700	105,400	108,700	103,000	99,710

(D) Withheld to avoid disclosing data for individual operations.
(X) Not applicable.

Tomato Fresh Market Yield and Production – States and United States: 2009-2011

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Alabama	310	315	350	403	410	438
Arkansas	64	170	192	64	187	230
California	290	310	355	11,310	11,160	12,425
Florida	366	290	330	12,298	8,555	10,230
Georgia	280	(D)	(D)	1,260	(D)	(D)
Indiana	150	120	110	120	108	84
Michigan	300	200	220	600	400	440
New Jersey	220	215	210	638	624	609
New York	140	140	160	350	392	432
North Carolina	340	220	440	1,122	704	1,408
Ohio	334	270	235	1,536	1,269	752
Pennsylvania	170	110	91	289	253	173
South Carolina	175	170	195	333	408	488
Tennessee	340	310	275	1,360	1,426	1,045
Texas	140	(D)	(D)	112	(D)	(D)
Virginia	300	210	220	1,440	945	1,012
Other States [1]	(X)	233	173	(X)	1,120	640
United States	306	271	305	33,235	27,961	30,406

(D) Withheld to avoid disclosing data for individual operations.
(X) Not applicable.

Fresh Market Tomato Price and Value – States and United States: 2009-2011

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Alabama	32.30	31.40	32.00	13,017	12,874	14,016
Arkansas	56.00	56.00	64.00	3,584	10,472	14,720
California	34.80	33.00	30.40	393,588	368,280	377,720
Florida	42.30	72.50	55.20	520,205	620,238	564,696
Georgia	49.40	(D)	(D)	62,244	(D)	(D)
Indiana	80.00	78.00	50.00	9,600	8,424	4,200
Michigan	35.00	54.00	40.00	21,000	21,600	17,600
New Jersey	53.20	51.90	51.70	33,942	32,386	31,485
New York	93.50	72.70	84.80	32,725	28,498	36,634
North Carolina	31.00	30.00	37.50	34,782	21,120	52,800
Ohio	44.00	36.90	49.20	67,584	46,826	36,998
Pennsylvania	74.10	84.00	68.50	21,415	21,252	11,851
South Carolina	48.00	46.00	46.00	15,984	18,768	22,448
Tennessee	33.00	37.00	36.00	44,880	52,762	37,620
Texas	57.60	(D)	(D)	6,451	(D)	(D)
Virginia	43.90	54.50	47.00	63,216	51,503	47,564
Other States [1]	(X)	33.30	33.60	(X)	37,312	21,523
United States	40.40	48.40	42.50	1,344,217	1,352,315	1,291,875

(D) Withheld to avoid disclosing data for individual operations.
(X) Not applicable.
[1] Other States includes Georgia and Texas.

Watermelon Fresh Market Area Planted and Harvested – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Alabama	3,600	3,300	3,500	2,600	2,800	2,800
Arizona	5,500	5,500	5,300	5,500	5,300	5,200
Arkansas	1,500	1,400	1,400	1,400	1,300	1,200
California	10,200	12,700	13,100	10,000	12,700	13,000
Delaware	2,500	2,700	2,800	2,500	2,700	2,800
Florida	27,700	25,900	25,900	25,800	24,600	24,400
Georgia	24,000	26,000	25,000	23,000	24,000	22,000
Indiana	7,700	7,300	7,300	7,400	7,100	7,200
Maryland	2,100	2,100	2,200	2,100	2,100	2,100
Mississippi	2,800	2,900	2,800	2,300	2,500	2,400
Missouri	3,100	3,300	3,000	2,600	3,200	2,900
North Carolina	6,900	7,200	8,000	6,700	7,100	7,600
Oklahoma	5,500	5,500	5,400	3,500	5,000	2,300
South Carolina	7,500	8,500	7,800	6,500	8,000	7,000
Texas	23,000	28,000	24,000	20,900	24,900	21,000
Virginia	1,200	1,100	1,100	1,100	1,000	1,000
United States	134,800	143,400	138,600	123,900	134,300	124,900

Watermelon Fresh Market Yield and Production – States and United States: 2009-2011

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Alabama	160	155	125	416	434	350
Arizona	490	430	450	2,695	2,279	2,340
Arkansas	200	260	265	280	338	318
California	540	540	600	5,400	6,858	7,800
Delaware	375	370	375	938	999	1,050
Florida	317	305	310	8,179	7,503	7,564
Georgia	300	280	195	6,900	6,720	4,290
Indiana	355	400	420	2,627	2,840	3,024
Maryland	300	300	320	630	630	672
Mississippi	145	180	155	334	450	372
Missouri	330	335	330	858	1,072	957
North Carolina	270	280	255	1,809	1,988	1,938
Oklahoma	95	110	100	333	550	230
South Carolina	230	330	380	1,495	2,640	2,660
Texas	280	250	250	5,852	6,225	5,250
Virginia	150	210	190	165	210	190
United States	314	311	312	38,911	41,736	39,005

Watermelon Fresh Market Price and Value – States and United States: 2009-2011

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Alabama	10.60	9.30	12.00	4,410	4,036	4,200
Arizona	11.80	12.70	16.30	31,801	28,943	38,142
Arkansas	7.60	8.20	11.50	2,128	2,772	3,657
California	12.50	13.30	14.00	67,500	91,211	109,200
Delaware	11.00	11.00	13.00	10,318	10,989	13,650
Florida	16.60	15.00	14.80	135,771	112,545	111,947
Georgia	9.80	11.30	20.50	67,620	75,936	87,945
Indiana	9.00	11.40	11.40	23,643	32,376	34,474
Maryland	12.00	12.00	13.00	7,560	7,560	8,736
Mississippi	10.20	10.50	11.30	3,407	4,725	4,204
Missouri	7.20	8.00	10.10	6,178	8,576	9,666
North Carolina	12.80	12.10	15.00	23,155	24,055	29,070
Oklahoma	12.90	10.00	11.10	4,296	5,500	2,553
South Carolina	9.00	13.50	14.50	13,455	35,640	38,570
Texas	8.20	8.40	8.60	47,986	52,290	45,150
Virginia	9.00	12.60	14.00	1,485	2,646	2,660
United States	11.60	12.00	13.90	450,713	499,800	543,824

Asparagus for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	13,000	12,000	12,000	12,500	11,500	11,500
Michigan	11,200	10,700	10,400	10,700	10,500	9,800
Washington	6,500	6,500	6,500	6,000	6,000	6,000
United States	30,700	29,200	28,900	29,200	28,000	27,300

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	32	35	33	400	403	384
Michigan	22	16	22	235	168	216
Washington	44	38	40	264	228	240
United States	31	29	31	899	799	840

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	130.00	147.00	149.00	52,000	59,241	57,216
Michigan	70.40	83.00	80.20	16,553	13,948	17,322
Washington	76.90	77.10	78.90	20,302	17,588	18,936
United States	98.80	114.00	111.00	88,855	90,777	93,474

Asparagus for Fresh Market and Processing Production, Price, and Value by Utilization – States and United States: 2009-2011

Utilization and State	Production 2009	Production 2010	Production 2011
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Fresh market			
California [1]	400	403	384
Other States [2]	303	276	286
United States	703	679	670
	(tons)	(tons)	(tons)
Processing			
Other States [2]	9,800	6,000	8,500
United States	9,800	6,000	8,500
Canning	5,100	2,100	3,100
Freezing	4,700	3,900	5,400

Utilization and State	Price per unit			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars per cwt)	(dollars per cwt)	(dollars per cwt)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Fresh market						
California [1]	130.00	147.00	149.00	52,000	59,241	57,216
Other States [2]	78.60	84.60	81.80	23,827	23,356	23,409
United States	108.00	122.00	120.00	75,827	82,597	80,625
	(dollars per ton)	(dollars per ton)	(dollars per ton)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Processing						
Other States [2]	1,330.00	1,360.00	1,510.00	13,028	8,180	12,849
United States	1,330.00	1,360.00	1,510.00	13,028	8,180	12,849
Canning	1,360.00	1,280.00	1,620.00	6,918	2,688	5,022
Freezing	1,300.00	1,410.00	1,450.00	6,110	5,492	7,827

[1] Includes a small amount of processing asparagus.
[2] Other States include Michigan and Washington.

Broccoli for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	9,000	7,300	7,300	9,000	7,200	7,200
California	118,000	125,000	126,000	117,000	123,000	124,000
United States	127,000	132,300	133,300	126,000	130,200	131,200

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	130	145	130	1,170	1,044	936
California	160	150	165	18,720	18,245	20,247
United States	158	148	161	19,890	19,289	21,183

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	37.20	41.00	62.60	43,524	42,804	58,594
California	40.10	37.50	33.80	750,600	684,659	684,033
United States	39.90	37.70	35.10	794,124	727,463	742,627

Broccoli for Fresh Market and Processing Production, Price, and Value by Utilization – States and United States: 2009-2011

Utilization and State	Production		
	2009	2010	2011
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Fresh market			
Arizona	1,170	1,044	936
California	18,240	17,835	19,840
United States	19,410	18,879	20,776
	(tons)	(tons)	(tons)
Processing			
California	24,000	20,500	20,361
United States	24,000	20,500	20,361

Utilization and State	Price per unit			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars per cwt)	(dollars per cwt)	(dollars per cwt)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Fresh market						
Arizona	37.20	41.00	62.60	43,524	42,804	58,594
California	40.00	37.40	33.60	729,600	667,029	666,624
United States	39.80	37.60	34.90	773,124	709,833	725,218
	(dollars per ton)	(dollars per ton)	(dollars per ton)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Processing						
California	875.00	860.00	855.00	21,000	17,630	17,409
United States	875.00	860.00	855.00	21,000	17,630	17,409

Cauliflower for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Arizona	3,200	3,000	3,000	3,200	3,000	3,000
California	35,300	35,300	34,200	35,000	35,000	34,000
New York	430	490	480	400	460	430
United States	38,930	38,790	37,680	38,600	38,460	37,430

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Arizona	200	240	220	640	720	660
California	185	180	190	6,475	6,300	6,460
New York	130	145	115	52	67	49
United States	186	184	192	7,167	7,087	7,169

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Arizona	44.50	46.40	59.10	28,480	33,408	39,006
California	44.00	41.00	44.60	284,705	258,361	288,309
New York	45.50	51.00	49.00	2,366	3,417	2,401
United States	44.00	41.70	46.00	315,551	295,186	329,716

Cauliflower for Fresh Market and Processing Production, Price, and Value by Utilization – States and United States: 2009-2011

Utilization and State	Production 2009	Production 2010	Production 2011
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Fresh market			
Arizona	640	720	660
California	6,308	6,185	6,210
New York	52	67	49
United States	7,000	6,972	6,919
	(tons)	(tons)	(tons)
Processing			
California	8,350	5,755	12,500
United States	8,350	5,755	12,500

Utilization and State	Price per unit			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars per cwt)	(dollars per cwt)	(dollars per cwt)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Fresh market						
Arizona	44.50	46.40	59.10	28,480	33,408	39,006
California	44.30	41.20	45.40	279,444	254,822	281,934
New York	45.50	51.00	49.00	2,366	3,417	2,401
United States	44.30	41.80	46.70	310,290	291,647	323,341
	(dollars per ton)	(dollars per ton)	(dollars per ton)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Processing						
California	630.00	615.00	510.00	5,261	3,539	6,375
United States	630.00	615.00	510.00	5,261	3,539	6,375

Strawberries for Fresh Market and Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	39,800	38,600	38,000	39,800	38,600	38,000
Florida	8,800	8,800	9,900	8,800	8,800	9,900
Michigan	950	950	950	800	750	750
New York	1,600	1,600	1,600	1,400	1,400	1,400
North Carolina	1,600	1,600	1,600	1,500	1,500	1,500
Ohio	1,100	1,100	1,100	710	730	730
Oregon	2,200	2,100	2,200	1,700	1,900	2,000
Pennsylvania	1,100	1,100	990	1,100	1,100	990
Washington	1,500	1,500	1,500	1,500	1,500	1,500
Wisconsin	870	820	820	770	710	700
United States	59,520	58,170	58,660	58,080	56,990	57,470

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(cwt)	(cwt)	(cwt)	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
California	625	670	680	24,856	25,859	25,750
Florida	270	220	250	2,376	1,936	2,475
Michigan	58	39	44	46	29	33
New York	31	25	26	44	35	36
North Carolina	130	120	130	195	180	195
Ohio	42	48	36	30	35	26
Oregon	125	125	115	211	236	226
Pennsylvania	59	51	40	65	56	40
Washington	95	83	83	143	125	125
Wisconsin	61	58	57	47	41	40
United States	482	501	504	28,013	28,532	28,946

State	Price per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	69.40	70.10	75.70	1,725,232	1,813,557	1,948,118
Florida	132.00	187.00	148.00	313,632	362,032	366,300
Michigan	144.00	141.00	146.00	6,615	4,089	4,826
New York	205.00	197.00	235.00	9,020	6,895	8,460
North Carolina	135.00	135.00	140.00	26,325	24,300	27,300
Ohio	191.00	272.00	210.00	5,730	9,520	5,460
Oregon	65.80	69.00	66.50	13,888	16,291	15,034
Pennsylvania	208.00	207.00	212.00	13,520	11,592	8,480
Washington	58.30	61.10	71.80	8,338	7,640	8,971
Wisconsin	155.00	157.00	161.00	7,285	6,437	6,440
United States	76.00	79.30	82.90	2,129,585	2,262,353	2,399,389

Strawberries for Fresh Market and Processing Production, Price, and Value by Utilization – States and United States: 2009-2011

Utilization and State	Production 2009	Production 2010	Production 2011
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Fresh market			
California	20,040	20,851	20,451
Florida	2,376	1,936	2,475
Michigan	43	27	31
New York	44	35	36
North Carolina	195	180	195
Ohio	30	35	26
Oregon	29	37	28
Pennsylvania	65	56	40
Washington	11	10	17
Wisconsin	47	41	40
United States	22,880	23,208	23,339
Processing			
California	4,816	5,008	5,299
Michigan	3	2	2
Oregon	182	199	198
Washington	132	115	108
United States	5,133	5,324	5,607

Utilization and State	Price Per cwt			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars per cwt)	(dollars per cwt)	(dollars per cwt)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Fresh market						
California	79.00	80.30	86.50	1,583,160	1,674,335	1,769,012
Florida	132.00	187.00	148.00	313,632	362,032	366,300
Michigan	150.00	147.00	152.00	6,450	3,969	4,712
New York	205.00	197.00	235.00	9,020	6,895	8,460
North Carolina	135.00	135.00	140.00	26,325	24,300	27,300
Ohio	191.00	272.00	210.00	5,730	9,520	5,460
Oregon	140.00	166.00	148.00	4,060	6,142	4,144
Pennsylvania	208.00	207.00	212.00	13,520	11,592	8,480
Washington	158.00	189.00	231.00	1,738	1,890	3,927
Wisconsin	155.00	157.00	161.00	7,285	6,437	6,440
United States	86.10	90.80	94.40	1,970,920	2,107,112	2,204,235
Processing						
California	29.50	27.80	33.80	142,072	139,222	179,106
Michigan	55.00	60.00	57.00	165	120	114
Oregon	54.00	51.00	55.00	9,828	10,149	10,890
Washington	50.00	50.00	46.70	6,600	5,750	5,044
United States	30.90	29.20	34.80	158,665	155,241	195,154

Fresh Market Vegetable Prices Received Monthly – States and United States: 2009-2011

Crop, State, and year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Asparagus												
California												
2009	(S)	(S)	82.00	137.00	165.00	(S)	(S)	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	122.00	140.00	180.00	154.00	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	132.00	160.00	138.00	147.00	(S)	(S)	(S)	(S)	(S)	(S)
Washington												
2009	(S)	(S)	(S)	(D)	(D)	(D)	(S)	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(D)	(D)	(D)	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(D)	(D)	(D)	(S)	(S)	(S)	(S)	(S)	(S)
United States												
2009	(S)	(S)	82.00	130.00	112.00	(D)	(S)	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	122.00	118.00	137.00	86.30	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	132.00	160.00	77.60	80.80	(S)	(S)	(S)	(S)	(S)	(S)
Snap beans												
California												
2009	(S)	(S)	(S)	70.20	70.20	64.60	46.90	78.30	62.70	63.50	(S)	(S)
2010	(S)	(S)	(S)	130.00	91.50	73.20	60.10	67.50	64.70	67.70	57.90	(S)
2011	(S)	(S)	(S)	72.40	57.00	87.40	67.10	51.20	63.00	69.40	50.00	(S)
Florida												
2009	37.40	86.20	68.80	39.30	32.10	(S)	(S)	(S)	(S)	(S)	59.20	66.80
2010	105.00	(S)	97.70	77.50	45.90	(S)	(S)	(S)	(S)	(S)	43.40	87.30
2011	131.00	48.50	48.80	57.20	55.60	(S)	(S)	(S)	(S)	(S)	(S)	(S)
Georgia												
2009	(S)	(S)	(S)	(S)	73.80	51.60	(S)	(S)	(S)	41.30	53.40	(S)
2010	(S)	(S)	(S)	(S)	21.80	30.40	(S)	(S)	(S)	51.30	32.90	(S)
2011	(S)	(S)	(S)	(S)	59.10	52.00	(S)	(S)	(S)	57.90	35.80	(S)
New York												
2009	(S)	(S)	(S)	(S)	(S)	(S)	91.70	84.60	90.90	88.00	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	89.60	88.80	74.70	79.20	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	96.40	95.30	96.90	96.30	(S)	(S)
North Carolina												
2009	(S)	(S)	(S)	(S)	(S)	50.00	65.00	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
United States												
2009	37.40	86.20	68.80	40.20	44.20	54.40	60.10	81.30	74.00	51.10	57.80	66.80
2010	105.00	(S)	97.70	78.90	43.00	53.00	68.80	79.50	69.30	62.00	44.60	87.30
2011	131.00	48.50	48.80	57.40	58.10	69.20	73.50	71.30	77.70	66.30	56.60	56.50

See footnote(s) at end of table. --continued

Fresh Market Vegetable Prices Received Monthly – States and United States: 2009-2011 (continued)

Crop, State and year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Broccoli												
Arizona												
2009	46.60	30.70	37.80	48.20	(S)	(S)	(S)	(S)	(S)	(S)	62.20	52.70
2010	28.70	30.10	62.00	31.40	(S)	(S)	(S)	(S)	(S)	(S)	79.00	71.90
2011	67.50	52.50	49.80	53.30	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
California												
2009	44.00	29.00	48.60	41.90	32.80	31.00	26.50	29.70	31.60	64.60	56.90	53.80
2010	25.50	25.40	46.50	35.40	43.50	34.50	29.30	25.70	33.30	30.40	54.50	65.00
2011	54.70	43.80	39.40	33.80	40.20	55.70	28.70	35.60	33.60	33.10	42.70	49.60
United States												
2009	44.60	29.40	47.00	41.90	32.80	31.00	26.50	29.70	31.60	64.60	57.10	53.60
2010	25.50	25.40	46.50	35.40	43.50	34.50	29.30	25.70	33.30	30.40	54.50	65.00
2011	57.10	45.40	40.80	33.90	40.20	55.70	28.70	35.60	33.60	33.10	42.90	34.90
Cantaloupes												
Arizona												
2009	(S)	(S)	(S)	(S)	14.80	22.50	13.50	(S)	24.60	26.60	15.40	15.10
2010	(S)	(S)	(S)	(S)	30.80	18.20	15.70	(S)	11.90	16.10	37.10	(S)
2011	(S)	(S)	(S)	(S)	18.10	16.30	23.00	(S)	(S)	(S)	(S)	(S)
California												
2009	(S)	(S)	(S)	(S)	28.60	12.50	11.20	12.60	12.90	17.80	(S)	(S)
2010	(S)	(S)	(S)	(S)	16.30	16.30	15.70	9.70	11.50	11.50	(S)	(S)
2011	(S)	(S)	(S)	(S)	18.00	16.20	25.40	11.90	15.50	13.10	(S)	(S)
Texas												
2009	(S)	(S)	(S)	(S)	(S)	40.20	29.70	17.30	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
United States												
2009	(S)	(S)	(S)	(S)	24.30	19.20	11.40	12.60	14.00	23.00	15.40	15.10
2010	(S)	(S)	(S)	(S)	19.50	17.50	15.70	9.70	11.50	14.30	37.10	(S)
2011	(S)	(S)	(S)	(S)	18.00	16.30	25.00	11.90	15.50	13.10	(S)	(S)

See footnote(s) at end of table.

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Fresh Market Vegetable Prices Received Monthly – States and United States: 2009-2011 (continued)

Crop, State, and year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Cauliflower												
Arizona												
2009	50.60	32.20	51.50	62.70	(S)	(S)	(S)	(S)	(S)	(S)	60.80	52.00
2010	35.50	38.90	64.30	39.50	(S)	(S)	(S)	(S)	(S)	(S)	107.30	71.80
2011	45.00	57.70	57.20	54.00	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
California												
2009	79.00	28.80	51.20	41.20	46.60	43.50	41.70	31.90	26.90	58.10	53.80	44.00
2010	31.80	35.00	45.50	58.50	68.60	32.90	31.20	26.30	27.70	31.50	47.00	64.30
2011	39.60	55.10	49.70	42.80	56.80	52.80	38.40	30.90	29.70	30.30	67.90	63.80
United States												
2009	68.90	29.90	51.30	41.40	46.60	43.50	41.70	31.90	26.90	58.10	54.30	45.70
2010	33.10	36.50	49.90	58.10	68.60	32.90	31.20	26.30	27.70	31.50	57.60	66.90
2011	41.10	55.90	51.30	43.10	56.80	52.80	38.40	30.90	29.70	30.30	67.30	46.70
Carrots												
California												
2009	25.20	25.20	25.20	25.20	25.50	25.80	25.60	23.80	25.60	26.10	27.60	27.80
2010	28.50	23.90	27.50	27.40	27.40	26.20	27.10	27.10	27.30	27.50	27.60	33.00
2011	38.00	40.70	44.60	46.20	44.80	35.10	28.40	27.40	27.40	27.40	27.30	25.50
Michigan												
2009	(S)	(S)	(S)	(S)	(S)	(S)	(S)	27.00	21.30	18.90	20.60	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	(S)	27.60	22.00	21.10	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	(S)	20.40	17.30	14.80	14.10	16.30
United States												
2009	25.20	25.20	25.20	25.20	25.50	25.80	25.60	24.00	25.20	25.30	27.20	27.80
2010	28.50	23.90	27.50	27.40	27.40	26.20	27.10	27.10	26.80	27.00	27.60	33.00
2011	38.00	40.70	44.60	46.20	44.80	35.10	28.40	20.40	17.30	14.80	14.10	33.10
Celery												
California												
2009	35.10	29.70	15.00	17.40	17.40	11.70	10.90	10.80	11.50	21.10	21.10	38.80
2010	37.40	21.60	25.70	17.10	20.00	15.80	15.40	12.80	14.00	14.70	14.30	20.20
2011	25.10	46.50	29.50	19.30	33.10	17.10	17.00	13.30	11.90	11.80	15.00	14.90
Michigan												
2009	(S)	(S)	(S)	(S)	(S)	(S)	18.10	14.60	14.60	18.00	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	22.00	21.50	21.90	21.90	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	20.00	16.70	16.30	16.40	(S)	(S)
United States												
2009	35.10	29.70	15.00	17.40	17.40	11.70	11.40	11.40	12.00	20.90	21.10	38.80
2010	37.40	21.60	25.70	17.10	20.00	15.80	16.10	13.90	15.10	15.00	14.30	20.20
2011	25.10	46.50	29.50	19.30	33.10	17.10	20.00	16.70	16.30	16.30	15.00	20.30

See footnote(s) at end of table.

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Fresh Market Vegetable Prices Received Monthly – States and United States: 2009-2011 (continued)

Crop, State, and year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Sweet corn												
California												
2009	(S)	(S)	(S)	37.20	19.50	23.90	32.80	24.80	22.00	24.30	20.30	(S)
2010	(S)	(S)	(S)	25.70	18.80	21.40	16.00	15.60	16.70	21.30	19.90	(S)
2011	(S)	(S)	(S)	20.00	16.00	28.50	25.00	14.00	13.00	15.80	22.30	14.90
Florida												
2009	24.90	46.40	59.30	30.30	21.70	(S)	(S)	(S)	(S)	(S)	18.90	22.70
2010	42.10	58.50	62.70	50.90	28.30	(S)	(S)	(S)	(S)	(S)	(S)	31.60
2011	62.20	51.80	42.40	21.80	21.90	(S)	(S)	(S)	(S)	(S)	(S)	(S)
Georgia												
2009	(S)	(S)	(S)	(S)	21.30	25.90	33.30	(S)	(S)	22.50	20.30	(S)
2010	(S)	(S)	(S)	(S)	17.30	14.70	14.90	(S)	(S)	33.50	21.20	(S)
2011	(S)	(S)	(S)	(S)	22.50	22.20	26.30	(S)	(S)	34.00	30.10	(S)
Michigan												
2009	(S)	(S)	(S)	(S)	(S)	(S)	33.50	23.80	21.50	21.50	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	24.60	22.80	29.80	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	33.00	20.70	24.40	26.50	(S)	(S)
New York												
2009	(S)	(S)	(S)	(S)	(S)	(S)	37.90	28.20	25.30	24.80	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	30.40	25.90	24.50	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	36.10	29.00	25.70	34.30	(S)	(S)
Ohio												
2009	(S)	(S)	(S)	(S)	(S)	(S)	30.50	24.90	22.10	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	19.30	22.70	29.10	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	31.90	25.40	26.30	(S)	(S)	(S)
Pennsylvania												
2009	(S)	(S)	(S)	(S)	(S)	(S)	40.20	30.50	23.80	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	28.70	27.80	29.00	26.00	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	38.60	38.60	33.40	(S)	(S)	(S)
United States												
2009	24.90	46.40	59.30	33.10	20.80	25.30	34.60	26.40	23.50	23.40	19.50	22.70
2010	42.10	58.50	62.70	40.10	24.90	16.10	20.00	23.00	23.90	28.30	20.50	31.00
2011	62.20	51.80	42.40	21.50	19.90	24.30	32.90	20.70	24.40	26.40	26.60	14.90

See footnote(s) at end of table.

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Fresh Market Vegetable Prices Received Monthly – States and United States: 2009-2011 (continued)

Crop, State, and year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Cucumbers												
California												
2009	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
Florida												
2009	39.10	(S)	(S)	28.60	13.60	(S)	(S)	(S)	(S)	30.00	22.60	20.20
2010	14.50	15.00	18.50	26.50	14.60	20.00	(S)	(S)	(S)	(S)	14.50	19.70
2011	(S)	(S)	(S)	26.40	16.90	(S)	(S)	(S)	(S)	(S)	(S)	(S)
Georgia												
2009	(S)	(S)	(S)	(S)	29.30	23.30	29.70	(S)	22.00	22.50	19.50	(S)
2010	(S)	(S)	(S)	(S)	23.70	27.50	(S)	(S)	23.00	24.60	13.90	(S)
2011	(S)	(S)	(S)	(S)	23.10	31.90	35.00	(S)	28.40	30.40	23.20	(S)
Michigan												
2009	(S)	(S)	(S)	(S)	(S)	31.30	19.50	17.00	22.30	21.90	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	26.10	24.40	21.10	21.80	22.00	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	31.90	23.80	21.60	24.10	24.10	(S)	(S)
New York												
2009	(S)	(S)	(S)	(S)	(S)	(S)	45.30	42.70	40.30	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	39.80	37.80	40.30	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	23.60	36.90	45.50	32.20	(S)	(S)
United States												
2009	39.10	(S)	(S)	28.60	17.20	23.40	23.40	26.40	26.10	23.20	21.60	20.20
2010	14.50	15.00	18.50	26.50	17.70	26.70	26.10	28.00	28.50	24.60	14.30	19.70
2011	(S)	(S)	(S)	26.40	19.20	31.90	25.50	28.10	35.00	30.50	28.00	(S)
Lettuce												
Arizona												
2009	29.90	18.00	20.10	31.10	(S)	(S)	(S)	(S)	(S)	(S)	51.40	40.90
2010	18.20	14.60	23.40	19.30	(S)	(S)	(S)	(S)	(S)	(S)	38.00	18.20
2011	28.00	54.90	37.70	16.70	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
California												
2009	26.10	17.10	18.30	27.50	18.20	18.90	16.90	16.70	16.60	27.20	48.80	31.40
2010	13.10	10.50	13.90	16.20	20.70	21.80	22.10	19.80	14.60	17.20	29.30	12.80
2011	24.40	53.30	29.60	17.90	26.40	17.10	19.40	14.70	14.80	17.00	30.40	17.10
United States												
2009	28.60	17.80	19.40	27.70	18.20	18.90	16.90	16.70	16.60	27.20	49.70	38.00
2010	16.50	13.60	20.00	16.50	20.70	21.80	22.10	19.80	14.60	17.20	32.20	17.30
2011	27.20	54.40	35.20	17.80	26.40	17.10	19.40	14.70	14.80	17.00	30.50	23.10

See footnote(s) at end of table. --continued

Fresh Market Vegetable Prices Received Monthly – State and United States: 2009-2011 (continued)

Crop, State, and year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Spring onions												
California												
2009	(S)	(S)	(S)	6.80	7.70	9.30	13.90	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	27.80	19.20	16.00	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	8.20	10.10	13.30	16.70	(S)	(S)	(S)	(S)	(S)
Georgia												
2009	(S)	(S)	(S)	(S)	31.70	31.20	(S)	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	63.50	48.00	45.40	51.40	54.80	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	33.10	24.10	31.00	40.10	42.50	(S)	(S)	(S)	(S)
Texas												
2009	(S)	(S)	(S)	13.70	13.70	16.30	(S)	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	71.10	44.40	37.20	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	13.20	15.30	19.60	(S)	(S)	(S)	(S)	(S)	(S)
United States												
2009	(S)	(S)	(S)	13.50	10.40	11.10	13.90	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	28.50	19.30	16.10	51.40	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	17.50	16.70	22.30	25.10	42.50	(S)	(S)	(S)	(S)
Summer onions non-storage												
California												
2009	(S)	(S)	(S)	(S)	(S)	(S)	9.00	8.00	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	8.00	6.80	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	5.30	4.50	(S)	(S)	(S)	(S)
New Mexico												
2009	(S)	(S)	(S)	(S)	(S)	18.70	20.00	(S)	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	26.40	31.40	21.90	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	16.00	15.60	14.30	(S)	(S)	(S)	(S)
Texas												
2009	(S)	(S)	(S)	(S)	(S)	(S)	36.80	39.50	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
Washington [1]												
2009	(S)	(S)	(S)	(S)	(S)	34.30	28.40	27.80	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	52.40	49.50	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	25.50	22.90	21.80	(S)	(S)	(S)	(S)
United States												
2009	(S)	(S)	(S)	(S)	(S)	21.20	15.50	10.50	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	29.00	21.90	12.20	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	25.50	8.05	6.89	(S)	(S)	(S)	(S)
Summer onions storage												
California												
2009	(S)	(S)	(S)	(S)	(S)	(S)	9.30	6.20	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	12.70	13.00	10.00	8.30	15.80	8.80
2011	(S)	(S)	(S)	(S)	(S)	(S)	(S)	8.64	9.18	9.78	10.10	10.40
Colorado												
2009	13.30	(S)	(S)	(S)	(S)	(S)	(S)	19.00	14.30	13.30	11.60	11.70
2010	15.80	(S)	(S)	(S)	(S)	(S)	(S)	20.10	16.80	15.10	18.20	18.20
2011	18.30	(S)	(S)	(S)	(S)	(S)	(S)	16.90	14.40	14.00	13.00	12.20
Idaho [1]												
2009	7.10	5.70	5.20	4.40	(S)	(S)	(S)	10.50	9.40	7.40	7.00	6.70
2010	10.30	14.60	33.20	31.80	(S)	(S)	(S)	8.30	10.30	9.20	9.80	10.40
2011	10.50	7.80	5.50	5.10	(S)	(S)	(S)	7.60	7.60	7.00	7.10	(S)
Michigan												
2009	14.10	15.30	15.50	(S)	(S)	(S)	(S)	(S)	15.10	12.70	12.20	12.20
2010	13.40	16.90	(S)	(S)	(S)	(S)	(S)	19.60	16.30	12.00	14.10	14.40
2011	17.10	(S)	(S)	(S)	(S)	(S)	(S)	16.60	16.40	15.10	15.40	(S)

See footnote(s) at end of table.

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Fresh Market Vegetable Prices Received Monthly – States and United States: 2009-2011 (continued)

Crop, State, and year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Summer onions storage (continued)												
New York												
2009	16.70	17.00	15.00	13.90	11.70	(S)	(S)	(S)	17.70	14.90	13.40	12.60
2010	11.00	14.90	29.90	39.20	37.30	(S)	(S)	22.00	18.80	16.80	18.70	21.70
2011	23.20	21.00	18.40	17.80	(S)	(S)	(S)	(S)	23.70	20.30	18.60	20.80
Oregon-Malheur [1]												
2009	7.17	6.33	5.18	5.27	(S)	(S)	(S)	10.70	9.34	7.29	7.05	6.50
2010	10.40	14.80	33.10	34.50	(S)	(S)	(S)	8.42	10.30	9.23	10.20	10.40
2011	10.50	7.88	5.45	4.74	(S)	(S)	(S)	6.97	7.47	6.92	7.17	7.14
Oregon-Other [1]												
2009	7.34	6.66	4.02	3.98	(S)	(S)	(S)	12.40	7.62	7.34	7.82	7.21
2010	10.30	13.50	33.30	48.80	(S)	(S)	(S)	14.80	10.30	7.59	10.50	11.90
2011	11.60	9.90	7.19	6.02	(S)	(S)	(S)	11.60	7.41	7.19	7.40	7.61
Washington [1]												
2009	7.85	6.80	5.50	5.20	4.80	(S)	12.70	13.30	8.50	6.50	6.20	5.50
2010	11.00	15.40	37.80	60.90	(S)	(S)	25.60	16.60	13.30	12.00	12.00	11.80
2011	11.70	9.60	6.50	5.10	(S)	(S)	11.00	11.70	8.70	7.40	7.30	6.60
United States												
2009	9.01	7.97	6.58	5.92	4.80	(S)	9.39	7.59	10.20	9.09	8.55	7.76
2010	11.20	15.00	34.20	45.20	37.30	(S)	13.30	14.10	12.10	10.00	12.60	12.30
2011	12.40	9.97	7.77	6.18	7.70	(S)	11.00	9.64	8.59	7.82	9.35	8.79
All summer onions												
United States												
2009	9.01	7.97	6.58	5.92	4.80	21.20	12.50	8.11	10.20	9.09	8.55	7.76
2010	11.20	15.00	34.20	45.20	37.30	29.00	17.60	13.70	12.10	10.00	12.60	12.30
2011	12.40	9.97	7.77	6.18	7.70	25.50	10.30	9.21	8.59	7.82	9.35	9.48
All onions												
United States												
2009	9.01	7.97	6.58	9.48	9.31	14.70	12.50	8.11	10.20	9.09	8.55	7.76
2010	11.20	15.00	34.20	29.30	19.30	16.10	18.60	14.20	12.10	10.00	12.60	12.30
2011	12.40	9.97	8.04	10.80	15.10	22.40	19.00	9.46	8.59	7.82	9.35	8.79

See footnote(s) at end of table.

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Fresh Market Vegetable Prices Received Monthly – States and United States: 2009-2011 (continued)

Crop, State, and year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)	($/cwt)
Tomatoes												
California												
2009	(S)	(S)	(S)	(S)	(S)	59.60	28.90	32.30	32.40	38.70	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	23.50	31.40	33.30	36.60	31.20	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	32.40	30.90	28.60	34.60	26.60	28.20	(S)
Florida												
2009	29.30	32.70	41.50	45.40	33.20	75.20	(S)	(S)	(S)	(S)	89.40	69.50
2010	61.50	84.60	109.00	103.40	65.20	41.10	(S)	(S)	(S)	44.20	38.10	37.30
2011	51.90	108.00	98.70	67.60	49.10	48.80	(S)	(S)	(S)	(S)	(S)	(S)
South Carolina												
2009	(S)	(S)	(S)	(S)	(S)	71.10	53.00	49.40	(S)	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
Virginia												
2009	(S)	(S)	(S)	(S)	(S)	(S)	37.10	49.10	45.80	(S)	(S)	(S)
2010	(S)	(S)	(S)	(S)	(S)	(S)	50.50	53.80	59.80	(S)	(S)	(S)
2011	(S)	(S)	(S)	(S)	(S)	(S)	50.40	45.50	44.80	(S)	(S)	(S)
United States												
2009	29.30	32.70	41.50	45.40	33.20	66.70	31.10	35.20	34.20	39.90	89.40	69.50
2010	61.50	84.60	109.00	103.00	65.20	37.50	34.00	35.70	38.70	32.40	36.00	37.30
2011	51.90	108.00	98.70	67.60	49.10	44.60	33.10	30.30	35.50	26.60	42.40	42.50
Strawberries												
California												
2009	104.00	122.00	89.30	78.90	76.10	62.80	74.80	73.50	75.00	108.00	87.60	142.00
2010	187.00	150.00	88.40	66.90	78.90	67.70	62.00	81.70	73.30	87.60	139.00	206.00
2011	154.00	122.00	96.90	93.50	80.80	72.70	89.20	78.80	87.60	66.90	84.40	152.00
Florida												
2009	120.00	134.00	101.00	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	203.10
2010	205.40	255.20	214.20	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	330.00
2011	248.00	128.00	102.00	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)	(S)
United States												
2009	116.00	128.00	91.10	78.90	76.10	62.80	74.80	73.50	75.00	108.00	87.60	183.00
2010	198.00	171.00	116.00	76.90	78.90	67.70	62.00	81.70	73.30	87.60	139.00	294.00
2011	217.00	126.00	99.20	93.50	80.80	72.70	89.20	78.80	87.60	66.90	84.40	94.40

(S) Insufficient number of reports to establish an estimate.
[1] Equivalent packinghouse door returns.

Selected Fresh Market Vegetables and Melons Area Harvested by Crop – States and United States: Winter Season 2009-2011

Crop and State	Usual harvest period	Area harvested		
		2009	2010	2011
		(acres)	(acres)	(acres)
Snap beans				
Florida	January-March	12,000	11,300	17,000
Broccoli [1]				
California	January-March	26,000	27,500	27,500
Cabbage				
Florida	January-March	4,900	4,800	4,000
Texas	December-March	6,820	7,040	5,270
United States		11,720	11,840	9,270
Carrots				
California	January-March	15,500	12,000	15,000
Texas	December-March	700	600	600
United States		16,200	12,600	15,600
Cauliflower [1]				
California	January-March	9,000	9,000	9,200
Celery				
California	January-March	7,200	7,000	7,200
Sweet corn				
Florida	January-March	8,800	8,400	7,500
Head lettuce				
Arizona - western	November-April	32,000	34,000	36,000
California	January-March	15,000	15,000	17,500
United States		47,000	49,000	53,500
Bell peppers [1]				
Florida	January-March	6,800	6,500	6,300
Spinach				
Texas	December-March	600	1,000	700
Tomatoes				
Florida	January-March	9,300	8,500	9,000

[1] Includes fresh market and processing.

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Selected Fresh Market Vegetables and Melons Area Harvested by Crop – States and United States: Spring Season 2009-2011

Crop and State	Usual harvest period	Area harvested		
		2009	2010	2011
		(acres)	(acres)	(acres)
Snap beans				
Florida	April-July	10,700	9,800	14,500
Georgia	May-June	6,900	5,700	5,000
New Jersey	June-August	1,600	1,600	1,600
United States		19,200	17,100	21,100
Broccoli [1]				
California	April-June	33,000	34,500	35,000
Cabbage				
Florida	April-July	2,760	3,000	2,600
Georgia	April-June	2,300	2,400	2,100
New Jersey	May-August	900	1,000	1,000
Texas	April-June	500	600	580
United States		6,460	7,000	6,280
Cantaloupes				
Arizona	April-July	13,500	12,000	10,300
California	April-June	9,300	10,300	10,800
Georgia	April-June	3,400	3,300	2,600
Texas	April-June	1,100	1,300	1,500
United States		27,300	26,900	25,200
Carrots				
California	April-June	11,800	9,000	10,500
Texas	April-June	400	600	600
United States		12,200	9,600	11,100
Cauliflower [1]				
California	April-June	7,700	8,100	7,400
Celery [1]				
California	April-June	6,000	5,900	5,900
Sweet corn				
California	April-June	12,500	14,500	14,400
Florida	April-July	28,000	27,600	31,000
United States		40,500	42,100	45,400

See footnote(s) at end of table. --continued

Selected Fresh Market Vegetables and Melons Area Harvested by Crop – States and United States: Spring Season 2009-2011 (continued)

Crop and State	Usual harvest period	Area harvested		
		2009	2010	2011
		(acres)	(acres)	(acres)
Cucumbers				
Florida	April-July	8,200	7,900	6,000
South Carolina	May-August	1,000	1,000	1,000
Texas	April-June	300	300	300
United States		9,500	9,200	7,300
Honeydews				
California	April-June	2,200	2,400	2,300
Texas	April-June	600	600	600
United States		2,800	3,000	2,900
Head lettuce				
California	April-June	29,000	27,000	27,500
Bell peppers [1]				
Florida	April-June	7,800	7,700	7,600
Tomatoes				
California	May-June	7,500	6,500	7,000
Florida	April-July	16,800	15,500	16,500
South Carolina	May-July	1,900	2,400	2,500
United States		26,200	24,400	26,000
Watermelons				
California	April-June	2,500	3,200	4,000
Florida	April-June	25,800	24,600	24,400
Texas	April-June	10,000	12,900	10,000
United States		38,300	40,700	38,400

[1] Includes fresh market and processing.

Selected Fresh Market Vegetables and Melons Area Harvested by Crop – States and United States: Summer Season 2009-2011

Crop and State	Usual harvest period	Area harvested 2009	Area harvested 2010	Area harvested 2011
		(acres)	(acres)	(acres)
Snap beans				
Georgia	July-September	3,800	3,200	2,300
Michigan	July-October	3,100	3,200	2,900
New York	June-October	6,700	6,700	5,300
Virginia	June-August	3,000	2,600	2,600
United States		16,600	15,700	13,100
Broccoli [1]				
California	July-September	32,000	34,000	34,500
Cabbage				
Georgia	July-September	300	900	600
Michigan	June-November	2,600	3,000	3,300
New York	June-December	9,000	10,400	10,700
United States		11,900	14,300	14,600
Cantaloupes				
California	July-September	24,000	24,200	21,400
Georgia	July-September	1,600	1,700	1,400
South Carolina	June-October	1,200	1,200	1,400
Texas	July-September	1,300	1,400	1,000
United States		28,100	28,500	25,200
Carrots				
California	July-September	17,000	16,500	18,000
Michigan	August-November	2,200	1,900	1,800
United States		19,200	18,400	19,800
Cauliflower [1]				
California	July-September	8,800	8,300	8,100
Celery [1]				
California	July-September	6,000	5,900	5,800
Sweet corn				
California	July-September	11,100	13,200	13,500
Illinois	July-September	7,100	7,500	6,700
Michigan	July-October	9,100	9,400	9,500
New Jersey	July-October	7,100	7,400	7,000
New York	July-October	21,500	22,800	19,600
North Carolina	July-August	6,300	6,900	6,700
Ohio	July-September	11,400	13,600	15,100
Pennsylvania	July-September	14,400	14,100	13,000
Wisconsin	July-September	7,000	7,500	7,300
United States		95,000	102,400	98,400

See footnote(s) at end of table.

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Selected Fresh Market Vegetables and Melons Area Harvested by Crop – States and United States: Summer Season 2009-2011 (continued)

Crop and State	Usual harvest period	Area harvested 2009	Area harvested 2010	Area harvested 2011
		(acres)	(acres)	(acres)
Cucumbers				
New Jersey	July-October	3,100	3,200	3,100
Virginia	June-August	900	800	900
United States		4,000	4,000	4,000
Honeydews				
Arizona	May-July	1,700	1,700	2,000
California	July-September	7,100	8,200	6,200
United States		8,800	9,900	8,200
Head lettuce				
California	July-September	32,000	31,000	34,000
Bell peppers [1]				
New Jersey	July-September	3,200	3,300	3,400
Tomatoes				
California	July-August	19,000	18,000	17,000
Michigan	July-September	2,000	2,000	2,000
New Jersey	July-October	2,900	2,900	2,900
New York	May-October	2,500	2,800	2,700
Pennsylvania	June-October	1,700	2,300	1,900
Virginia	June-August	4,800	4,500	4,600
United States		32,900	32,500	31,100
Watermelons				
California	July-September	7,500	9,500	9,000
Georgia	July-September	23,000	24,000	22,000
Mississippi	June-September	2,300	2,500	2,400
South Carolina	May-August	6,500	8,000	7,000
Texas	July-September	10,900	12,000	11,000
United States		50,200	56,000	51,400

[1] Includes fresh market and processing.

Selected Fresh Market Vegetables and Melons Area Harvested by Crop – States and United States: Fall Season 2009-2011

Crop and State	Usual harvest period	Area harvested		
		2009	2010	2011
		(acres)	(acres)	(acres)
Snap beans				
Florida [1]	October-December	10,100	11,100	8,500
Georgia	October-December	5,300	3,600	4,000
New Jersey	September-October	1,200	1,000	1,100
Virginia	September-October	2,200	2,500	2,700
United States		18,800	18,200	16,300
Broccoli [2]				
California	October-December	26,000	27,000	27,000
Cabbage				
Florida [1]	October-December	1,840	1,900	1,500
Georgia	October-December	3,700	2,400	2,500
New Jersey	September-November	700	700	400
Texas	September-November	180	160	150
United States		6,420	5,160	4,550
Cantaloupes				
Arizona	November-December	9,800	8,800	9,700
California	October-December	3,700	4,500	4,700
United States		13,500	13,300	14,400
Carrots				
California	October-December	16,700	18,500	19,500
Texas	October-December	100	100	100
United States		16,800	18,600	19,600
Cauliflower [2]				
California	October-December	9,500	9,600	9,300
Celery [2]				
California	October-December	7,400	7,300	7,500
Sweet corn				
California	October-December	4,400	4,800	5,100
Florida [1]	October-December	6,300	6,100	4,500
United States		10,700	10,900	9,600

See footnote(s) at end of table.

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Selected Fresh Market Vegetables and Melons Area Harvested by Crop – States and United States: Fall Season 2009-2011 (continued)

Crop and State	Usual harvest period	Area harvested		
		2009	2010	2011
		(acres)	(acres)	(acres)
Cucumbers				
Florida [1]	October-December	3,100	3,700	3,500
South Carolina	October-December	700	400	700
Texas	September-November	800	800	900
Virginia	September-November	400	400	400
United States		5,000	5,300	5,500
Honeydews				
Arizona	November-December	1,600	1,400	1,500
California	October-December	1,700	2,300	1,800
United States		3,300	3,700	3,300
Head lettuce				
California	October-December	27,000	25,000	26,000
Bell peppers [2]				
Florida [1]	October-December	3,600	3,500	3,700
Tomatoes				
California	September-December	12,500	11,500	11,000
Florida [1]	October-December	7,500	5,500	5,500
United States		20,000	17,000	16,500

[1] Fall Season for Florida refers to previous year. For example the 2010 marketing year consists of Fall 2009, Winter 2010, and Spring 2010.
[2] Includes fresh market and processing.

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2011 Processing Production of 8 Selected Vegetables Down 4 Percent from 2010

Processing production of eight selected vegetables estimated in 2011 totaled 17.0 million tons, down 4 percent from last year. Area harvested is estimated at 1.05 million acres, down 8 percent from a year ago. Processing crop value is estimated at 1.76 billion dollars, 6 percent above 2010. The three largest crops, in terms of production, are tomatoes, sweet corn, and snap beans, which combine to account for 92 percent of the total. The top three crops in terms of value are tomatoes, sweet corn, and cucumbers. These three processing vegetables account for 80 percent of the total value when combined.

For the eight processed vegetables estimated in 2011, California leads the nation with 26 percent of the harvested acreage, 72 percent of the production, and 55 percent of the value.

Leading Processing Vegetable States in 2011

[Lima beans, snap beans, carrots, sweet corn, cucumbers for pickles, green peas, spinach, and tomatoes]

Rank	Area harvested		Production		Value	
	State	Percent of total	State	Percent of total	State	Percent of total
1	California	25.9	California	71.5	California	54.6
2	Wisconsin	18.6	Wisconsin	6.5	Wisconsin	10.1
3	Minnesota	18.5	Washington	5.9	Minnesota	8.2
4	Washington	10.1	Minnesota	5.0	Washington	7.0
5	Oregon	4.8	Michigan	(D)	Michigan	(D)

(D) Withheld to avoid disclosing data for individual operations.

Principal Processing Vegetable Area Planted, Harvested, Production, and Value by Crop – United States: 2009-2011 (Domestic Units)

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]

Crop	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Beans, lima	36,040	42,630	30,830	34,740	42,430	30,120
Beans, snap	202,529	205,810	176,050	196,179	193,060	163,950
Carrots	13,880	13,380	12,790	13,130	12,610	12,190
Corn, sweet	402,200	347,500	334,450	379,500	335,200	326,650
Cucumbers	100,500	92,000	85,000	97,500	87,900	82,630
Peas, green	213,500	187,600	162,400	205,400	172,600	159,100
Spinach	10,300	11,100	10,200	10,100	11,000	9,900
Tomatoes	331,900	290,000	273,100	327,800	288,900	267,800
Total	1,310,849	1,190,020	1,084,820	1,264,349	1,143,700	1,052,340

Crop	Production			Value of production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Beans, lima	48,030	62,230	42,680	24,945	29,456	22,398
Beans, snap	816,440	766,040	680,960	156,092	147,536	160,961
Carrots	354,440	317,130	338,590	33,583	29,288	29,034
Corn, sweet	3,234,080	2,694,210	2,627,330	335,519	229,786	302,695
Cucumbers	548,640	551,370	482,030	179,836	185,928	173,425
Peas, green	441,680	345,640	294,920	140,707	99,216	117,682
Spinach	95,660	149,940	145,200	12,144	22,276	19,243
Tomatoes	13,970,560	12,776,280	12,396,150	1,218,912	926,692	936,861
Total	19,509,530	17,662,840	17,007,860	2,101,738	1,670,178	1,762,299
Asparagus	9,800	6,000	8,500	13,028	8,180	12,849
Broccoli	24,000	20,500	20,361	21,000	17,630	17,409
Cauliflower	8,350	5,755	12,500	5,261	3,539	6,375
Total	42,150	32,255	41,361	39,289	29,349	36,633
Total all	19,551,680	17,695,095	17,049,221	2,141,027	1,699,527	1,798,932

Principal Processing Vegetable Area Planted, Harvested, and Production by Crop – United States: 2009-2011 (Metric Units)

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]

Crop	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(hectares)	(hectares)	(hectares)	(hectares)	(hectares)	(hectares)
Beans, lima	14,590	17,250	12,480	14,060	17,170	12,190
Beans, snap	81,960	83,290	71,250	79,390	78,130	66,350
Carrots	5,620	5,410	5,180	5,310	5,100	4,930
Corn, sweet	162,770	140,630	135,350	153,580	135,650	132,190
Cucumbers	40,670	37,230	34,400	39,460	35,570	33,440
Peas, green	86,400	75,920	65,720	83,120	69,850	64,390
Spinach	4,170	4,490	4,130	4,090	4,450	4,010
Tomatoes	134,320	117,360	110,520	132,660	116,910	108,380
Total [1]	530,490	481,590	439,020	511,670	462,840	425,870

Crop	Production		
	2009	2010	2011
	(metric tons)	(metric tons)	(metric tons)
Beans, lima	43,570	56,450	38,720
Beans, snap	740,660	694,940	617,750
Carrots	321,540	287,690	307,160
Corn, sweet	2,933,890	2,444,130	2,383,460
Cucumbers	497,720	500,190	437,290
Peas, green	400,680	313,560	267,550
Spinach	86,780	136,020	131,720
Tomatoes	12,673,810	11,590,390	11,245,540
Total [1]	17,698,660	16,023,380	15,429,190
Asparagus	8,890	5,440	7,710
Broccoli	21,770	18,600	18,470
Cauliflower	7,570	5,220	11,340
Total [1]	38,240	29,260	37,520
Total all [1]	17,736,890	16,052,640	15,466,710

[1] Totals may not add due to rounding.

Principal Processing Vegetable Area Planted and Harvested – States and United States: 2009-2011

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]
[Excludes the dual usage crops (asparagus, broccoli, and cauliflower)]

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	340,740	299,630	277,970	335,940	298,630	272,760
Delaware	31,100	30,600	26,000	31,000	29,400	25,700
Georgia	4,800	4,000	2,600	4,200	4,000	2,600
Illinois	46,100	40,300	29,000	41,800	37,800	27,700
Maryland	16,600	15,400	8,600	16,600	15,200	8,500
Minnesota	217,980	194,680	200,190	204,030	184,010	194,190
Missouri	11,300	9,500	2,300	10,600	8,250	800
New Jersey	4,100	4,800	4,100	4,100	4,800	3,900
New York	51,500	58,600	25,200	50,000	49,000	23,400
Ohio	9,300	8,000	8,200	8,800	7,800	7,900
Oregon	63,500	55,300	51,960	62,250	53,600	50,860
Texas	21,400	16,000	9,300	19,600	14,600	8,200
Virginia	960	2,000	1,300	960	1,500	1,200
Washington	133,800	108,300	107,400	130,100	107,100	106,500
Wisconsin	231,800	217,900	200,700	223,600	208,200	195,500
Other States [1]	125,869	125,010	130,000	120,769	119,810	122,630
United States	1,310,849	1,190,020	1,084,820	1,264,349	1,143,700	1,052,340

[1] Other States include Alabama, Arkansas, Florida, Iowa, Idaho, Indiana, Massachusetts, Michigan, North Carolina, Pennsylvania, and South Carolina.

Principal Processing Vegetable Production and Value – States and United States: 2009-2011

[Only includes estimates for the selected crops in the NASS annual program. These crops are not estimated for all States that might produce them. See the 2007 Census of Agriculture for a comprehensive tally of total vegetable acres by State]
[Excludes the dual usage crops (asparagus, broccoli, and cauliflower)]

State	Production			Value of production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	13,501,580	12,545,090	12,163,370	1,200,827	945,812	961,510
Delaware	107,680	82,920	76,830	19,546	17,426	16,199
Georgia	18,750	16,600	11,000	6,291	5,619	4,163
Illinois	195,410	157,080	128,930	22,621	15,752	15,892
Maryland	81,200	54,370	40,200	12,064	9,818	5,560
Minnesota	1,183,500	972,010	850,130	164,425	117,961	144,821
Missouri	27,620	24,490	1,200	5,022	4,868	336
New Jersey	19,710	19,790	18,380	4,885	4,147	4,330
New York	208,030	244,600	112,770	47,567	47,624	26,988
Ohio	220,220	179,900	144,050	29,776	25,267	21,768
Oregon	388,250	345,390	356,850	62,889	46,358	59,398
Texas	132,340	94,840	66,970	33,460	23,863	8,650
Virginia	3,910	3,670	3,240	1,109	1,131	1,014
Washington	1,075,910	867,220	1,003,900	134,852	84,856	122,672
Wisconsin	1,243,870	1,093,810	1,100,100	157,736	125,755	177,936
Other States [1]	1,101,550	961,060	929,940	198,668	193,921	191,062
United States	19,509,530	17,662,840	17,007,860	2,101,738	1,670,178	1,762,299

[1] Other States include Alabama, Arkansas, Florida, Iowa, Idaho, Indiana, Massachusetts, Michigan, North Carolina, Pennsylvania, and South Carolina.

Lima Beans for Processing Area Planted and Harvested, Yield, Production, Price, and Value by Utilization – United States: 2009-2011

State and utilization	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
United States [1]	36,040	42,630	30,830	34,740	42,430	30,120
Canning	5,040	4,530	3,670	4,740	4,530	3,560
Freezing	31,000	38,100	27,160	30,000	37,900	26,560
Fordhooks	2,700	2,900	3,200	2,600	2,900	3,200
Baby limas	28,300	35,200	23,960	27,400	35,000	23,360

State and utilization	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
United States [1]	1.38	1.47	1.42	48,030	62,230	42,680
Canning	0.95	1.19	1.11	4,490	5,390	3,950
Freezing	1.45	1.50	1.46	43,540	56,840	38,730
Fordhooks	1.42	2.20	2.10	3,690	6,380	6,720
Baby limas	1.45	1.44	1.37	39,850	50,460	32,010

State and utilization	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
United States [1]	519.00	473.00	525.00	24,945	29,456	22,398
Canning	421.00	457.00	481.00	1,891	2,461	1,898
Freezing	529.00	475.00	529.00	23,054	26,995	20,500
Fordhooks	720.00	770.00	782.00	2,657	4,913	5,255
Baby limas	512.00	438.00	476.00	20,397	22,082	15,245

[1] Other States include California, Delaware, Illinois, Maryland, Oregon, Washington, and Wisconsin.

Snap Beans for Processing Area Planted and Harvested, Yield, Production, Price, and Value by Utilization – States and United States: 2009-2011

State and utilization	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Illinois	12,100	12,500	7,500	11,500	11,100	7,200
Indiana	4,600	5,600	(D)	4,400	5,500	(D)
Michigan	17,000	14,800	15,900	16,500	14,800	15,600
Minnesota	7,700	8,400	(D)	7,600	8,300	(D)
New York	20,000	25,600	15,100	19,400	22,100	13,600
Oregon	19,100	17,000	17,200	18,950	16,800	17,000
Pennsylvania	7,200	12,000	16,600	7,000	11,400	15,400
Wisconsin	83,600	78,900	72,600	81,700	75,800	69,100
Other States [1]	31,229	31,010	31,150	29,129	27,260	26,050
United States	202,529	205,810	176,050	196,179	193,060	163,950
Canning	145,789	143,210	121,000	140,539	134,260	111,100
Freezing	56,740	62,600	55,050	55,640	58,800	52,850

State and utilization	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
Illinois	3.80	3.73	3.87	43,700	41,410	27,860
Indiana	3.56	3.09	(D)	15,650	17,000	(D)
Michigan	3.95	3.98	3.37	65,180	58,910	52,560
Minnesota	3.11	3.31	(D)	23,640	27,480	(D)
New York	2.87	3.91	3.75	55,670	86,520	50,970
Oregon	5.94	6.45	6.65	112,600	108,350	112,980
Pennsylvania	3.95	2.75	2.83	27,660	31,360	43,580
Wisconsin	4.32	3.97	4.36	353,290	300,700	301,240
Other States [1]	4.09	3.46	3.52	119,050	94,310	91,770
United States	4.16	3.97	4.15	816,440	766,040	680,960
Canning	4.23	3.81	4.19	594,640	511,080	464,960
Freezing	3.99	4.34	4.09	221,800	254,960	216,000

State and utilization	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Illinois	136.00	110.00	145.00	5,943	4,555	4,040
Indiana	209.00	284.00	(D)	3,277	4,824	(D)
Michigan	220.00	240.00	280.00	14,340	14,138	14,736
Minnesota	195.00	175.00	(D)	4,619	4,803	(D)
New York	267.00	250.00	298.00	14,864	21,587	15,204
Oregon	216.00	186.00	219.00	24,307	20,205	24,777
Pennsylvania	256.00	272.00	292.00	7,070	8,545	12,704
Wisconsin	149.00	136.00	194.00	52,613	41,028	58,434
Other States [1]	244.00	295.00	339.00	29,059	27,851	31,066
United States	191.00	193.00	236.00	156,092	147,536	160,961
Canning	177.00	173.00	215.00	105,317	88,252	99,942
Freezing	229.00	233.00	282.00	50,775	59,284	61,019

(D) Withheld to avoid disclosing data for individual operations.
[1] For 2009 and 2010, Other States include Arkansas, California, Delaware, Florida, Georgia, Maryland, Missouri, New Jersey, North Carolina, Texas, and Virginia. Beginning in 2011, Other States include Indiana and Minnesota.

Carrots for Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	1,000	1,000	(D)	1,000	1,000	(D)
Minnesota	980	1,280	(D)	930	1,010	(D)
Washington	3,900	3,700	3,500	3,800	3,600	3,400
Wisconsin	3,900	3,500	3,800	3,700	3,400	3,700
Other States [1]	4,100	3,900	5,490	3,700	3,600	5,090
United States	13,880	13,380	12,790	13,130	12,610	12,190

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
California	33.00	30.00	(D)	33,000	30,000	(D)
Minnesota	31.02	20.12	(D)	28,850	20,320	(D)
Washington	31.00	31.00	35.50	117,800	111,600	120,700
Wisconsin	23.43	21.65	24.97	86,690	73,610	92,390
Other States [1]	23.81	22.67	24.66	88,100	81,600	125,500
United States	26.99	25.15	27.78	354,440	317,130	338,590

State	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	180.00	175.00	(D)	5,940	5,250	(D)
Minnesota	83.30	80.00	(D)	2,403	1,625	(D)
Washington	85.00	82.00	86.00	10,013	9,151	10,380
Wisconsin	79.90	68.80	77.20	6,927	5,064	7,133
Other States [1]	94.20	100.00	91.80	8,300	8,198	11,521
United States	94.70	92.40	85.70	33,583	29,288	29,034

(D) Withheld to avoid disclosing data for individual operations.
[1] For 2009 and 2010, Other States include Michigan and Texas. Beginning in 2011, Other States include California and Minnesota.

Sweet Corn for Processing Area Planted and Harvested, Yield, Production, Price, and Value by Utilization – States and United States: 2009-2011

State and utilization	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Illinois	18,900	16,400	(D)	16,500	16,100	(D)
Minnesota	132,000	122,300	124,400	122,400	117,200	119,900
Oregon	24,200	20,200	(D)	24,000	20,000	(D)
Washington	84,200	66,400	73,000	81,700	65,600	72,700
Wisconsin	91,200	79,300	75,300	85,700	77,700	74,500
Other States [1]	51,700	42,900	61,750	49,200	38,600	59,550
United States	402,200	347,500	334,450	379,500	335,200	326,650
Canning	196,400	167,500	155,000	181,300	161,600	150,700
Freezing	205,800	180,000	179,450	198,200	173,600	175,950

State and utilization	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
Illinois	7.85	6.10	(D)	129,500	98,210	(D)
Minnesota	8.00	7.01	6.14	979,250	821,730	735,760
Oregon	10.00	10.10	(D)	240,000	201,950	(D)
Washington	10.37	10.00	10.75	847,010	656,280	781,500
Wisconsin	7.78	7.79	8.00	666,630	604,980	595,780
Other States [1]	7.55	8.06	8.64	371,690	311,060	514,290
United States	8.52	8.04	8.04	3,234,080	2,694,210	2,627,330
Canning	8.33	7.70	7.47	1,510,380	1,244,310	1,125,640
Freezing	8.70	8.35	8.53	1,723,700	1,449,900	1,501,690

State and utilization	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Illinois	81.00	76.00	(D)	10,490	7,464	(D)
Minnesota	99.60	90.70	131.00	97,501	74,561	96,385
Oregon	117.00	88.40	(D)	28,140	17,848	(D)
Washington	109.00	79.80	109.00	92,372	52,372	85,212
Wisconsin	93.50	74.40	110.00	62,310	45,000	65,362
Other States [1]	120.00	105.00	108.00	44,706	32,541	55,736
United States	104.00	85.30	115.00	335,519	229,786	302,695
Canning	95.20	81.50	116.00	143,855	101,396	130,794
Freezing	111.00	88.60	114.00	191,664	128,390	171,901

(D) Withheld to avoid disclosing data for individual operations.
[1] For 2009 and 2010, Other States include Delaware, Idaho, Iowa, Maryland, New Jersey, New York, and Pennsylvania. Beginning in 2011, Other States include Illinois and Oregon.

Cucumbers for Pickles Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Florida	7,000	9,800	13,000	7,000	9,800	13,000
Indiana	1,500	1,500	1,200	1,500	1,200	830
Michigan	33,000	32,000	32,400	32,500	31,000	31,600
North Carolina	10,000	9,700	8,000	9,600	8,900	7,400
Ohio	2,700	2,100	2,600	2,200	2,000	2,600
South Carolina	2,200	2,000	2,000	2,000	2,000	2,000
Texas	7,600	6,100	3,500	7,000	5,300	3,200
Wisconsin	6,500	6,300	5,600	6,500	6,100	5,600
Other States [1]	30,000	22,500	16,700	29,200	21,600	16,400
United States	100,500	92,000	85,000	97,500	87,900	82,630

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
Florida	7.00	8.30	6.50	49,000	81,340	84,500
Indiana	6.41	6.25	3.00	9,620	7,500	2,490
Michigan	5.80	6.40	5.60	188,500	198,400	176,960
North Carolina	4.88	4.15	4.70	46,850	36,940	34,780
Ohio	8.00	10.78	6.89	17,600	21,560	17,910
South Carolina	6.00	3.00	3.00	12,000	6,000	6,000
Texas	5.50	6.20	4.90	38,500	32,860	15,680
Wisconsin	6.16	5.28	5.48	40,040	32,210	30,690
Other States [1]	5.02	6.23	6.89	146,530	134,560	113,020
United States	5.63	6.27	5.83	548,640	551,370	482,030

State	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Florida	468.00	501.00	445.00	22,932	40,751	37,603
Indiana	366.00	366.00	358.00	3,521	2,745	891
Michigan	260.00	250.00	255.00	49,010	49,600	45,125
North Carolina	226.00	289.00	305.00	10,588	10,676	10,608
Ohio	460.00	450.00	490.00	8,096	9,702	8,776
South Carolina	330.00	220.00	220.00	3,960	1,320	1,320
Texas	511.00	500.00	234.00	19,674	16,430	3,669
Wisconsin	216.00	251.00	233.00	8,649	8,085	7,151
Other States [1]	364.00	346.00	516.00	53,406	46,619	58,282
United States	328.00	337.00	360.00	179,836	185,928	173,425

[1] Other States include Alabama, California, Delaware, Georgia, and Maryland.

Pickle Stocks in Tanks, Barrels, and Fresh Pack – United States: December 1, 2010 and 2011

Year	From current year crop			From previous year crop	
	Salt stock including dill	Fresh pack	Refrigerated	Salt stock including dill	Fresh pack
	(tons)	(tons)	(tons)	(tons)	(tons)
United States					
2010	137,800	34,225	2,000	9,440	-
2011	182,863	65,191	2,250	9,211	-

Year	Combined stocks from current year	Combined stocks from previous year crop	Total stocks
	(tons)	(tons)	(tons)
United States			
2010	174,025	9,440	183,465
2011	250,304	9,211	259,515

Green Peas for Processing Area Planted and Harvested, Yield, Production, Price, and Value by Utilization – States and United States: 2009-2011

State and utilization	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Delaware	5,500	3,900	4,100	5,500	3,900	4,100
Minnesota	77,300	62,700	67,300	73,100	57,500	66,000
Oregon	18,300	15,700	12,800	17,600	14,500	12,100
Washington	41,300	34,100	28,300	40,200	33,800	27,900
Wisconsin	41,400	44,100	37,000	40,800	39,500	36,600
Other States [1]	29,700	27,100	12,900	28,200	23,400	12,400
United States	213,500	187,600	162,400	205,400	172,600	159,100
Canning	90,700	70,400	68,300	86,800	64,700	67,000
Freezing	122,800	117,200	94,100	118,600	107,900	92,100

State and utilization	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
Delaware	1.82	1.80	2.00	10,030	7,020	8,200
Minnesota	2.08	1.78	0.96	151,760	102,480	63,230
Oregon	1.78	1.98	2.68	31,400	28,700	32,400
Washington	2.49	2.66	3.43	100,100	89,910	95,700
Wisconsin	2.25	1.87	1.99	91,760	73,850	72,670
Other States [1]	2.01	1.87	1.83	56,630	43,680	22,720
United States	2.15	2.00	1.85	441,680	345,640	294,920
Canning	2.19	1.93	1.40	190,400	125,070	94,040
Freezing	2.12	2.04	2.18	251,280	220,570	200,880

State and utilization	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
Delaware	280.00	280.00	320.00	2,808	1,966	2,624
Minnesota	395.00	361.00	608.00	59,902	36,972	38,413
Oregon	255.00	196.00	233.00	8,019	5,621	7,534
Washington	265.00	212.00	252.00	26,527	19,061	24,116
Wisconsin	271.00	309.00	491.00	24,847	22,784	35,679
Other States [1]	329.00	293.00	410.00	18,604	12,812	9,316
United States	319.00	287.00	399.00	140,707	99,216	117,682
Canning	334.00	312.00	524.00	63,524	39,026	49,308
Freezing	307.00	273.00	340.00	77,183	60,190	68,374

[1] Other States include Illinois, Maryland, New Jersey, and New York.

Spinach for Processing Area Planted and Harvested, Yield, Production, Price, and Value by Utilization – States and United States: 2009-2011

State and utilization	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	7,500	8,100	7,300	7,500	8,100	7,300
Other States [1]	2,800	3,000	2,900	2,600	2,900	2,600
United States	10,300	11,100	10,200	10,100	11,000	9,900
Canning	500	500	800	400	400	800
Freezing	9,800	10,600	9,400	9,700	10,600	9,100

State and utilization	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
California	8.34	14.50	15.35	62,550	117,450	112,060
Other States [1]	12.73	11.20	12.75	33,110	32,490	33,140
United States	9.47	13.63	14.67	95,660	149,940	145,200
Canning	24.00	19.00	22.00	9,600	7,600	17,600
Freezing	8.87	13.43	14.02	86,060	142,340	127,600

State and utilization	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	118.00	156.00	135.00	7,381	18,322	15,128
Other States [1]	144.00	122.00	124.00	4,763	3,954	4,115
United States	127.00	149.00	133.00	12,144	22,276	19,243
Canning	68.00	68.00	68.00	653	517	1,197
Freezing	134.00	153.00	141.00	11,491	21,759	18,046

[1] Other States include New Jersey and Texas.

Tomatoes for Processing Area Planted and Harvested, Yield, Production, Price, and Value – States and United States: 2009-2011

State	Area planted			Area harvested		
	2009	2010	2011	2009	2010	2011
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
California	312,000	271,000	255,000	308,000	270,000	250,000
Indiana	9,800	9,600	9,000	9,800	9,600	9,000
Michigan	3,500	3,500	3,500	3,400	3,500	3,500
Ohio	6,600	5,900	5,600	6,600	5,800	5,300
United States	331,900	290,000	273,100	327,800	288,900	267,800

State	Yield per acre			Production		
	2009	2010	2011	2009	2010	2011
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
California	43.23	45.54	47.76	13,314,000	12,297,000	11,941,000
Indiana	32.79	21.40	24.89	321,340	205,440	224,010
Michigan	39.00	33.00	30.00	132,600	115,500	105,000
Ohio	30.70	27.30	23.80	202,620	158,340	126,140
United States	42.62	44.22	46.29	13,970,560	12,776,280	12,396,150

State	Price per ton			Value of production		
	2009	2010	2011	2009	2010	2011
	(dollars)	(dollars)	(dollars)	(1,000 dollars)	(1,000 dollars)	(1,000 dollars)
California	86.10	71.40	74.30	1,146,335	878,006	887,216
Indiana	113.00	105.00	113.00	36,311	21,571	25,313
Michigan	110.00	100.00	108.00	14,586	11,550	11,340
Ohio	107.00	98.30	103.00	21,680	15,565	12,992
United States	87.20	72.50	75.60	1,218,912	926,692	936,861

Vegetables for Processing Area and Production by Type of Procurement – United States: 2010 and 2011

Crop	Area				Production	
	Planted		Harvested			
	2010	2011	2010	2011	2010	2011
	(acres)	(acres)	(acres)	(acres)	(tons)	(tons)
Beans, lima (shelled)						
Contract	42,630	30,030	42,430	29,320	62,230	41,750
Open market	(X)	(X)	(X)	(X)	(X)	(X)
Beans, snap						
Contract	204,065	172,300	191,340	160,200	761,410	669,075
Open market	1,745	3,750	1,720	3,750	4,630	11,885
Carrots						
Contract	11,600	11,070	10,910	10,490	292,120	298,147
Open market	1,780	1,720	1,700	1,700	25,010	40,443
Corn, sweet						
Contract	347,500	334,050	335,200	326,250	2,694,280	2,623,000
Open market	(X)	(X)	(X)	(X)	(X)	(X)
Cucumbers (for pickles)						
Contract	83,400	74,800	79,600	72,900	497,434	451,080
Open market	8,600	10,200	8,300	9,730	53,936	30,950
Peas, green						
Contract	187,600	162,400	172,600	159,100	345,640	294,920
Open market	(X)	(X)	(X)	(X)	(X)	(X)
Spinach						
Contract	10,900	10,000	10,800	9,700	147,040	142,130
Open market	200	200	200	200	2,900	3,070
Tomatoes						
Contract	288,000	272,100	286,900	266,800	12,691,280	12,355,150
Open market	2,000	1,000	2,000	1,000	85,000	41,000

(X) Not applicable.

Definitions

Hundredweight (cwt.) is the unit used for fresh market yield and production and is equal to one hundred pounds.

Prices are a marketing year average for all methods of sale. For a crop sold for both fresh market and processing, the **Marketing Year Average Price (MYA)** is a weighted average of the fresh and processing price.

Prices for fresh vegetables are the average prices producers receive at the point of first sale. This is commonly referred to as the **average price as sold**. Since the point of first sale is not the same for all producers, prices for the various methods of sale are weighted by the proportionate quantity sold. For example, if in a given State part of the vegetables are sold free on board (F.O.B.) packed by growers, part are sold as bulk vegetables at the packinghouse door, and some are sold retail at roadside stands, the fresh vegetable **average price as sold** is a weighted average of the average price for each method of sale.

F.O.B. packed prices are adjusted to an equivalent incoming packinghouse door price by subtracting all costs that accumulate between the incoming packinghouse door and the F.O.B. price. These costs include grading, packing, inspecting fees, selling, and other costs.

Prices for vegetables sold for processing are equivalent returns for vegetables delivered to the processing plant door.

Crop value estimates in this report cover the marketing season or crop year and should not be confused with cash receipts from these crops which are on a calendar year.

State Value of Utilized Production and MYA Price Computations

The following procedure is used to compute State Values of Utilized Production and MYA Prices:

Fresh Market Value of Production:
(Fresh Market MYA) *Times* (Fresh Market Production)

Processing Value of Production:
(Processing MYA) *Times* (Processing Production)

"All" Value of Production:
(Fresh Market Value of Production) *Plus* (Processing Value of Production)

"All" MYA:
("All" Value of Production) *Divided By* ("All" Production)

United States MYA Price Computations

The following procedure is used to compute the U.S. MYA Prices:

Fresh Market MYA:
(Fresh Market Value of Production for All States) *Divided By* (Fresh Market Production for All States)

Processing MYA:
(Processing Value of Production For All States) *Divided By* (Processing Production For All States)

"All" Sales MYA:
(Total Value of Production for All States) *Divided By* (Total Production for All States)

Weights and Measures

The following table on weights, measures, and conversion factors covers the vegetables in this report. It does not cover all containers for any one product.

The information has been assembled from State schedules of legal weights, various sources within the United States Department of Agriculture, and other Government agencies. For many vegetables, there is a considerable variation in weight per unit of volume due to differences in variety or size of commodity, condition and tightness of pack, degree to which the container is heaped, etc. Effort has been made to select the most representative and fairest average for each product. For those commodities which develop considerable shrinkage, the point of origin weight or weight at harvest has been used.

The approximate or average weights as given in this table do not necessarily have official standing as a basis for packing or as grounds for settling disputes. Not all of them are recognized as legal weight. The table was prepared chiefly for use of workers in the United States Department of Agriculture who have need of conversion factors in statistical computations.

Approximate net weight

Commodity	United States Pounds	Metric Kilograms
Artichokes:		
Wax-treated carton, by count or loose pack	23	10.4
Asparagus:		
Pyramid carton /crate, bunched or loose	30	13.6
Beans:		
Lima unshelled bushel	32	14.5
Lima shelled		
Snap bushel wirebound crates/bushel hampers	26-31	11.8-14.1
Broccoli:		
Bunched - carton /crate	23	10.4
Crowns - bulk box	20	9.1
Cabbage:		
Carton/mesh sack	50	22.7
Flat crate	50-60	22.7-27.2
1-3//4 bushel crate	50	22.7
Cantaloupes:		
Bushel basket	40	18.1
Carrots:		
Table carton	50	22.7
48 1 lb. Poly bags in sacks	48	21.8
Cauliflower:		
Long Island wirebound crate	60	27.2
Catskill carton	50	22.7
Carton, 12 and 16 film wrapped, trimmed heads	25-30	11.3-13.6

Celery:		
Carton	50-60	22.7-27.2
Hearts - carton	18-28	8.1-12.7
Corn, sweet:		
Wirebound crate	42	19.1
Carton, crates, sacks	42	19.1
Carton/crate	50	22.7
Cucumbers:		
Bushel and 1 1//9 - bushel carton/crates	55	25.1
3.56 dekaliter carton	55	25.1
Garlic:		
Carton	5-30	2.2-13.6
Bags	3	1.3

Approximate net weight

Commodity	United States Pounds	Metric Kilograms
Honeydew Melons:		
Flat crates	35	15.9
2//3 carton, various counts	30	13.6
Carton, including imports	30	13.6
Lettuce, Iceberg:		
Carton, 18, 24, and 30 count	50	22.7
Carton	30	13.6
Carton, 15 and 16 count	20	9.1
Onions, dry:		
Sack, carton, crate	50	22.7
Peas:		
Green, bushel basket/crate/hamper and 1 1//9-bushel crate	30	13.6
Peppers:		
Green, bushel & 1 1//9-bushel carton /crate	28	12.7
1 1//4-bushel carton	35	15.9
Chilis, Jalapenos & Yellow wax, 1//2& 5//9-bushel crate/ carton		
Other chilis, bin	500	227.2
Cases, bulk	10	4.5
Pumpkins:		
Bin	1,000	454.5
Carton /crate/sack	50	22.7
Bushel carton /crate	25	11.3
Spinach:		
Carton, 24-count (bunched)	20	9.1
1 2//5-bushel carton/crate	32	14.5
Bushel containers	25	11.3
Squash, summer:		
Zucchini, Yellow Crookneck, carton /crate	35	15.9
Bushel and 1 1//9-bushel container	42	19.1
3//4-bushel carton/crate	30	13.6
Strawberries:		
Flats, 12 1-pint containers	12	5.4
Tomatoes:		
Carton, loose	25	11.3
Flats/carton	20	9.1
Watermelons:		
Bulk	45,000	20,454.5
Bins	1,050	477.2
Carton, various counts	85	38.6

Statistical Methodology

Survey Procedures: Acreage and production information included in this report is collected six times during the year. Acreage forecasts are obtained on a quarterly basis for fresh market and processing vegetables. For fresh market vegetables, growers are surveyed seasonally for estimates of crops such as onions and strawberries. Producers growing multiple fresh market crops are surveyed at seasonal intervals in major producing States for the remaining vegetable crops in the program. Data are collected by telephone interviews, mail out, faxed questionnaires, and personal interviews. Data accuracy and reducing respondent burden are taken into account in conducting the surveys. The most desirable survey method is to do a complete enumeration of growers. When this is not possible, a mail inquiry, sent to a sample of growers, is conducted. Due to the variable nature of the vegetable industry, mail lists are frequently updated to ensure complete coverage.

Summary and Estimation Procedures: The vegetable surveys collect data in the major producing States for each respective commodity. States with a small number of growers survey all known commercial producers of vegetable commodities. States with a large number of producers contact a sample of growers to get data. Sampling may still result in a census for some vegetables.

Revision Policy: At the end of the calendar year, all producers have the opportunity to update or provide any additional data corresponding to any of the weeks for the current and previous year. After these data are incorporated with previously reported data, revised seasonal estimates are published in the Vegetables Annual Summary.

Reliability: Survey indications are subject to sampling variability because all operations growing vegetables are not included in the sample. Survey results are also subject to non-sampling errors such as omission, duplication, imputation for missing data, and mistakes in reporting, recording, and processing the data. These errors cannot be measured directly, but are minimized through rigid quality controls in the data collection process and a careful review of all reported data for consistency and reasonableness.

Information Contacts

Listed below are the commodity statisticians in the Crops Branch of the National Agricultural Statistics Service to contact for additional information. E-mail inquiries may be sent to nass@nass.usda.gov

Lance Honig, Chief, Crops Branch .... (202) 720-2127

Jorge Garcia-Pratts, Head, Fruits, Vegetables and Special Crops Section .... (202) 720-2127
Debbie Flippin – Fresh and Processing Vegetables, Onions, Strawberries .... (202) 720-2157
Fred Granja – Apples, Apricots, Cherries, Plums, Prunes, Tobacco .... (202) 720-4288
Chris Hawthorn – Citrus, Coffee, Grapes, Sugar Crops, Tropical Fruits .... (202) 720-5412
Dave Losh – Hops .... (360) 709-2400
Dan Norris – Austrian Winter Peas, Dry Edible Peas, Lentils, Mints,
Mushrooms, Peaches, Pears, Wrinkled Seed Peas, Dry Beans .... (202) 720-3250
Daphne Schauber – Berries, Cranberries, Potatoes, Sweet Potatoes .... (202) 720-4285
Erika White – Floriculture, Maple Syrup, Nursery, Tree Nuts .... (202) 720-4215

Access to NASS Reports

For your convenience, you may access NASS reports and products the following ways:

- All reports are available electronically, at no cost, on the NASS web site: http://www.nass.usda.gov

- Both national and state specific reports are available via a free e-mail subscription. To set-up this free subscription, visit http://www.nass.usda.gov and in the "Receive NASS Updates" box under "Receive reports by Email," click on "National" or "State" to select the reports you would like to receive.

- Printed reports may be purchased from the National Technical Information Service (NTIS) by calling toll-free (800) 999-6779, or (703) 605-6220 if calling from outside the United States or Canada. Accepted methods of payment are Visa, MasterCard, check, or money order.

For more information on NASS surveys and reports, call the NASS Agricultural Statistics Hotline at (800) 727-9540, 7:30 a.m. to 4:00 p.m. ET, or e-mail: nass@nass.usda.gov.

Specimen Label

RESTRICTED USE PESTICIDE

Due to high acute inhalation toxicity and carcinogenicity.
For retail sale to and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification.

Dow AgroSciences

Telone® EC

Soil Fumigant

®Trademark of Dow AgroSciences LLC

A liquid fumigant for preplant treatment of soil to control plant parasitic nematodes and certain other soil pests in cropland using drip irrigation systems only.

Active Ingredient:	(by weight)
1,3-dichloropropene	93.6%
Other Ingredients	6.4%
Total	100.0%

1 gallon of Telone EC weighs 10.1 lb at 70°F. Contains 9.45 lb of 1,3-dichloropropene per gallon.

Keep Out of Reach of Children

WARNING AVISO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label, find someone to explain it to you in detail.)

Agricultural Use Requirements

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. Refer to label booklet under "Agricultural Use Requirements" in the Directions for Use section for information about this standard.

Refer to inside of label booklet for additional precautionary information including Directions for Use.

Notice: Read the entire label. Use only according to label directions. **Before using this product, read Warranty Disclaimer, Inherent Risks of Use, and Limitation of Remedies at end of label booklet. If terms are unacceptable, return at once unopened.**

In case of emergency endangering health or the environment involving this product, call 1-800-992-5994.

Agricultural Chemical: Do not ship or store with food, feeds, drugs or clothing.

Precautionary Statements

Hazards to Humans and Domestic Animals

EPA Reg. No. 62719-321

WARNING

Hazardous Liquid and Vapor

- **Do not swallow any of this product. May be fatal if swallowed.**
- **Do not get in eyes. Causes substantial, but temporary eye injury.**
- **Do not get on skin. May be fatal if absorbed through the skin. Causes skin irritation and, if confined, skin burns. May cause allergic skin reaction.**
- **Do not breathe vapor. May be fatal if inhaled. May cause lung, liver, and kidney damage and respiratory system irritation upon prolonged contact.**
- **The use of this product may be hazardous to your health. This product contains 1,3-dichloropropene, which has been determined to cause tumors in laboratory animals. Risks can be reduced by exactly following directions for use, precautionary statements, by wearing the personal protective equipment specified in this labeling.**

Personal Protective Equipment (PPE)

Chemical-Resistant Materials: Some materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for Category H on an EPA chemical resistance category selection chart. PPE constructed of saranex, neoprene, and chlorinated polyethylene provide short-term contact or splash protection against liquid in this product. Longer-term protection is provided by PPE constructed of viton, Teflon, and EVAL barrier laminates (for example, responder suits manufactured by Life-guard or silvershield gloves manufactured by North). Where chemical-resistant materials are required, leather, canvas, or cotton materials offer no protection from this product and must not be worn when contact with this product is possible. Coveralls must be loose-fitting and constructed of woven fabrics (e.g., tight knit cotton or cotton/polyester), non-woven fabrics (e.g., tyvek or sontara), or fabrics containing microporous Teflon.

1. **Handlers Performing Mechanical Transfer of Product - Closed Delivery Systems**
   - Long-sleeved shirt and long pants
   - Chemical-resistant gloves, such as barrier laminate (EVAL) or viton
   - Chemical-resistant footwear and socks
   - Face-sealing goggles

   The following PPE must be immediately available to the handler in case of emergency:
   - Coveralls
   - Full-face respirator with either an organic-vapor-removing cartridge with a prefilter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C) or canister approved for pesticides (MSHA/NIOSH approval number prefix TC-14G), or a NIOSH approved respirator with an organic vapor (OV) cartridge or canister with any N, R, P or HE prefilter.
2. **Handlers Performing Tasks with Liquid Contact Potential**

   Tasks with liquid contact potential are tasks performed outdoors. These tasks are:
   - Equipment calibration or adjustment
   - Equipment clean-up and repair
   - Product sampling
   - Rinsate disposal
   - Fumigant transfer - open delivery systems
   - Clean-up of small spills
   - Preparing containers for aeration
   - Any activity less than 6 feet from an unshielded pressurized hose containing this product.

   Handlers performing tasks with liquid contact potential must wear:
   - Coveralls over short-sleeved shirt and short pants
   - Chemical-resistant gloves, such as barrier laminate (EVAL) or viton
   - Chemical-resistant footwear plus socks
   - Chemical-resistant headgear for overhead exposure
   - Chemical-resistant apron
   - A face shield or safety glasses with brow and temple shields (do not wear chemical goggles)
   - A half-face respirator with either an organic-vapor-removing cartridge with a prefilter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C) or canister approved for pesticides (MSHA/NIOSH approval number prefix TC-14G), or a NIOSH approved respirator with an organic vapor (OV) cartridge or canister with any N, R, P or HE prefilter.
3. **Handlers in the Treated Area Within 5 Days After Application**

   Only the following handler tasks may be performed in the treated area within 5 days after the application is complete:
   - Assessing pest control, application technique, or application efficacy
   - Sampling air or soil for this product
   - Assessing/adjusting the soil seal (tarped applications only)
   - Removal of tarp or plastic film (tarped applications only)

   All other tasks are prohibited until the 5-day period has expired.

   Handlers performing the above tasks in the treated area within 5 days after application must wear:
   - Coveralls
   - Chemical-resistant gloves, such as barrier laminate (EVAL) or viton
   - Chemical-resistant footwear and socks

- Full-face respirator with either an organic-vapor-removing cartridge with a prefilter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C) or canister approved for pesticides (MSHA/NIOSH approval number prefix TC-14G), or a NIOSH approved respirator with an organic vapor (OV) cartridge or canister with any N, R, P or HE prefilter.

4. **Handlers Exposed to High Concentrations**

   Handlers exposed to high airborne concentrations of this product, such as cleanup following large spills, must wear:
   - Chemical-resistant suit
   - Chemical-resistant gloves, such as barrier laminate (EVAL) or viton
   - Chemical-resistant footwear plus socks
   - Chemical-resistant headgear
   - Supplied-air respirator with MSHA/NIOSH approval number prefix TC-19C **or** self-contained breathing apparatus (SCBA) with MSHA/NIOSH approval number prefix TC-13F. See further respirator requirements in the User Safety Requirements section on this label.

Note: In-tank cleaning of bulk tanks must be performed only by persons who have been specifically trained for this activity. Refer to OSHA 29 CFR Part 1910.146.

Engineering Controls

With all bulk and mini-bulk containers, Telone EC must be transferred through connecting hoses, pipes, and/or couplings sufficiently tight to prevent workers or other persons from coming in contact with liquid Telone EC.

- All hoses, piping, and tanks used in connection with Telone EC shall be of the type appropriate for use under the pressure and vacuum conditions to be encountered.
- External sight gauges shall be equipped with valves so that pipes to sight gauge can be shut off in case of breakage or leakage.
- The mechanical transfer system must be adequate to make necessary measurements of the pesticide being used.
- Shut-off devices must be installed on the exit end of all hoses and at all disconnect points to prevent leakage of Telone EC when the transfer is stopped and hose is removed or disconnected. A dry coupler that will minimize pesticide leakage must be installed at the disconnect point.
- The pressure in hoses used to move Telone EC beyond a pump must not exceed the manufacturer's maximum pressure specification.

User Safety Requirements

1. **Respirator Requirements:** When a respirator is required for use with this product, the following criteria must be met:
   a. Respirators must be fit-tested and fit-checked using a program that conforms to OSHA's requirements (described in 29 CFR Part 1910.134).
   b. Cartridges or canisters must be replaced daily or when odor or irritation from this product becomes apparent, whichever is sooner.
   c. Respirator users must be trained using a program that conforms to OSHA's requirements (described in 29 CFR Part 1910.134).
   d. Respirator users must be examined by a qualified medical practitioner to ensure physical ability to safely wear the style of respirator to be worn.
2. **Dispose of Contaminated Clothing:** Discard clothing and other absorbent materials that have been drenched or heavily contaminated with liquid from this product. Do not reuse them.
3. **Clean and Maintain PPE:** Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry. Wash PPE after each day's use.
4. **Contact with Mouth:** Never siphon this product by mouth or use mouth to blow out clogged lines, nozzles, etc.
5. **Heat Illness Avoidance:** Use measures to avoid or minimize heat illness while using this product. These measures include gradual adjustment to heat and respirator stress, fans for cooling, cooling vests, frequent breaks to cool down, frequent intake of drinking water, and maintaining weight from day to day.

User Safety Recommendations

Users should:
- Wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

First Aid

If inhaled: Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to-mouth, if possible. Call a poison control center or doctor for further treatment advice.
If on skin or clothing: Take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes. Call a poison control center or doctor for treatment advice.
If in eyes: Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. Call a poison control center or doctor for treatment advice.
If swallowed: Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by the poison control center or doctor. Do not give anything by mouth to an unconscious person.

Note to physician: Because rapid absorption may occur through lungs if product is aspirated and cause systemic effects, the decision to induce vomiting or not should be made by a physician. If lavage is performed, endotracheal and/or esophageal control is suggested. Danger from lung aspiration must be weighed against toxicity when considering emptying the stomach.

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may also contact 1-800-992-5994 for emergency medical treatment information.

Environmental Hazards

Do not apply directly to water, to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water by disposal of equipment washwaters. See Storage and Disposal section. In case of spills properly dispose of contaminated materials.

Groundwater advisory: 1,3-dichloropropene is known to move through soil and under certain conditions has the potential to reach groundwater as a result of agricultural use. Application in areas where soils are permeable and groundwater is near the surface could result in groundwater contamination.

Physical or Chemical Hazards

Combustible. Do not use or store near heat or open flame.

Directions for Use

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.
Read all Directions for Use carefully before applying.

Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your state or tribe, consult the agency responsible for pesticide regulation.

Agricultural Use Requirements

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment (PPE), and restricted-entry intervals, and notification to workers. The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard (WPS).

Entry Restriction:
Entry (including early entry that would otherwise be permitted under the WPS) by any person -- other than a correctly trained and equipped handler who is performing a handling task permitted on this labeling -- is **prohibited** from the start of application until 5 days after application. Non-handler entry is prohibited while tarps are being removed.

Notification:
Notify workers of the application by warning them orally and by posting fumigant warning signs at entrances to treated areas. The sign must bear the skull and crossbones symbol and state: (1) **"DANGER/PELIGRO,"** (2) Areas under fumigation, **DO NOT ENTER/NO ENTRE,"** (3) the date and time of fumigation, (4) "Telone EC fumigant in use," and (5) name, address, and telephone number of the applicator." Post the fumigant warning sign instead of the WPS sign for this application, but follow all WPS requirements pertaining to location, legibility, size and timing of posting and removal.

PPE for Reentry During the Entry Restricted Period:
PPE for entry that is permitted by this labeling is listed in the Hazards to Humans and Domestic Animals section of this labeling.

POSTING REQUIREMENTS

Posting of areas to be chemigated is required when any part of a treated area is within 300 feet of sensitive areas such as residential areas, labor camps, businesses, day care centers, hospitals, in-patient clinics, nursing homes or any public areas such as schools, parks, playgrounds, or other public facilities not including public roads.

Posting must conform to the following requirements: Treated areas shall be posted with signs at all usual points of entry and along likely routes of approach from the listed sensitive areas. When there are no usual points of entry, signs must be posted in corners of the treated areas and in any other location affording maximum visibility to sensitive areas. The printed side of signs should face away from the treated area towards the sensitive area. The signs shall be printed in English. Signs must be posted prior to application and must remain posted for 14 days. Signs may remain in place indefinitely as long as they are composed of materials to prevent deterioration and maintain legibility for duration of the posting period.

All words shall consist of letters at least 2 1/2inches tall, and all letters and the symbol shall be a color that sharply contrasts with their immediate background. At the top of the sign shall be the words KEEP OUT, followed by an octagonal stop sign symbol at least 8 inches in diameter containing the word STOP. Below the symbol shall be the words PESTICIDES IN IRRIGATION WATER.

Storage and Disposal

Do not contaminate water, food or feed by storage and disposal.

Pesticide Storage: Store in tightly closed original container in a cool place away from dwellings. Do not allow contamination of seeds, plants, fertilizers, or other pesticide chemicals.

Pesticide Disposal: Pesticide wastes are acutely hazardous. Improper disposal of excess pesticide or rinsate is a violation of Federal law. If these wastes cannot be disposed of by use according to label instructions, contact your state pesticide or environmental control agency, or the hazardous waste representative at the nearest EPA regional office for guidance.

Because Telone EC is corrosive under certain conditions, flush all application equipment with fuel oil, kerosene or a similar type of petroleum solvent immediately after use. Fill pumps and meters with new motor oil or a 50% motor oil/fuel oil mixture before storing. **Do not use water.** Dispose of rinsate by applicable Federal, state and local regulations. Never introduce rinsate or unused Telone EC into surface or underground water supplies.

Refillable containers 5 gallons or larger:

Container Handling: Refillable container. Refill this container with pesticide only. Do not reuse this container for any other purpose. Cleaning the container before final disposal is the responsibility of the person disposing of the container. Cleaning before refilling is the responsibility of the refiller. To clean the container before final disposal, empty the remaining contents from this container into application equipment. Fill the container about 10% full with water and, if possible, spray all sides while adding water. If practical, agitate vigorously or recirculate water with the pump for two minutes. Pour or pump rinsate into application equipment or rinsate collection system. Repeat this rinsing procedure two more times. Then offer for recycling if available, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures allowed by state and local authorities.

Nonrefillable containers 5 gallons or larger:

Container Handling: Nonrefillable container. Do not reuse or refill this container.

Triple rinse or pressure rinse container (or equivalent) promptly after emptying. **Triple rinse** as follows: Empty the remaining contents into application equipment. Fill the container 1/4 full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one com[plete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Turn the container over onto its other end and tip it back and forth several times. Empty the rinsate into application equipment or store rinsate for later use or disposal. Repeat this procedure two more times. **Pressure rinse** as follows: Empty the remaining contents into application equipment and continue to drain for 10 seconds after the flow begins to drip. Hold container upside down over application equipment and continue to drain for 10 seconds after the flow begins to drip. Hold container upside down over application equipment or collect rinsate for later use or disposal. Insert pressure rinsing nozzle in the side of the container, and rinse at about 40 psi for at least 30 seconds. Drain for 10 seconds after the flow begins to drip. Then offer for recycling if available, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures allowed by state and local authorities.

General Information

Telone® EC soil fumigant is a liquid fumigant for preplant treatment of cropland soil that can be used as part of a management program involving rotation, resistant varieties, and other cultural practices designed to alleviate nematode and disease pressure.

Telone EC may be applied as a preplant soil treatment to control the following types of plant parasitic nematodes: burrowing, citrus, cyst (golden, sugarbeet, soybean, carrot and wheat), dagger, lance, pin, needle, reniform, ring, root knot, root lesion, spiral, sting and stubby root.

Telone EC can also be used to suppress *Fusarium* wilt of cotton.

Telone EC may be applied through buried drip (drip lines buried at least 6 inches below soil surface) irrigation equipment without a secured tarp seal or surface and/or buried drip irrigation equipment with a secured tarp seal. **In the state of California,** the use of a tarp seal is mandatory for all applications of this product.

Before fumigation, soil sampling for the type and number of pests present is recommended. In fields where pre-treatment soil samples indicate the presence of high population levels of nematodes, a successful fumigation cannot be expected to eradicate entire populations. Therefore, post-treatment sampling is recommended to determine the need for additional pest management practices.

Consult State Agricultural Experiment Station or Extension Service specialists for information on other practices such as post-harvest destruction of crop residues, weed control or other cultural practices, and use of nematode resistant crop varieties that may aid in reducing crop losses from soil borne pests.

General Use Precautions

Soil fumigation using Telone EC should be conducted only according to directions and conditions of use described in this label.

Not for use in greenhouses or other enclosed areas.

Do not formulate and/or tank mix this product into other end-use agricultural products.

Soil must be in good seed bed condition, free of clods and undecomposed plant material.

Recontamination prevention: Telone EC will control pests that are present in the soil treatment zone at time of fumigation. It will not control pests that are introduced into soil after fumigation. To avoid reinfestation of treated soil, do not use irrigation water, transplants, or equipment that could carry soil borne pests from infested land. Avoid contamination from moving infested soil onto treated beds through cultivation, movement of soil from below the treated zone, dumping contaminated tare soil in treated fields and soil contamination from equipment or crop remains. Clean equipment carefully before entering treated fields.

Do not use containers, pumps or other transfer equipment made of aluminum, magnesium or their alloys, as under certain conditions Telone EC may be severely corrosive to such metals.

Fertility Interactions: Fumigation may temporarily raise the level of ammonia nitrogen and soluble salts in the soil. This is most likely to occur when high rates of fertilizer and fumigant are applied to soils that are either cold, wet, acidic, or high in organic matter. To avoid crop injury, fertilize when possible as indicated by soil tests made after fumigation. To avoid ammonia injury or nitrate starvation (or both) to crops grown on high organic soils, do not use fertilizers containing ammonium salts. Use only fertilizers containing nitrates until after the crop is well established and the soil temperature is above 65°F.

Do not apply within 100 feet of any well used for potable water. Do not apply this product within 100 feet from the edge of karst topographical features. Karst topography is identified from landscape features that result from the dissolving activity of water in carbonate rock formations (limestone, dolomite and marble). Surface features that are associated with karst topography include sinkholes, caverns, springs, and sinking or disappearing streams. In North Dakota, South Dakota, Wisconsin, Minnesota, New York, Maine, New Hampshire, Vermont, Massachusetts, Utah, and Montana: Where groundwater aquifers exist at a depth of 50 feet or less from the surface, do not apply this product where soils are Hydrologic Group A.

Use Restrictions for Certain Florida Counties: For application of this product in Brevard, Charlotte, Citrus, Collier, DeSoto, Glades, Hardee, Hendry, Hernando, Highlands, Hillsborough, Indian River, Lake, Lee, Manatee, Martin, Monroe, Okeechobee, Orange, Osceola, Palm Beach, Pasco, Pinellas, Polk, Sarasota, Seminole, St. Lucie, Sumter, and Volusia counties, applicators must have in their possession FIFRA Section 24(c) Special Local Need (SLN) FL-010008 and comply with stated requirements. Use of Telone EC is prohibited in Broward and Dade counties.

Application Directions

Buffer Zone: An application of Telone EC shall not be made within 100 feet of an occupied structure, such as a school, hospital, business or residence. No person shall be present at this structure at any time during the seven consecutive day period following application. **This buffer zone does not apply to use on soils that will not experience an additional 1,3-D treatment for at least three years, for example, on soils to be planted with perennial crops.**

Drip Application: Apply Telone EC as a preplant application through buried drip (drip lines buried at least 6 inches below soil surface) irrigation equipment without a secured tarp seal or surface and/or buried drip irrigation systems with a tarped seal. **In the state of California,** a secured tarp seal is required for all applications. For optimum control when using a tarp, the tarp seal must remain in place for a minimum of 14 days.

Planting Interval: Leave the soil undisturbed and unplanted for at least 14 days after applying Telone EC. A longer undisturbed interval is required under cold or wet soil conditions.

After fumigation, to prevent phytotoxicity, allow the fumigant to dissipate completely before planting the crop. Under optimum soil conditions for dissipation, 1 week for each 10 gallons per acre is recommended with a minimum interval of 14 days following application. Dissipation is usually complete when Telone EC can no longer be detected at the application depth. Seed or transplants to be grown may be used as a bioassay to determine if Telone EC is present in the soil at concentrations sufficient to cause plant injury. Do not plant if the odor of Telone EC is detected.

Frequency/Timing of Application: Apply any time of the year when soil temperatures are between 40°F and 80°F at the depth of application.

Preharvest Interval: Not applicable.

Compatible Materials: The following materials are recommended for use in drip systems where applications of Telone EC are to be made:

- Copper, stainless steel, stainless steel braided hose, steel, brass, Kynar, Kalrez, Chemraz, Santoprene, Hasteloy, Monel, polypropylene, polyethylene, nylon, Teflon, rigid PVC and viton (F/G best).
- Rigid PVC should not be exposed to undiluted Telone EC or more than 1500 ppm of Telone EC in the diluted form.

The following materials are **not** recommended for use with Telone EC and/or drip systems where Telone EC is to be applied:

- Do not use containers, pumps, drip tube or other transfer or drip equipment made of aluminum, magnesium, zinc (including galvanized), cadmium, tin and alloys, or vinyl under certain conditions Telone EC may be severely corrosive to such metals.
- Buna-N, neoprene and fiberglass have the potential to disintegrate and should not be used in a system where Telone EC is to be applied.

Drip Irrigation Design:
- A drip irrigation specialist should be consulted on the design of a drip system to insure irrigation and fumigant application uniformity.
- A drip irrigation specialist should be consulted in the selection of a proper drip tape based upon the water needs of the crop to be grown with the understanding that the tape will also be used for drip fumigation. Selection of the proper emitter spacing, flow rate, and number of tapes per bed is important in obtaining a quality drip fumigant application.
- Drip emitters should be spaced 12 to 24 inches apart on the drip lines.
- It is important to note that drip tape installed on top of the soil surface has the potential to kink, twist and snake when water is introduced. This could result in tape damage and a lack of irrigation and fumigation uniformity.
- Planting must occur within the treated area.

Drip Fumigation Procedures:

Step 1, Pre-Irrigation:
- To obtain more uniform water movement, insure quality fumigant distribution and to test for leaks, a pre-irrigation prior to the planned drip fumigation application is recommended.
- During pre-irrigation, use sufficient water to increase soil moisture throughout the treatment zone to near or at field capacity. This should occur over a 7- to 10-day period prior to application in order to stimulate nematode hatch and activity.
- Allow the soil moisture to return to below field capacity before making the drip fumigant application.
- The pre-irrigation may enhance coverage in very sandy soils, very dry soils, or in soil with deep buried tape (5 inches in depth or greater).

Step 2, Drip Fumigant Application:
- Apply appropriate rate (see Table 1) of Telone EC in enough water so that soil moisture throughout the treatment zone, including near the soil surface, is again at or near field capacity.
- The concentration of Telone EC must be between 500 and 1500 ppm in the drip irrigation lines.
- Do not exceed a concentration of 1500 ppm of Telone EC.
- Water flow and chemical flow rates must be known in order to calculate the correct ppm.
- Telone EC must be metered into the water supply and pass through a mixing device (centrifugal pump or static mixer) to assure proper agitation before it is distributed into the drip irrigation line system.
- Calculating the correct flow rate of Telone EC is important in achieving the correct dose rate to control the targeted pest. Calibration of the chemical flow and water meters is recommended. A chemical flow totalizer and/or scale are recommended to validate the chemical flow.
- Fumigant injections made within 50 feet of the first "T" and/or under conditions of low velocity water flow (less than 2 feet per second) must pass through a mixing device (such as a centrifugal pump or static mixer, coarse filter or fine strainer) to assure proper agitation.
- A separate mixing device is not needed if the chemical injection point is at least 50 feet in front of the first "T" junction point and significant turbulent flow is present to insure mixing.
- For low velocity (laminar) flows, more distance or a mixing device is needed to insure thorough mixing of the fumigant and water before it reaches the site to be treated.
- The minimum turbulent flow that is required for adequate mixing and to prevent damage to PVC pipe is 2 feet per second.
- Do not allow treatment solution to puddle on the soil surface. If ponding, puddling or run-off occurs, then discontinue application immediately and cover with soil to absorb.

Step 3, Post Application:
- After application of Telone EC, continue to irrigate the area with sufficient untreated water to flush the mixture from the irrigation system.
- Do not allow Telone EC to remain in the irrigation system.
- Make sure that any PVC dead ends or low spots are flushed completely.
- Leave the soil undisturbed for at least 14 days. Then proceed with normal crop management activities.
- Do not plant if Telone EC is detected.

Special Use Precautions for Chemigation Application Equipment
- Apply this product only through surface and buried tape drip irrigation systems. Do not apply this product through any other type of irrigation system.
- Crop injury or lack of effectiveness can result from non-uniform distribution of treated water.
- If you have questions about calibration, contact State Extension Service specialists, equipment manufacturers or other experts.
- Do not connect irrigation system used for pesticide application to a public water system unless the pesticide label-prescribed safety devices for public water systems are in place.
- Only a person knowledgeable of the chemigation system and responsible for its operation, or a person under the supervision of the responsible person, shall operate the system and make necessary adjustments should the need arise.
- The system must contain a functional check valve, vacuum relief valve and low pressure drain or approved backflow prevention valve appropriately located on the irrigation pipeline to prevent backflow contamination of the water source.
- The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the chemical supply or injection pump.
- The pesticide injection pipeline must also contain a functional, normally closed, automatic valve located on the intake side of the injection pump and connected to the system interlock to prevent fumigant from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down. The valve must be compatible with the fumigant.
- The system must contain a functional inter-lock to automatically shut off the pesticide injection pump if used when the water pressure drops too low for acceptable irrigation uniformity or the water pump motor stops.
- The irrigation line or water pump must include a functional pressure switch that will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected.
- A hydraulic interlock valve operated by irrigation water pressure may be used in lieu of a functional pressure switch and/or an automatic functional inter-lock.
- Injection systems must use a metering system, such as a positive displacement injection pump or diaphragm pump, or venturi system, and/or a pressure-safe cylinder containing Telone EC equipped with a metering valve and flow meter. This equipment must be constructed of materials that are compatible with Telone EC and capable of being fitted with a system interlock.
- Telone EC should be injected into the center of the irrigation water stream by using a suitable dip tube. This will prevent damage from undiluted fumigant contacting PVC pipe at the point of injection.

Uses

Control of Nematodes

Use Telone EC for control of nematodes in soils to be planted to vegetable crops, field crops, fruit and nut crops, and nursery crops. Refer to Table 1 for application rates.

- Dilution rate as applied: 500 to 1500 ppm of Telone EC.
- 1500 ppm 1,3-D is equivalent to 1 gallon of Telone EC in 740 gallons of water.

Table 1. Application Rates for Control of Nematodes

Crop	Soil Type (2)	Broadcast Application Rates (1) (Gallons/Acre)
field crops vegetable crops (3)	mineral	9 – 18 (4, 5)
fruit and nut crops nursery crops	mineral	9 – 24

[1] Rates given are broadcast equivalent.
[2] Not intended for use on muck or peat soils.
[3] Potatoes: Before fumigation, soil sampling for the type and number of pests present is recommended and can help to determine the need for additional treatment with a contact nematicide. Preharvest tuber sampling for nematodes also is recommended. If the nematode population is high enough to damage the crop, potatoes can be harvested early. Do not store potatoes with a detectable nematode infestation.
[4] For cyst-forming nematodes, use 18 gallons per acre of bedded row.
[5] For use in a second crop culture or when nematode pressure is a concern, the upper end of the rate range is recommended.

Control of Plant Diseases

***Fusarium* Wilt of Cotton**: The effects of this disease can be suppressed by controlling the root knot nematodes associated with this disease/nematode complex. Use Telone EC at the rate of 12 gallons per acre.

Terms and Conditions of Use

If terms of the following Warranty Disclaimer, Inherent Risks of Use, and Limitation of Remedies are not acceptable, return unopened package at once to the seller for a full refund of purchase price paid. Otherwise, use by the buyer or any other user constitutes acceptance of the terms under Warranty Disclaimer, Inherent Risks of Use and Limitations of Remedies.

Warranty Disclaimer

Dow AgroSciences warrants that this product conforms to the chemical description on the label and is reasonably fit for the purposes stated on the label when used in strict accordance with the directions, subject to the inherent risks set forth below. Dow AgroSciences MAKES NO OTHER EXPRESS OR IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY OTHER EXPRESS OR IMPLIED WARRANTY.

Inherent Risks of Use

It is impossible to eliminate all risks associated with use of this product. Plant injury, lack of performance, or other unintended consequences may result because of such factors as use of the product contrary to label instructions (including conditions noted on the label, such as unfavorable temperature, soil conditions, etc.), abnormal conditions (such as excessive rainfall, drought, tornadoes, hurricanes), presence of other materials, the manner of application, or other factors, all of which are beyond the control of Dow AgroSciences or the seller. To the extent permitted by law, all such risks shall be assumed by buyer.

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1. Refund of purchase price paid by buyer or user for product bought, or
2. Replacement of amount of product used.

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1. Added buried drip without a secured tarp seal directions.

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UNIVERSITY OF KENTUCKY
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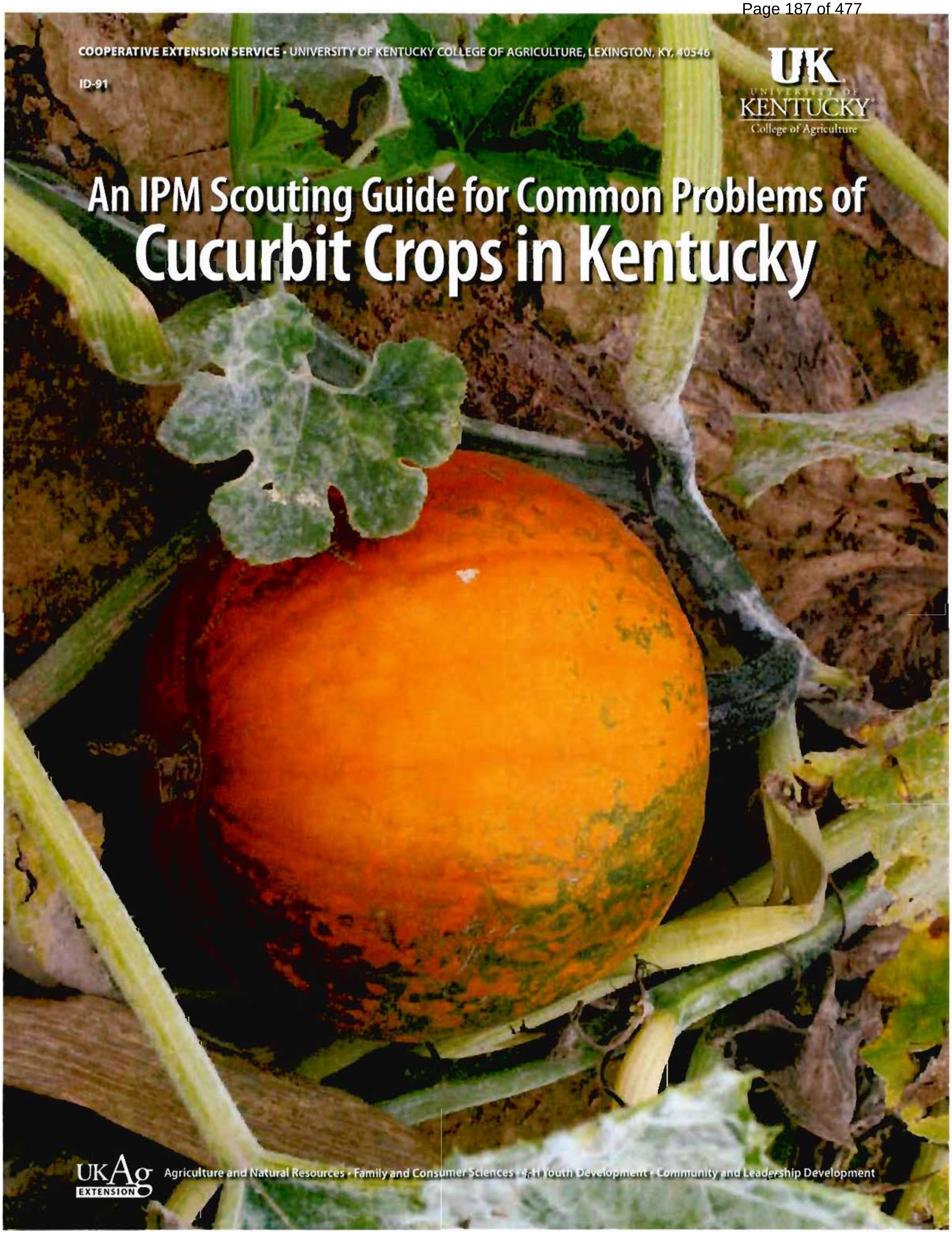
An IPM Scouting Guide for Common Problems of Cucurbit Crops in Kentucky



UKAg EXTENSION Agriculture and Natural Resources • Family and Consumer Sciences • 4-H Youth Development • Community and Leadership Development

Cover: Powdery mildew (on the foliage) and potyvirus complex symptoms (on the fruit) on pumpkin.
Kenny Seebold

An IPM Scouting Guide for Common Problems of Cucurbit Crops in Kentucky

This manual is the result of efforts of the University of Kentucky Vegetable IPM team.
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Contents

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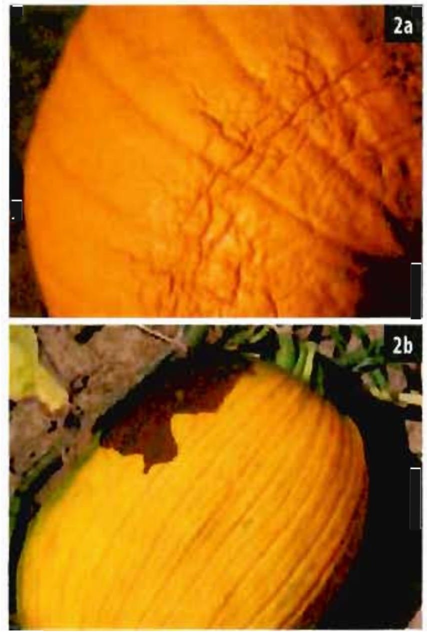
Long before the term "sustainable" became a household word, farmers were implementing sustainable practices in the form of integrated pest management (IPM) strategies. IPM uses a combination of biological, cultural, physical, and chemical methods to reduce and/or manage pest populations. These strategies are used to minimize environmental risks, costs, and health hazards. Pests are managed to reduce their negative impact on the crop, although pests are rarely eliminated.

Essential to the IPM approach is scouting and monitoring of diseases, insects, weeds, and abiotic disorders in order to identify potential problems before they result in serious losses. The key to effective monitoring is accurate identification. This guide covers the more common abiotic and biotic problems that occur on cucurbits (Cucurbitaceae family) in Kentucky. This plant group, also referred to as vining crops, includes cucumber, muskmelon (cantaloupe), watermelon, specialty melons, squash, pumpkin, and gourds.

This guide has been designed to serve as a companion to the University of Kentucky publication *Vegetable Production Guide for Commercial Growers* (ID-36), available from your county office of the Cooperative Extension Service or online at http://www.ca.uky.edu/agc/pubs/id/id36/id36.htm. Within ID-36, you will find detailed information on the production of cucurbits, fertility, and pest management. Should you need additional information on the problems covered by this publication or for a problem not discussed here, please consult ID-36 or contact your county agent.

Physiological and Nutrient Disorders

Blossom end rot on watermelon fruit.



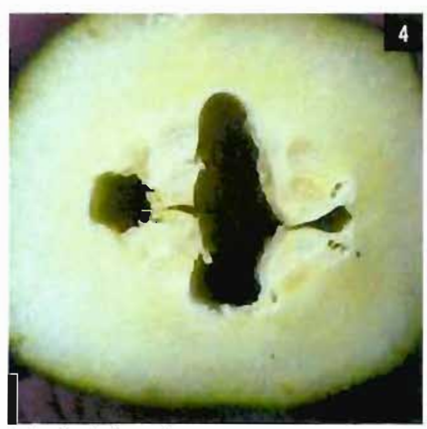
Drought (a) and drought/sunburn (b) symptoms on pumpkin.

1. Blossom end rot is a physiological disorder observed in many cucurbits as well as other crops (for example, tomato and pepper). It typically appears as a general rot at the blossom end of developing fruit. Blossom end rot is usually the result of inadequate or uneven irrigation, high humidity, or other factors that slow the movement of water through the plant. Since calcium is taken into the plant with the transpiration stream (water), slow water movement can often lead to temporary calcium deficiencies, resulting in blossom end rot.
Management—Provide adequate calcium fertility and proper irrigation. Do not use high levels of ammonia fertilizer, which can aggravate this problem. Avoid root injury.

2. Drought stress. Cucurbits are particularly sensitive to drought. Fruit are typically 85% to 90% water and can suffer under drought conditions. Pumpkins often produce long vines with many leaves and can transpire large quantities of water during hot summer days. Severe drought stress affects fruit development, resulting in unmarketable produce. Affected cucumber fruit may appear curled, distorted, or tapered at the blossom end; pumpkins become soft and wrinkled. In addition, drought-stressed pumpkins fail to gain appropriate size, which affects yields. A loss of foliage during drought will also result in sunburn of the fruit.
Management—Irrigate when necessary.

Yellowed foliage due to flooding.

3. Flood damage symptoms often appear as nutrient deficiencies or a generalized yellowing. Prolonged exposure to flooded soils will result in anaerobic (low oxygen) conditions for plant roots, eventually causing death. When large numbers of roots die, the plant is often unable to take up sufficient nutrients, resulting in nutrient deficiencies.
Management—While damage from flooding is often unavoidable, planting in raised beds will improve drainage.



Hollow heart of cucumber.

4. Hollow heart is the formation of a hollow cavity inside some cucurbit fruit. This disorder can result from a number of factors, including low boron levels, genetics, and uneven water management. Although not outwardly visible, hollow heart makes fruit unmarketable.
Management—Avoid varieties with a tendency to exhibit hollow heart. Ensure that boron levels in the soil are adequate; however, be careful not to overfertilize. Follow recommended plant spacing, and avoid erratic irrigation.

Magnesium deficiency on muskmelon leaves.

Manganese toxicity on a muskmelon leaf.

Molybenum deficiency.

Nitrogen deficiency on pumpkin.

5. Magnesium deficiency is more likely to occur on sandy soils with a low pH, especially in dry years. Sandy soils often have a low cation exchange capacity and may not contain adequate levels of magnesium. Deficiency symptoms are more commonly observed in muskmelon than in other cucurbits. Symptoms first appear as a yellowing between the leaf veins (interveinal chlorosis), beginning on the oldest leaves and slowly spreading to newer growth. Yellowed tissues may turn brown, die, and drop out, giving the leaf a shot-hole pattern. Magnesium deficiency usually appears during periods of rapid growth, when the fruit is enlarging.

Management—Maintain the soil pH near 6.5. Soil test results should show at least 200 lb of magnesium/acre. Potential sources of preplant magnesium include magnesium oxide and dolomitic lime. If necessary, fertigate Epsom salts (magnesium sulfate) and magnesium oxide through a drip irrigation system. Avoid heavy applications of fertilizers containing competing cations (K+, Ca++, NH4++). Foliar sprays are generally ineffective in correcting significant deficiencies.

6. Manganese toxicity symptoms include water-soaked areas on the underside of leaves and yellow or bronzed spots on the upper leaf surface. Although manganese is an essential plant micronutrient, high levels of it can lead to toxicity symptoms in cucurbits. Manganese toxicity is generally the result of a low soil pH, which allows manganese to become available to plants in toxic levels.

Management—Check the soil pH in the fall prior to planting; if it is below 6.0, apply lime in the fall and disk in.

7. Molybdenum deficiency usually affects muskmelons grown on dark heavy soils with a pH below 6.0. Heavy applications of ammonium nitrate through the drip lines may lower the pH in the plant root zone and contribute to either manganese toxicity or molybdenum deficiency. Other cucurbits do not show symptoms under the same growing conditions. Molybdenum deficiency usually is seen in the crown leaves about the time the plants begin to vine. Leaves become pale green to slightly chlorotic between the veins. As symptoms progress, the leaf margins become necrotic and plant growth ceases.

Management—Maintain a soil pH between 6.0 to 6.5; foliar treatments with sodium molybdate will help alleviate symptoms and permit normal growth

8. Nitrogen deficiency generally appears as a yellowing of older foliage on plants. Nitrogen is the most abundant nutrient in the plant and often the most limiting nutrient for plant

Early (a) and severe (b) ozone injury to watermelon.

growth. Cucurbits are not particularly heavy nitrogen feeders but can experience nitrogen deficiencies during periods of rapid growth or fruit set.

Management—For cucurbit crops that are grown with drip tape and black plastic mulch, broadcast and disk in about ⅓ to ½ of the total nitrogen requirement for a season prior to forming beds; fertigate the remainder throughout the season. When not using drip irrigation or black plastic, the remaining nitrogen can be banded in one or two side-dressings prior to fruit formation. For specific fertility recommendations in Kentucky, see the *Vegetable Production Guide for Commercial Growers* (ID-36).

9. Ozone damage is common to cucurbits in many regions of Kentucky. Although mainly observed on watermelons, most cucurbits can be affected. Symptoms first appear as small yellow flecks on leaves, eventually turning into large brown and gray areas that die and slough off. Severe damage can result in almost complete defoliation of some plants. Ozone damage is often mistaken for disease or spray injury.

Management—Tolerance to ozone varies with crop and variety. Seeded (diploid) watermelons tend to be more sensitive to ozone than seedless (triploid) varieties.

10. Poor pollination. With the exception of parthenocarpic cucumbers, cucurbits require pollination to produce fruit. Several visits from pollinators on the day that a flower is open are often required to ensure appropriate fruit development. Many fruits will appear misshapen and small when pollination is poor. Cucumbers will be reduced in size at the fruit stem end. Very high and low temperatures can also affect pollen viability, resulting in poor pollination. If too much nitrogen is used (resulting in excessive vegetative growth) or plants were improperly spaced, bees may have difficulty locating the flowers.

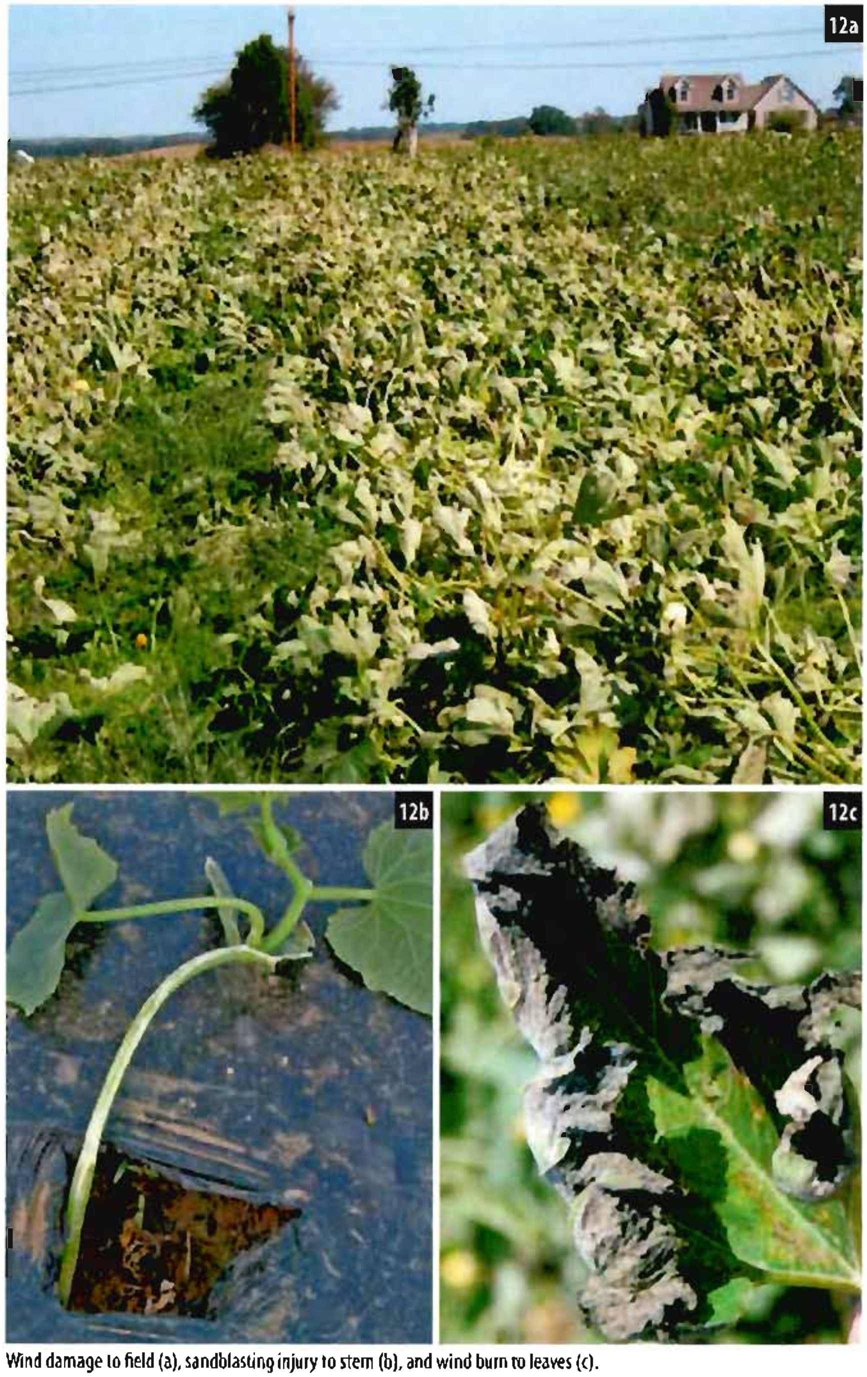
Management—Provide pollinators to ensure good fruit set and high yields. Do not spray insecticides during morning hours when flowers are open and insects are actively pollinating plants.

Poorly pollinated yellow squash.

11. Stem splitting is most often observed in transplant production when temperatures are low or when there is a period of rapid growth resulting from high temperatures, increased irrigation, or high fertility. In minor cases plants can be transplanted with few ill effects; however, in severe cases seedlings should not be transplanted if possible.
Management—Provide warm, uniform temperatures for seedlings and allow for even growth during transplant production.

Stem splitting on watermelon transplants.

12. Wind damage/sandblasting is a condition to which many cucurbits seem particularly susceptible due to their large leaves. High winds often cause stem damage and drying of transplants, particularly on the area of the stem facing prevailing winds. Excessive winds will desiccate leaves, causing them to die from the margins toward the center. Entire fields can be affected, leading to significant losses.
Management—Employ windbreaks along fields and avoid transplanting in high winds whenever possible.



Wind damage to field (a), sandblasting injury to stem (b), and wind burn to leaves (c).

Insect Pests

13. Cucumber beetles. The striped cucumber beetle *(Acalymma vittatum)* and the spotted cucumber beetle *(Diabrotica undecimpunctata howardi)* are the most common insect pests on all the cucurbit crops. The spotted cucumber beetle is recognized by the 12 black spots on its yellow-green body, while the striped cucumber beetle has three black stripes on its wings. Both of these pests are highly attracted to cucurbits and will cause significant damage to young seedlings and ripening fruit. They also transmit the bacterium that causes bacterial wilt of cucurbits, which is particularly problematic in cucumbers and melons. Close to harvest, a second generation may appear that can feed on the fruit's developing rinds.

Management—Early treatment is essential both for beetle and management of bacterial wilt. Begin treatment as soon as seedlings emerge or immediately after transplanting. A single post-transplant soil drench with a systemic insecticide can provide three to five weeks of control. Scout for beetles and apply foliar insecticides as necessary to protect susceptible plants, particularly close to harvest. Because watermelon is not susceptible to bacterial wilt, protection is necessary only when plants are small and beetle populations are high and again closer to harvest in order to prevent rind scarring by adult feeding.

14. Melonworm *(Diaphania hyalinata)* is an uncommon late-season pest of cucurbits. The 1-inch larva is yellow-green and will have fine yellow stripes running down its back in its last instar. The melonworm feeds on the foliage of summer and winter squashes but also may feed on muskmelon rinds. Some growers refer to these insects as rindworms.

Management—Treat with foliar insecticides if feeding on rinds is observed.

Spotted and striped cucumber beetle adults (a) and damage to leaves (b), melon fruit (c), pumpkin fruit (d), and seedlings (e).

Melonworm larva.

Squash bee in pumpkin flower.

Squash beetle.

15. Squash Bee *(Peponapis pruinosa)* is a pollination specialist of squash and pumpkin flowers. This is a ground nesting bee. The female will dig vertical holes in the ground to make solitary nests, but often a site has multiple females and nests. The females collect pollen and nectar from cucurbit flowers and are synchronized with the flowering pattern of squashes. They are active very early in the morning, with activity diminishing by midmorning.

16. Squash beetle *(Epilachna borealis)* is a coppery colored, leaf-feeding lady beetle similar to other lady beetles. This particular beetle, which is bigger than other lady beetles, has 12 black spots on its back and an orange thorax (the area just in front of the wings). It does not feed on other insects and can be a serious pest of squash and pumpkin. Squash beetle feeds on the underside of leaves and causes skeletonized, lace-like damage to the leaves. The larva is found on the underside of leaves and is yellow, with branched black spines covering the body. The pupa hangs from the leaf, is yellow in color, and lacks spines. **Management**—Apply foliar insecticides as necessary during the mid- and late season. While this insect is common in some areas of the state, economic levels on commercial cucurbit plantings are uncommon.

17. Squash bug *(Anasa tristis)* is brown and about 1 inch in length. Adults move into fields in early June and damage plants by removing sap as well as causing leaves to wilt and collapse. With newly set plants, the adults may feed on the stem base near the soil. Young plants may be killed, and infested leaves on older plants may wilt. More importantly, this insect is the vector of a newly recognized disease of cucurbit crops (yellow vine decline) that affects melons, watermelon, and pumpkins. The bronze eggs are football-shaped and lie on their sides in groups of 12 or more. Eggs hatch in one to two weeks. Initially, the nymphs are dark with a light green abdomen. Older nymphs are light gray in color with black legs. Young nymphs feed together in groups and require five to six weeks to mature into adults. While all the cucurbit crops can be attacked, squash bugs show a preference for squashes and pumpkins. This insect can be very difficult to control in mid- and late summer if populations are allowed to build up. **Management**—Timing is the key to successful squash bug control, and eliminating squash bugs is the key to management of yellow vine decline. Because this insect is a persistent vector, disease management is dependent on con-

Squash bug adult (a), damage (b), eggs (c), and nymphs (d).

trol of the vector. Use insecticides to control squash bug as soon as the plants are set or seedlings emerge in the field. Systemic insecticides used for cucumber beetle control will provide up to three weeks of squash bug suppression. Foliar sprays targeting newly hatched nymphs are more effective than sprays used against larger stages. Multiple foliar sprays are often needed for extended periods of control.

18. Squash vine borer *(Melittia cucurbitae)* adults are stout, dark gray moths with "hairy" red hind legs, opaque front wings, and clear hind wings with dark veins. Unlike most moths, they fly about the plants during the daytime, appearing more like a paper wasp than a moth. The cream-colored, 1-inch larva tunnels into the stems of cucurbits. Symptoms appear in midsummer, when a long runner or an entire plant wilts suddenly. Infested vines usually die beyond the point of attack. Sawdust-like frass near the base of the plant is the best evidence of squash vine borer activity. Careful examination will uncover yellow-brown excrement pushed out through holes in the side of the stem at the point of wilting. The small brown eggs, laid individually on leaf stalks and vines, hatch in seven to 10 days. The newly hatched larva immediately bores into the stem. A larva feeds for 14 to 30 days before exiting the stem to pupate in the soil. A degree-day model has been developed that estimates adult emergence at 1,000 degree-days (base 50°F with a March 1 biofix). **Management**—The key to management of squash vine borer is controlling the borers before they enter the stem. Once they're inside the vine, insecticidal control is not possible. Poor timing of sprays is the usual cause of inadequate control. Monitor plants weekly from mid-June (or at 900 degree-days) through August for initial signs of borer frass. Very early signs of larval feeding indicate that other eggs will be hatching soon. Use two insecticide applications seven days apart to control newly hatching larvae and continue to monitor for additional activity. In order to be effective, sprays need to penetrate the canopy to cover the vines.

Squash vine borer moth (a) and larva tunneling into cucurbit stem (b).

19. Two-spotted spider mite *(Tetranychus urticae)* females are yellow to dark green, with two to four dark dorsal spots. At $1/60$ of an inch, they are almost microscopic. Males are smaller and have more pointed abdomens. The tiny, spherical eggs are laid on the underside of leaves, often under the webbing produced by the mites. Mites attacking cucurbits are more common in hot, dry weather, and infestations usually begin around the field margins. Under optimum conditions of high temperature and low humidity, the life cycle may be completed in seven days; females can lay 200 eggs. Initial damage appears as tiny, light spots in the leaves (stippling), which over time will turn brown, with the leaves dying prematurely. **Management**—Natural enemies of mites can keep their populations low, but the use of insecticides to control insect pests severely reduces the numbers of these beneficial insects. Therefore, apply insecticides only as needed rather than at regularly scheduled intervals. Destroy weeds adjacent to and in fields during the fall or early spring, and carefully manage weeds around fields during the season. Spraying or mowing of weeds after growth has become rank may increase the movement of mites to cultivated plants. Irrigation with an overhead sprinkler may provide some short-term relief of mite infestations. Use miticides only when needed. Because mite populations are often localized, spot spraying may be effective. When spraying only a portion of the field, expand the spray zone to include an area 100 to 200 feet beyond the mite-infested area.

Two-spotted spider mite (a) and damage to melon leaf (b).


Trichopoda pennipes fly.


Greenhouse whitefly.



Silverleaf whitefly (a), damage symptoms (b).

20. Trichopoda pennipes is a fly that parasitizes the squash bug. It lays one or more eggs on the outside of large nymph and adult squash bugs. Upon hatching, the fly larva burrows into the squash bug and eventually kills it. The fly larva exits the squash bug to pupate in the soil. This fly can also attack other true bugs. This insect is a naturally occurring squash bug enemy common across the state.

21. Greenhouse whitefly *(Trialeurodes vaporarium)* is about ⅛ inch in length. A common pest of cucurbits, all stages (eggs, nymphs, and adults) can be found on the underside of leaves, particularly on older foliage. The adult whitefly is white and holds its wings roof-like over its back. A generation can be completed in as little as three to four weeks. Each female can lay hundreds of eggs over a period of six to eight weeks.
Management—Greenhouse whitefly is not common outside the greenhouse. In the greenhouse, a small parasitoid wasp, *Encarsia formosa*, can be very effective. In the field, controls for silverleaf whitefly will be effective.

22. Silverleaf whitefly *(Bemisia tabaci)* can sometimes be distinguished from the greenhouse whitefly by how it holds its wings. The silverleaf whitefly often holds its wings with a visible space between them, while the greenhouse whitefly usually holds its wings touching the abdomen or slightly overlapping it. The silverleaf whitefly gets its name because it injects a toxin into the plant that causes whitening of the undersurface of newly emerging leaves. Unfortunately, small numbers of silverleaf whitefly can cause silvering of small squash transplants. Damage may be more severe on younger plants than to plants closer to harvest. Once whiteflies stop feeding, the new foliage will emerge with normal color.
Management—A number of predaceous insects feed on silverleaf whitefly and one commercial parasitoid wasp, *Eretmocerus emericus*, has been used successfully in greenhouses. Chemical control of whiteflies can be difficult, as the adults and immature stage occur on the underside of leaves, particularly older leaves, making spray coverage critical for good control.

Diseases

Diseases Caused by Fungi and Fungus-like Organisms

23. Alternaria leaf blight *(Alternaria cucumerina)* is found primarily on watermelon and muskmelon but may occur on cucumber, gourds, pumpkin, and squash. This disease affects foliage and sometimes fruit. Symptoms appear on older leaves first, as small, necrotic spots that may be surrounded by a yellow halo. Lesions expand to form large brown spots with a concentric ring pattern. As lesions expand, they may merge to form large, blighted areas followed by curling of leaves and eventual decline.
Management—Crop rotation, sanitation (removal of crop debris), planting of resistant varieties (muskmelons), and fungicides.

Alternaria leaf blight on muskmelon foliage (a) and close-up of leaf lesions (b).

24. Anthracnose *(Colletotrichum orbiculare)* is most common on cucumber, muskmelon, gourds, and watermelon. It may occur on squash and pumpkin. All aboveground plant parts can be affected. Small, circular lesions develop initially on leaves. These lesions enlarge to form large tan to brown spots that may coalesce to create extensive blighting. On watermelon, leaf lesions tend to be smaller, irregularly shaped, and darker in color. The centers of older lesions may crack or fall out entirely. Lesions on stems are tan-brown, somewhat elongated, and sunken. On maturing fruit, lesions appear as small, circular, sunken areas. Lesions may grow to the size of a quarter or larger on melons. Lesions on watermelon can be cracked and irregularly shaped. Under humid conditions, lesions will blacken and salmon-pink masses of spores may be seen.
Management—Pathogen-free seed, planting of resistant varieties (watermelon—races 1 and 3; cucumber—races 1, 2, and 3), crop rotation, sanitation (debris removal), irrigation management (avoid overhead irrigation where possible), and fungicides.

25. Belly rot *(Rhizoctonia solani)* primarily affects cucumber and is found rarely on other cucurbits. Belly rot develops where fruit comes in contact with soil. Symptoms include sunken cankers (lesions) that are tan-brown in color and resemble a dry rot.
Management—Physical barriers (mulches) to prevent fruit from contacting soil, irrigation management (avoid excessively wet soils), deep-turning of soil before planting, and fungicides.

Belly rot on cucumber.

Anthracnose on melon fruit (a, b) and on foliage (c).

Choanephora on yellow squash (a, b).

26. Choanephora fruit rot *(Choanephora cucurbitarum)* is commonly seen on summer squashes, and may occur on cucumber and pumpkin. Symptoms appear on flowers and fruit, beginning mostly at the blossom end and developing a soft, wet rot. Profuse, fuzzy growth may be observed. It later produces large masses of black, spore-forming structures. Infected flowers serve as a bridge for the fungus to colonize fruit.
Management—No practical controls are available, although fungicides may reduce incidence. Also, practices that reduce leaf wetness (avoiding overhead irrigation or timing overhead watering to allow for leaf drying) can be of benefit.

27. Cottony leak (*Pythium* spp.) affects most cucurbits but is most common on cucumber and squash. The disease generally appears first on portions of fruit in contact with soil. Small, water-soaked spots expand rapidly until large portions of the fruit are necrotic and soft. Profuse, white fungal growth resembling tufts of cotton can be found on rotted areas when humidity is high.

Management—Manage excess soil moisture (drainage, irrigation) and use plastic mulch. Fungicides may provide some disease suppression.

28. Damping-off (*Pythium* spp., *Phytophthora* spp.) affects all cucurbits. It is characterized by a soft rot of seeds before germination or death of seedlings pre- and post-emergence. On emerged plants, a soft and water-soaked necrosis will occur just above the soil line and will extend to roots belowground. Plants wilt rapidly and die.
Management—Manage excess soil moisture (drainage, irrigation), plant into warm soils, use fungicide-treated seed, and apply fungicides (pre-plant).

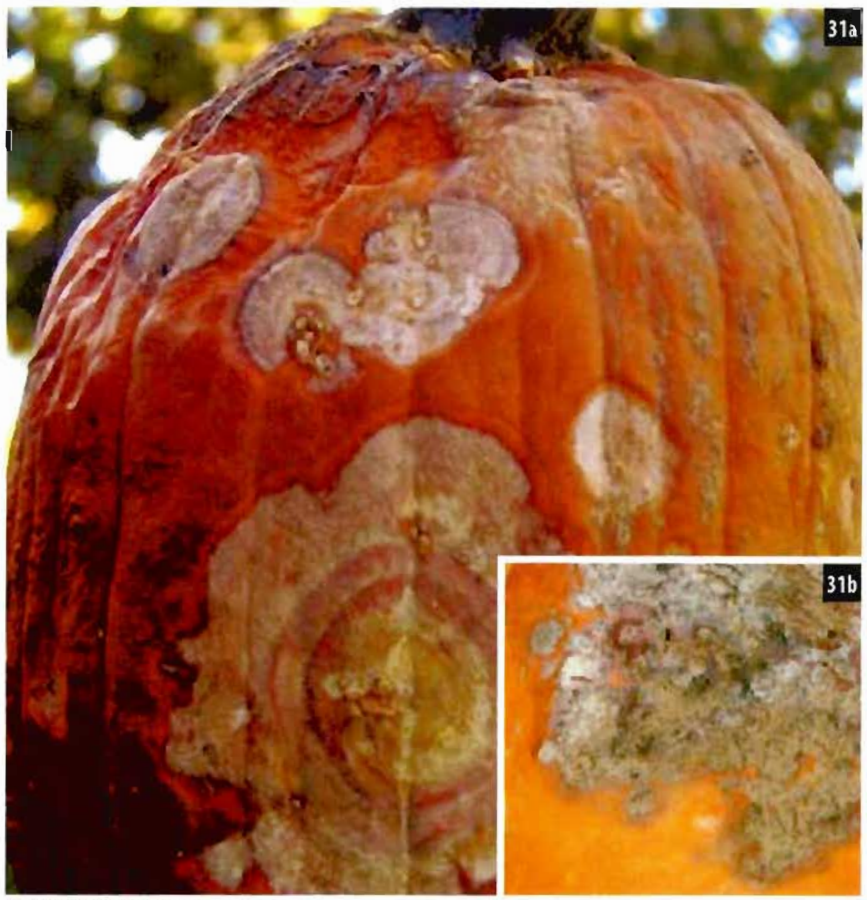
Cottony leak on cucumber.

Downy mildew on foliage—upper (a) and lower side (b) of cucumber plant and on pumpkin (c).

29. Downy mildew *(Pseudoperonospora cubensis)* occurs on most cucurbits. It first appears as pale to bright yellow spots on the upper surface of leaves in the crown area of the plant; these spots may be irregular or "blocky" in appearance. As lesions expand and the number of lesions increases, leaves become necrotic and plants will appear scorched. On the underside of leaves, lesions will be water-soaked and slightly sunken; profuse sporulation (light to dark gray or even purple in color) will be evident on lower leaf surfaces when humidity is high.
Management—Use resistant cultivars (primarily cucumber), avoid overhead irrigation, plant in sunny areas with good airflow, and apply fungicides.

30. Fusarium crown and foot rot *(Fusarium solani)* affects squash and pumpkin primarily. The wilting of one or more leaves is the first symptom, followed by plant collapse. A dark, necrotic canker is normally present at the soil line (crown of plant) and can extend into the main root. Sporulation, white to pink in color, may be present on infected tissue. Affected tissue may take on a "shredded" appearance in later stages as soft tissues degrade, leaving only the vascular bundles behind.
Management—Crop rotation and fungicides (seed-applied).

31. Fusarium fruit rot (*Fusarium* spp.) affects many cucurbits but is particularly devastating to pumpkin. It can occur in the field or in storage after harvest. Infected fruit develop lesions, usually circular, of varying size. The tissue beneath the lesions may be discolored and corky. Fungal growth ranging from white to purple in color may be seen.
Management—Crop rotation, physical barriers (minimizing contact of fruit with soil), proper curing, and careful handling during harvest.



Fusarium fruit rot on pumpkin (a, b).

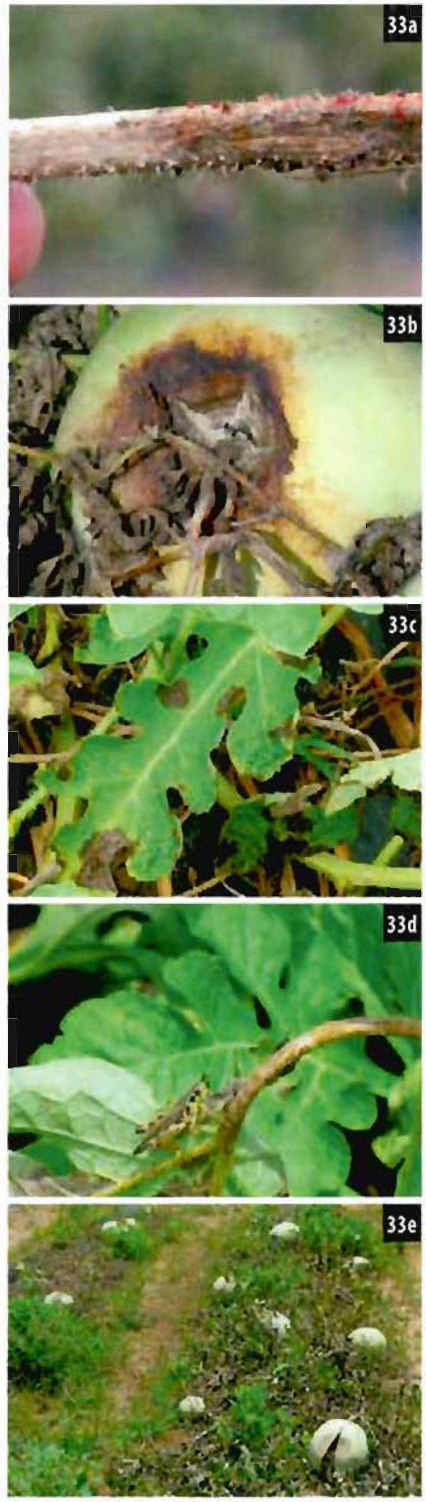
Fusarium wilt vascular discoloration (a) and symptoms in melon planting (b).

32. Fusarium wilt *(Fusarium oxysporum)* primarily affects watermelon but can occur less commonly on melons and cucumber. Symptoms include stunting, yellowing, and wilting of plants. Early on, individual runners wilt, and later the entire plant will collapse. Wilted plants may recover at night but gradually decline and die. Vascular tissue from the crown and lower stem will be discolored (brown) when cut and examined.

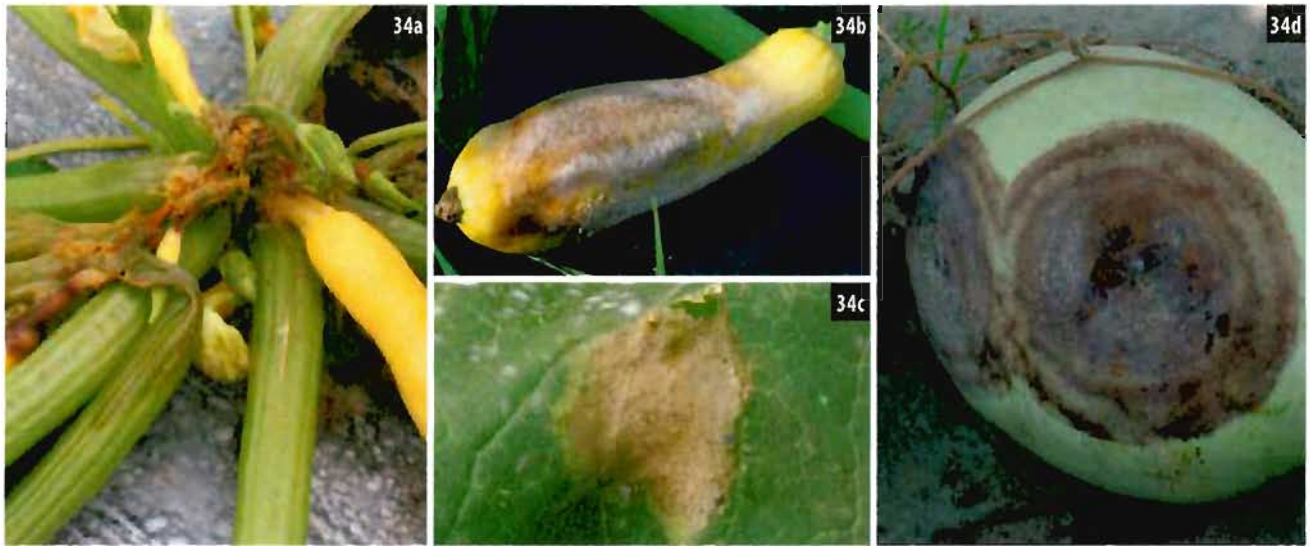
Management—Crop rotation (limited effectiveness), control of nematodes (wounds on roots caused by nematode feeding can be invaded by *Fusarium*), sanitation (avoid spreading contaminated soil), and planting of resistant varieties. Watermelon, melon, and cucumber are affected by different *formae speciales* (groups adapted to a specific host), and each of these groups have different pathogenic races. In the case of watermelon (caused by *F. oxysporum* f.sp. *niveum*), there are three races—0, 1, and 2. Good resistance is available to races 0 and 1 but not race 2. In Kentucky, thus far, race 2 has not been reported. Muskmelons are affected by *F. oxysporum* f.sp. *melonis*, which has four known races (0; 1; 2; and 1,2); race 2 is the most widely distributed in the United States, and resistant varieties are available to races 0, 1, and 2. Three races of *F. oxysporum* f.sp. *cucumerinum* affect cucumbers; race 1 is the most common in the United States.

33. Gummy stem blight/Black rot *(Didymella bryoniae)* affects most cucurbits, although it is seen infrequently on squash. This disease can occur on all plant parts—leaves, stems, and fruit (black rot). Lesions on leaves are circular and tan to brown in color and can expand quickly. Leaf veins affected by gummy stem blight will appear water soaked and orange-brown in color. Lesions on stems and vines are water soaked initially, orange-brown in color, and may exhibit a gummy, amber-colored exudate. Older lesions tend to form tan-colored cankers. Lesions on fruit begin as small, water-soaked spots that later expand and may exude a gummy ooze. Lesions on all plant parts will contain numerous, tiny black fruiting bodies (pycnidia).

Management—Crop rotation, sanitation (destruction of crop residue), use of pathogen-free seed, and fungicides.



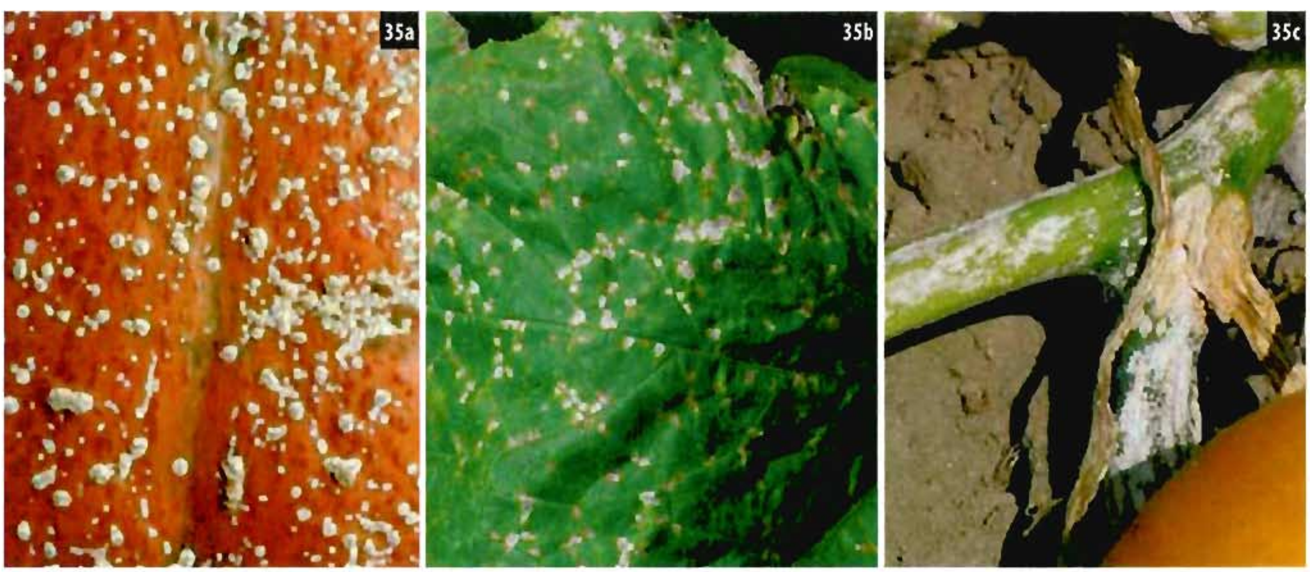
Gummy stem blight—exudate on muskmelon vine (a) and symptoms on watermelon fruit (b), foliage (c), vine (d), and in field (e).



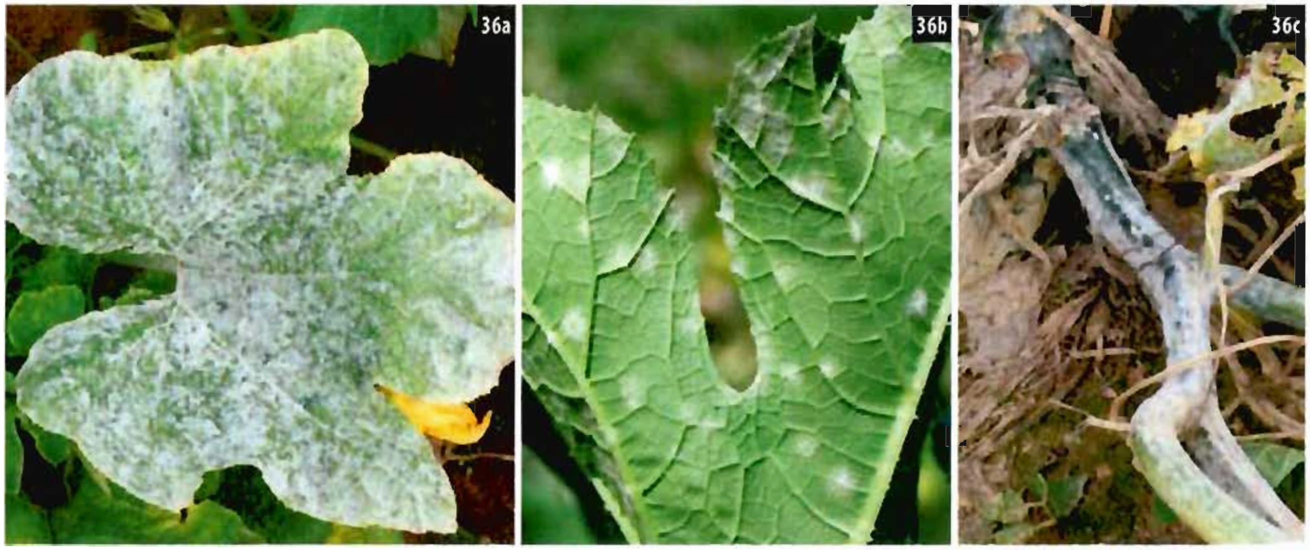
Phytophthora blight—crown rot (a), fruit rot (b), and leaf lesion (c) on yellow squash; fruit rot on watermelon fruit (d).

34. Phytophthora blight *(Phytophthora capsici)* affects all cucurbits, although different plant parts are affected on a given host. Symptoms on cucumber, muskmelon, and watermelon are normally found on leaves and fruit. The disease affects all parts of pumpkin and squash. Symptoms include damping-off, root rot, crown rot, stem rot, wilting/collapse of plants, and lesions on leaves and fruit. Lesions on stems are constricted, darkened, and water-soaked, often extending a few inches above the soil line, similar to black shank of tobacco. Lesions on leaves tend to be circular and initially water-soaked in appearance. Later, a tan to dark brown color will develop. Circular lesions are common on fruit and will appear water-soaked and sunken. Particularly in damp weather, the lesion's surface may be covered in a thin, yeasty film made up of mycelium and sporangia of *P. capsici.*
Management—Crop rotation, irrigation management (avoid excess soil moisture/overhead irrigation), sanitation (avoid movement of contaminated soil), and fungicides.

35. Plectosporium blight *(Plectosporium tabacinum)*, formerly called Microdochium blight, affects pumpkin primarily and squash to a lesser degree. Symptoms include elongated, white, somewhat diamond-shaped lesions on stems, petioles, and veins of leaves. Lesions also may be found on leaf surfaces. As the disease progresses, significant blighting (large bleached areas) and decline occur. Lesions can be found on fruit handles and rinds; these lesions can merge to form large, blighted areas on the fruit.
Management—Crop rotation, plastic mulch, and fungicides.



Plectosporium blight on pumpkin fruit (a), foliage (b), and stem (c).

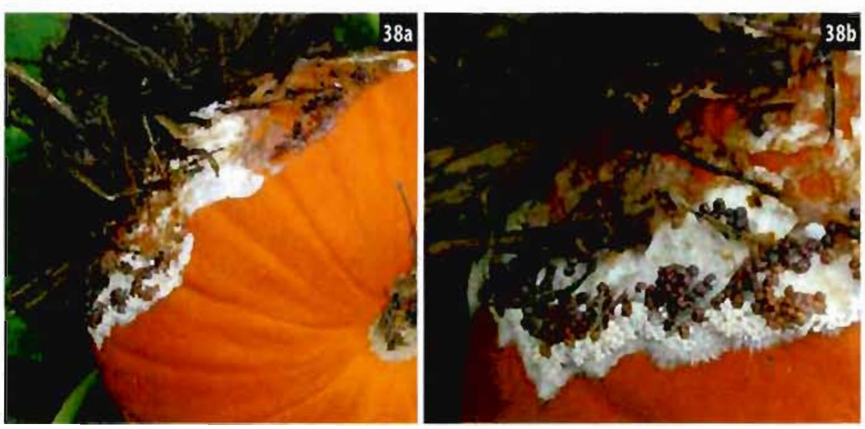


Powdery mildew on upper (a) and lower (b) pumpkin foliage and on cucurbit vine (c).

36. Powdery mildew *(Podosphaera xanthii)* affects all cucurbits. Symptoms appear first on leaves that are older or on shaded portions of the plant and appear as talc-like colonies on upper and lower leaf surfaces. As the disease progresses, the entire leaf surface will be colonized by the fungus, and symptoms can develop on stems and fruit. Severely infected leaves become yellow and then necrotic; these leaves die within a short period, which can result in large-scale defoliation. Powdery mildew is most severe after fruit-set and in densely planted fields.
Management—Resistant varieties (cucumber, muskmelon, and pumpkin) and fungicides.

Cucumber scab.

37. Scab *(Cladosporium cucumerinum)* may appear on cucumber, muskmelon, pumpkin, and squash. Leaves and stems can be affected, but the greatest losses occur when fruit are infected. On fruit, small, sunken spots develop that may be covered with an olive-green mass of spores. Secondary pathogens may invade lesions, leading to fruit rot.
Management—Resistant varieties, pathogen-free seed, crop rotation, and fungicides.



Southern blight on pumpkin (a) and close-up of sclerotia (b).

38. Southern blight *(Sclerotium rolfsii)* is primarily seen on cucumber, muskmelon, pumpkin, and watermelon. Symptoms begin where fruit comes in contact with the soil surface. Affected areas are soft and water-soaked and will be covered with a dense mat of white, fan-like fungal growth. Often, numerous survival structures called *sclerotia* will be associated with fungal growth and are generally small (roughly the size of a mustard seed), round, and tan to brown in color.
Management—Crop rotation and deep turning of crop residues prior to planting.

Angular leaf spot on cucumber foliage.

Diseases Caused by Bacteria

39. Angular leaf spot (*Pseudomonas syringae* pv. *lachrymans*) primarily affects cucumber but may occur on muskmelon, squash, pumpkin, and watermelon. Leaves develop small, water-soaked spots (lesions) that later enlarge. The shape of older lesions tend to be angular as they enlarge and encounter veins. Under very humid conditions and warm temperatures, white ooze may be found on the underside of lesions. Stems and fruit may develop water-soaked spots and necrosis.

Management—Pathogen-free seed, hot-water treatment of seed (cucumber only), crop rotation, irrigation management (minimize leaf wetness and soil splash), proper ventilation (greenhouses), resistant varieties, and applications of fixed copper.

40. Bacterial rind necrosis (undetermined bacterial pathogen[s]) affects watermelon only. Dry areas that are hardened, brown to reddish-brown, and corky develop in the rind interior. These necrotic spots can expand or merge to affect large portions of the rind. Symptoms are rarely visible on the surface of the rind, and flesh is not commonly affected.

Management—No controls are available; however, there is some indication that the pathogen can carry over in infested fields. Avoid fields where this disease has occurred in the past.

Internal (a) and external (b) symptoms of bacterial rind necrosis.

Bacterial wilt in pumpkin field (a) and sticky exudate in infected stem (b).

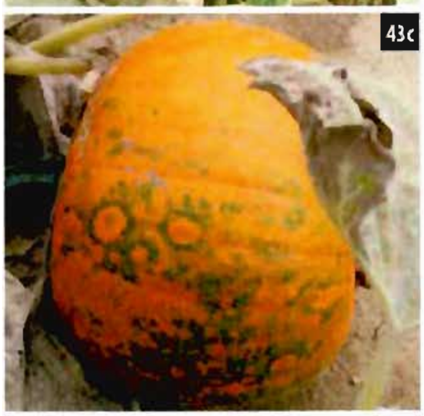
41. Bacterial wilt *(Erwinia tracheiphila)* affects cucumber and muskmelon most severely; however, this disease may occur on gourds, squash, and pumpkin as well. Initially, individual leaves or groups of leaves wilt on vines followed by rapid wilting of entire runners or whole plants. Collapsed foliage may be dark green in appearance and will later become necrotic. Cut stems may emit a sticky exudate, and a slight discoloration of xylem tissue may be seen—key diagnostic features for this disease. Cucumber beetles are the vector of this disease. The beetles or evidence of their feeding are often present on symptomatic vines and leaves.

Management—Begin an insect management program early (at emergence or transplanting) to prevent feeding by cucumber beetles. Refer also to the section on cucumber beetles (13).

Yellow vine decline.

42. Yellow vine decline *(Serratia marcescens)* affects muskmelon, pumpkin, squash, and watermelon. Symptoms begin to appear approximately two weeks before fruit matures. The disease may appear initially as stunting of plants and/or intense yellowing of foliage followed by a slow decline in plant health. In some cases, a sudden collapse of vines may occur with no other symptoms. Vascular tissue from crowns of affected plants is often discolored (light brown). The pathogen is transmitted through feeding by the squash bug, and the presence of these insects, along with symptoms of the disease, can help in the initial diagnosis.

Management—Effective control of yellow vine decline is completely dependent on early management of squash bugs, beginning at emergence or transplanting. Refer also to the section on squash bug (17).



Potyvirus complex symptoms on pumpkin foliage (a, b) and fruit (c); and on zucchini squash (d).

Root-knot nematode on summer squash roots.

Diseases Caused by Viruses

43. Diseases caused by viruses are common on cucurbits in Kentucky, especially during warm weather and later in the season, when insect populations tend to be higher. **Cucumber mosaic virus** (CMV), **papaya ringspot virus** (PRSV), **squash mosaic virus** (SqMV), **watermelon mosaic virus** (WMV), and **zucchini yellow mosaic virus** (ZYMV) are among the most common viral pathogens. Symptoms include stunting, mosaic patterns on leaves, and leaf distortion; different viruses may cause similar symptoms. Aphids are the primary vectors for the major viruses that attack cucurbits in Kentucky, although SqMV is vectored by cucumber beetles. Aphid-transmitted viruses are part of a complex belonging to the Potyvirus group.

Management—Adjusted planting date (viruses tend to be more severe in later plantings), resistant varieties (primarily squash), weed control (weeds can harbor vectors and viruses), vector control (minimally effective), reflective mulches, and stylet oils.

Diseases Caused by Nematodes

44. Root-knot nematode *(Meloidogyne incognita)* affects all cucurbits. In Kentucky, root-knot nematode is a problem mainly in areas with lightly textured or sandy soils. Aboveground symptoms include stunting and chlorosis of plants. Leaves of affected plants may develop chlorosis between veins or symptoms of nutrient deficiency; roots show a characteristic knotting and galling.

Management—Crop rotation, sanitation, and soil fumigants.

Chemical Injuries

Fertilizer burn to cucumber seedlings.

45. Fertilizer burn occurs when chemical fertilizers (which are composed of salts) are applied at high concentrations. Although all vegetables can be affected by fertilizer burn, cucurbits are particularly sensitive because they do not have a thick waxy cuticle on their leaves. Therefore, they do not shed water as well as some other vegetables, such as onions or the *Brassica* species. When the water containing the fertilizer evaporates from the leaves, all that is left is the fertilizer salt, which can quickly desiccate (dry out) the leaves, leading to fertilizer burn. Seedlings are very tender and are particularly sensitive. Symptoms include a generalized burned appearance or flecking resembling a spray pattern. **Management**—Avoid foliar feeding if possible; care should be taken when it is necessary. Compared to roots, the leaves are capable of taking up only small quantities of fertilizer. When using a water-soluble fertilizer in the greenhouse, growers may want to rinse the fertilizer off the leaves. Growers should plan on providing all the necessary fertility for their crops through fertigation or soil applications.

46. Chlorothalonil (Bravo, others) **injury.** Damage from this commonly used cucurbit fungicide has been observed on watermelon late in fruit development. Symptoms appear as a light brown or white burned appearance on watermelon fruit.

47. Clomazone (Command 3ME) **injury**. Used to control annual grasses and small-seeded broadleaf weeds, this herbicide is a chlorophyll/carotenoid pigment inhibitor. Affected leaves appear bleached, sometimes with a tinge of pink/purple. New growth initially appears normal except for the lack of green and yellow pigments. Clomazone is labeled for preplant or pre-emergence application. **Management**—Use according to the label and apply with a shielded sprayer if spraying row middles.

Chlorothalonil injury to watermelon.

Clomazone injury to foliage.


Dinitroanaline injury to watermelon roots.

48. Dinitroanaline injury. This class of herbicide contains an active ingredient which generally ends with "alin," (for example, ethalfluralin). Ethalfluralin is the active ingredient in Curbit, a commonly used herbicide labeled for cucurbit crops. Dinitroanalines alter root and shoot development and are used for pre-emergent control of grasses and broadleaf weeds. Symptoms of injury include a swelling or splitting of the primary root and shoot, which will eventually lead to poor growth, wilting, and typically death later in the season. Ethalfluralin is also an active ingredient in the herbicide Strategy.
Management—This herbicide should be applied to the soil surface (not incorporated) after seeding. Dinitroanalines prevent the full germination of weed seeds near the surface; seed of the crop to be grown is generally not affected since it is planted deeply enough to avoid damage. However, if the soils are wet or a heavy rain occurs after application, the herbicide will move deeply enough in the soil to affect the crop. For this reason, do not incorporate, do not apply to wet soils, and do not apply prior to an anticipated rain.

49. Glyphosate (Round-up) **injury.** This non-selective herbicide, which is used to control grasses and broadleaf weeds, is systemic. Any spray drift will be absorbed by leaves and translocated throughout the entire plant, often resulting in death. Symptoms appear as a strong yellowing of newly emerged leaves and a yellowing of the center/base of older leaves.
Management—Avoid spray drift by using shielded sprayers and spraying on calm days.


Glyphosate injury to pumpkin foliage.

50. Halosulfuron (Sandea) **injury.** An herbicide labeled for use on many cucurbits (cucumbers, melons, pumpkins), halosulfuron controls many broadleaf weeds and nutsedge but not grasses. This herbicide can be applied pre-plant under plastic or post-transplant on bare ground and row middles. Cool temperatures at time of application and use of an organophosphate insecticide may enhance injury. The application of Sandea over the top of melons or cucumbers growing on plastic can cause injury. Symptoms appear as a patchy yellowing of leaves on affected plants.
Management—Use only on labeled crops and at appropriate rates. Do not spray on plastic mulch, as this herbicide may wash from the surface of the plastic and concentrate in the planting hole.


Halosulfuron injury to pumpkin foliage (a) and muskmelon foliage (b).

For more information

Specific pest management and crop production information can be found in the following University of Kentucky publications available at county Extension offices, as well as on the Internet.

Production and pest management

Vegetable Production Guide for Commercial Growers (ID-36)
http://www.ca.uky.edu/agc/pubs/id/id36/id36.htm

Home Vegetable Gardening in Kentucky (ID-128)
http://www.ca.uky.edu/agc/pubs/id/id128/id128.pdf

Plant Pathology fact sheets

Blossom End Rot (PPFS-VG-02)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-VG-2.pdf

Southern Blight (PPFS-VG-03)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-VG-3.pdf

Entomology fact sheets

Cucumber Beetles (ENTFACT-311)
http://www.ca.uky.edu/entomology/entfacts/ef311.asp

Silverleaf Whitefly on Squash (ENTFACT-319)
http://www.ca.uky.edu/entomology/entfacts/ef319.asp

Squash Vine Borer and Squash Bug (ENTFACT-314)
http://www.ca.uky.edu/entomology/entfacts/ef314.asp

Two-Spotted Spider Mites (ENTFACT-310)
http://www.ca.uky.edu/entomology/entfacts/ef310.asp

Whiteflies in Gardens (ENTFACT-303)
http://www.ca.uky.edu/entomology/entfacts/ef303.asp

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ALABAMA COOPERATIVE Extension SYSTEM

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ANR-872

ALABAMA A&M AND AUBURN UNIVERSITIES

Plant Disease Notes

Fusarium Wilt of Cucurbits

Fusarium wilt, caused by soil-borne fungi in the genus *Fusarium*, affects most cucurbits. Although several *Fusarium* species and physiological races on cucurbits have been identified, this publication will only discuss Fusarium wilt of watermelon and cantaloupe.

Fusarium Wilt of Watermelon

Fusarium wilt of watermelon is caused by the fungus *Fusarium oxysporum f.* sp. *niveum*. The fungus also attacks summer squash but not cantaloupe or cucumber.

Symptoms. Plants infected early in their development often damp off at the soil line. Older plants may first exhibit temporary wilting only during the heat of midday but will die within a few days. Wilt symptoms develop in one or more lateral vines, starting at the tip. In wet weather, a white to pink fungal growth may be visible on the surface of the dead stems.

On a section of the main stem, cut back the epidermis and cortical tissue (bark) slightly above the soil line. If Fusarium wilt is present, you will see a light brown discoloration of the vascular tissue (the food- and water-conducting vessels just beneath the epidermis).

Persistence And Transmission. The causal fungus survives from season to season in old infected vines, on seed, and in soil. The fungus can live on dead plant material (saprophytically) or on the roots and stems of other plants such as tomatoes and several weeds. Infection occurs through the root tip, natural openings, or wounds (such as nematode feeding sites), and eventually the fungus invades the water-conducting vessels. Plugging of the vessels leads to reduced water movement followed by wilt and death. Disease incidence and severity are increased during warm, dry weather.

Control. The following are practical methods of control in Fusarium-infested soils:

- Plant Fusarium resistant varieties in the same field once every 5 to 7 years.
- Plant susceptible varieties no more than once every 15 years.
- Rotate to nonhost species.

Fusarium Wilt of Cantaloupe

Fusarium wilt of cantaloupe is caused by the fungus *Fusarium oxysporum f.* sp. *melonis*. The fungus infects only cantaloupe, crenshaw melon, and honeydew melon.

Symptoms. Fusarium wilt of cantaloupe causes symptoms similar to those described on watermelon. However, on cantaloupe, streaks may develop externally on the runner at the soil line and extend for some distance up the vine. Streaks are at first light brown, turning yellowish tan, then dark brown with age. This symptom is diagnostic for the disease. As with watermelon, a white to pink fungal growth may develop on infected stems during wet weather.

Persistence and Transmission. Fusarium wilt of cantaloupe overwinters and spreads like Fusarium wilt of watermelon.

Control. Fusarium wilt of cantaloupe is most reliably controlled by the following practices:

- Plant resistant varieties.
- Rotate to nonhost species.

ALABAMA COOPERATIVE Extension SYSTEM

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ANR-872

Edward J. Sikora, *Extension Plant Pathologist,* Professor, Entomology and Plant Pathology, Auburn University

Use chemicals only according to the directions on the label. Follow all directions, precautions, and restrictions that are listed.

Trade names are used only to give specific information. The Alabama Cooperative Extension Service does not endorse or guarantee any product and does not recommend one product instead of another that might be similar.

For more information, call your county Extension office. Look in your telephone directory under your county's name to find the number.

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University of Kentucky College of Agriculture Plant Pathology Extension

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PPFS-VG-07

Plant Pathology Fact Sheet

Fruit Rots of Cucurbits

Kenny Seebold
Extension Plant Pathologist

Introduction

Vegetables in the cucurbit family include cucumber, muskmelon (cantaloupe), summer squash, winter squash, and pumpkin. The following diseases primarily affect the fruit of these crops and can result in losses in commercial fields and home gardens.

Belly Rot

Belly rot mainly affects cucumber; it is rarely found on other cucurbits.

Symptoms and Signs

This rot develops where the fruits come into contact with the soil. Young infected fruit have a yellowish brown, superficial discoloration which later develops into sunken irregular spots on the underside or "belly" (Figure 1). Large water-soaked decayed areas may develop on mature fruit.

Cause and Disease Development

Belly rot is caused by the common soil-borne fungus, *Rhizoctonia solani*. This fungus survives in soil and infested crop debris as mycelia and sclerotia. Warm temperatures, high humidity, and excessive moisture favor infection and disease development. Under favorable conditions, symptoms can become evident within 24 hours of infection and entire fruits may decay in 72 hours.

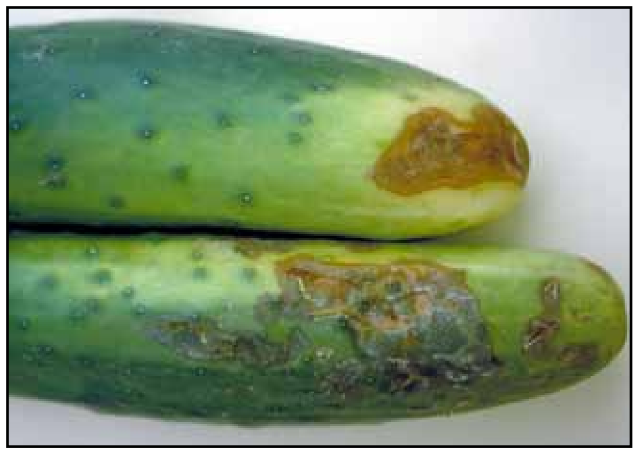


Figure 1. Belly Rot of Cucumber.

Disease Management

- Prior to planting, deeply till the soil.
- Provide a physical barrier, such as black plastic mulch, between the fruit and the soil.
- Manage irrigation practices to avoid excessively wet soils.
- Start a fungicide program when the cucumber plants begin to vine.

Choanephora Fruit Rot

This fungal disease is commonly observed on summer squash, but it may also affect cucumber and pumpkin.

Symptoms and Signs

Symptoms begin as a soft, wet rot of flowers and the blossom end of fruit. Infected fruits decay rapidly, becoming soft and watery. A profuse, fuzzy fungal growth with large masses of black spores forms on infected tissues (Figure 2). The pathogen's distinctive appearance (like numerous small black-headed pins sticking out of a pincushion) is diagnostic for this disease.

Figure 2. Choanephora Fruit Rot of Summer Squash.

Cause and Disease Development

The pathogen, *Choanephora cucurbitarum*, overwinters in the soil on dead plant tissue or as dormant spore structures. Spores released in the spring are spread by wind and insects to squash blossoms. This fungus infects wilted blossoms and then spreads to the attached fruit. High relative humidity and wet conditions favor disease development.

Disease Management

There are no effective controls available; however, the following may help:

- Fungicides may reduce disease incidence; however, it can be difficult to protect developing blossoms throughout the season.
- Practices that reduce leaf wetness can be of benefit. Avoid overhead irrigation or time overhead watering to allow for leaf drying.

Cottony Leak

Cottony leak, also referred to as Pythium fruit rot, affects most cucurbits; however, it is most common on cucumber and squash.

Symptoms and Signs

This disease generally appears first on portions of fruit in contact with soil. Small, water-soaked spots expand rapidly until large portions of the fruit are necrotic and soft. Profuse, white fungal growth resembling tufts of cotton (Figure 3) can be found on rotted areas when the humidity is high.

Cause and Disease Development

Several species of *Pythium*, a fungus-like organism, have been implicated in this disease. These soil-borne pathogens can overwinter as dormant spore structures in the residue of many different crops and weeds. Infection occurs through wounds or where the fruit touches the wet ground. *Pythium* spp. is easily disseminated via water and soil particles. Wet conditions promote infection and decay.

Figure 3. Cottony Blight of Cucumber.

Disease Management

- Manage excess soil moisture by providing good drainage and monitoring irrigation practices.
- Use plastic mulch.
- Fungicides may provide some disease suppression.

Fusarium Fruit Rot

Many cucurbits can be affected by Fusarium fruit rot, but it is particularly devastating on pumpkin. Decay can occur in the field or in storage after harvest.

Symptoms and Signs

Infected fruit develop lesions, usually circular and of varying size (Figure 4). The tissue beneath the lesions may be discolored and corky. Fungal growth ranging from white to pink to purple in color may be seen on infected tissues.

Figure 4. Fusarium Fruit Rot of Pumpkin.

Cause and Disease Development

Several species of *Fusarium* are known to cause fruit decays in cucurbits. These soil-borne fungi overwinter as mycelium in plant debris or as thick-walled chlamydospores. Infection generally occurs through wounds.

Disease Management

- Rotate out of cucurbits for several years.
- Provide physical barriers which minimize contact of the fruit with soil.
- Handle fruit carefully during harvest to avoid wounding.
- Cure fruit properly.

Scab

Scab may appear on cucumber, muskmelon, pumpkin, and squash. While leaves and stems can be affected, the greatest losses occur when fruit are infected.

Figure 5. Scab lesions on Cucumber

Symptoms and Signs

Small, sunken spots develop on fruit; lesions may be covered with an olive-green mass of spores (Figure 5). Secondary pathogens may invade lesions, leading to fruit rot.

Cause and Disease Development

The pathogen, *Cladosporium cucumerinum*, overwinters in cucurbit vines left in the field or garden, and in seeds. Spores produced by the fungus are easily spread via air currents to susceptible tissues. Wet conditions, including fogs and dews, along with moderate to cool temperatures, favor this disease.

Disease Management

- Purchase pathogen-free seed.
- Plant resistant varieties.
- Practice crop rotation.
- Follow a good fungicide spray program.

Southern Blight

Southern blight can cause fruit decay of cucumber, muskmelon, pumpkin, and watermelon. The pathogen has an extremely wide host range that also includes other vegetable crops (e.g. pepper, tomato, carrots, and beans), tree fruits (e.g. apple), herbaceous ornamentals (e.g. ajuga and vinca), and tobacco.

Symptoms and Signs
Symptoms begin where the fruit comes in contact with the soil surface. Affected areas are soft and water-soaked, later becoming covered with a dense mat of white, fan-like fungal growth. As the disease progresses, numerous small, round fungal survival structures (sclerotia) develop in the fungal mat (Figure 6). Initially the sclerotia are white; later becoming light brown, reddish brown, or golden brown in color. Each sclerotium is roughly the size of a mustard seed. The pathogen also attacks stems and crowns, resulting in sudden wilting of the foliage.

FIGURE 6. SOUTHERN BLIGHT ON PUMPKIN. NOTICE THE SMALL, ROUND SCLEROTIA DEVELOPING IN THE FUNGAL MAT.

Cause and Disease Development
Southern blight is caused by the soil-borne fungus *Sclerotium rolfsii*. This fungus survives as mycelium and sclerotia in the soil and in decomposing plant residue. The fungus is moved by running water, on infested soil particles clinging to cultivating tools, on infected plant material, and as sclerotia mixed with seeds. Disease development is enhanced by high temperatures and humidity. Southern blight is also more severe where undecomposed organic matter is left on and in the soil. Sclerotia enable the fungus to survive adverse conditions and can persist in the upper layers of soil for many years.

Disease Management
- Remove infected plants and fruit whenever practical.
- Deep plow plantings early to bury sclerotia and to allow for the complete decomposition of plant residues.
- Practice crop rotation using less susceptible plants such as corn, sorghum, small grains, and grasses.

BACTERIAL RIND NECROSIS
Only watermelon is affected by bacterial rind necrosis.

Symptoms and Signs
Hardened, brown to reddish-brown, corky, dry areas develop in the rind interior (FIGURE 7). These necrotic spots can expand or merge to affect large portions of the rind. Symptoms are rarely visible on the surface of the rind, and watermelon flesh is not commonly affected.

FIGURE 7. BACTERIAL RIND NECROSIS IN WATERMELON.

Cause and Disease Development
Various bacterial pathogens, such as *Erwinia* spp., have been reported as the cause of this disease. Little is known about the conditions favoring infection and disease development.

Disease Management
No controls are available; however, there is some indication that the pathogen can carry over in infested fields. Avoid fields where this disease has occurred in the past.

Additional Resources

University of Kentucky publications are available at County Extension offices, as well as on the Internet.

- Home Vegetable Gardening in Kentucky, ID-128 (University of Kentucky) http://www.ca.uky.edu/agc/pubs/id/id128/id128.pdf

- IPM Scouting Guide for Common Problems of Cucurbit Crops in Kentucky (University of Kentucky, 2009) http://www.ca.uky.edu/agc/pubs/id/id91/id91.pdf

- Southern Blight, PPFS-VG-03 (2008) http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-VG-3.pdf

- Vegetable Production Guide for Commercial Growers, ID-36 (University of Kentucky) http://www.ca.uky.edu/agc/pubs/id/id36/id36.htm

(Issued November 2010)

Photos by: Cheryl Kaiser (figs. 1 & 3), John Hartman (fig. 2), Julie Beale (fig. 4), Kenny Seebold (fig. 6); William Nesmith (fig. 7), University of Kentuicky; and Mary Ann Hansen (fig. 5), Virginia Tech, Bugwood.org

Table 8--Cultivated blueberries: Commercial acreage, yield per acre, production, and season-average grower price in the United States, 1980-201

State and year	Acreage harvested	Yield per acre	Utilized production	Utilization: Fresh	Utilization: Processed	Grower price: Fresh	Grower price: Processed	Grower price: All	Value of utilized production
	Acres	*Pounds*	*-- 1,000 pounds*			*-- Dollars/pound --*			*1,000 dollars*
1980	21,850	NA	81,063	43,183	37,885	NA	NA	NA	41,361
1981	22,180	NA	95,250	44,516	50,734	NA	NA	NA	55,161
1982	12,120	NA	85,770	43,430	42,340	NA	NA	NA	65,306
1983	25,400	NA	89,698	40,355	49,343	NA	NA	NA	61,501
1984	12,650	NA	95,376	57,084	37,292	NA	NA	NA	50,824
1985	12,500	NA	102,600	56,778	45,822	NA	NA	NA	59,009
1986	28,600	NA	111,417	53,817	57,600	NA	NA	NA	68,777
1987	13,000	NA	110,788	52,411	58,677	NA	NA	NA	77,064
1988	13,600	NA	100,502	45,904	54,214	NA	NA	NA	94,858
1989	30,420	NA	127,620	56,885	70,735	NA	NA	NA	86,842
1990	13,100	NA	103,845	51,730	52,115	NA	NA	NA	66,546
1991	13,550	NA	114,766	50,472	64,294	NA	NA	NA	88,155
1992	33,650	3,310	111,320	45,502	65,818	1.10	0.67	0.85	94,097
1993	36,500	4,600	167,748	69,545	98,203	0.88	0.33	0.56	93,254
1994	37,100	3,680	136,460	68,040	68,420	0.90	0.43	0.66	90,673
1995	38,040	4,180	159,000	74,760	84,240	0.90	0.40	0.64	101,279
1996	37,750	3,320	125,380	62,380	63,000	1.06	0.76	0.91	113,780
1997	38,670	4,310	166,620	69,300	97,320	1.10	0.64	0.83	138,490
1998	39,000	3,790	147,880	75,140	72,740	0.97	0.48	0.73	107,483
1999	39,630	4,400	174,260	77,520	96,740	1.16	0.66	0.88	153,978
2000	40,820	4,480	182,890	79,080	103,810	1.29	0.73	0.97	177,804
2001	40,430	4,670	188,750	88,290	100,460	1.26	0.53	0.87	164,059
2002	41,850	4,510	188,650	100,490	88,160	1.41	0.60	1.03	194,566
2003	42,070	4,470	187,900	103,620	84,280	1.49	0.78	1.17	220,649
2004	44,850	5,070	227,610	124,590	103,020	1.55	0.81	1.21	276,011
2005	48,980	4,860	238,210	123,140	115,070	1.93	0.91	1.44	342,347
2006	54,440	5,210	283,650	146,860	136,790	2.11	1.39	1.76	500,052
2007	53,420	5,370	286,780	149,830	136,950	2.14	1.54	1.85	531,075
2008	60,180	5,790	348,660	193,560	155,100	2.09	0.86	1.54	536,992
2009	63,770	5,720	364,900	225,050	139,850	1.88	0.45	1.33	485,380
2010	69,610	5,900	410,830	246,040	164,790	1.87	0.82	1.44	593,407
2011 P	72,000	5,940	427,900	278,200	149,700	2.14	1.28	1.84	788,765

NA = Not available. P = preliminary.

Source: USDA, National Agricultural Statistics Service, *Noncitrus Fruits and Nuts Summary,* various issues.

Cranberry Forecast

August 16, 2011

United States Department of Agriculture
National Agricultural Statistics Service
New England Field Office

NEW ENGLAND Agricultural Statistics
53 Pleasant Street
Room 2100
Concord, NH 03301

Gary R. Keough , Director | Phone: 603-224-9639 | Fax: 603-225-1434 | www.nass.usda.gov/nh | nass-nh@nass.usda.gov

A special “THANK YOU” goes to Massachusetts cranberry growers and handlers who have helped us by completing cranberry surveys throughout the year.

Massachusetts Cranberry Production Forecast Up Eleven Percent

The United States production forecast for the 2011 cranberry crop is 7.50 million barrels, up 10 percent from 2010. If realized, this will be the second largest production on record. Production forecasts are up from last year in Massachusetts, Oregon, Washington, and Wisconsin but down in New Jersey.

The Massachusetts cranberry forecast is 2.10 million barrels, up 11 percent from 2010. If this production comes to fruition it would be tied for the second largest crop on record. Favorable weather conditions during June and the first half of July aided pollination. Some growers reported higher than normal weed pressure.

Production in Wisconsin is forecast at 4.30 million barrels, up 9 percent from 2010. The crop was reported to be progressing well. A cool spring did not damage the crop but reportedly lengthened the growing season.

New Jersey expects a crop of 540,000 barrels, down 4 percent from 2010. Harvested acreage is reportedly down this season and some growers expressed concerns of potential sun scalding of fruit due to above normal temperatures. However, the crop was generally in good condition with no unusual problems reported.

The Oregon cranberry crop has rebounded from last year’s low production with a forecasted harvest of 385,000 barrels, up 33 percent from the 2010 crop. The growing season was delayed by a cool spring but recent favorable weather conditions have improved crop development.

CRANBERRIES: Total Production, 2009, 2010, and 2011 Forecast

State	Total Production		
	2009	2010	2011
	Barrels [1]		
Massachusetts	**1,817,000**	1,891,000	2,100,000
New Jersey	555,000	562,000	540,000
Oregon	430,000	290,000	385,000
Washington	161,000	108,000	173,000
Wisconsin	3,950,000	3,960,000	4,300,000
UNITED STATES	6,913,000	6,811,000	7,498,000

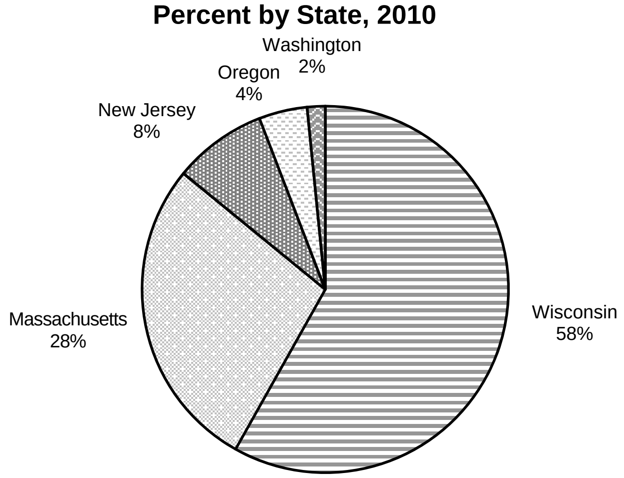
[1] A barrel weighs 100 pounds.
SOURCE: ***Cranberries,*** August 16, 2011, National Agricultural Statistics Service, USDA.

CRANBERRIES: Acres, Yield, Production, Utilization, Price and Value, by State, 2008 – 2010

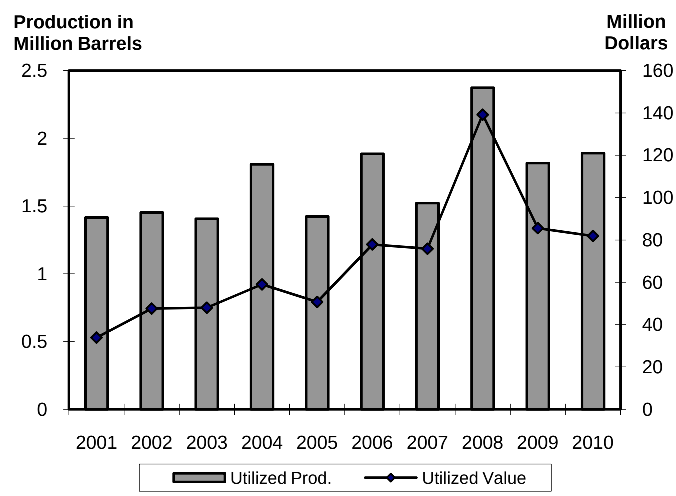
Year and State	Acres Harvested	Yield per Acre [1]	Production		Utilization		Price per Barrel [2]			Value of Utilized Production
			Total	Utilized	Fresh	Processed	Fresh	Processed	All	
	Acres	Barrels					Dollars			1,000 Dollars
2008										
Massachusetts	**13,000**	**182.6**	**2,374,000**	**2,374,000**	**128,000**	**2,246,000**	**75.20**	**57.70**	**58.60**	**139,220**
New Jersey [3]	3,100	165.2	512,000	512,000	—	512,000	(X)	53.60	53.60	27,443
Oregon [3]	2,700	148.1	400,000	400,000	—	400,000	(X)	91.50	91.50	36,600
Washington	1,700	64.1	109,000	109,000	23,000	86,000	73.20	53.20	57.40	6,259
Wisconsin	17,700	252.5	4,470,000	4,470,000	220,000	4,250,000	71.00	54.60	55.40	247,670
UNITED STATES	38,200	205.9	7,865,000	7,865,000	371,000	7,494,000	72.60	57.40	58.10	457,192
2009										
Massachusetts	**13,000**	**139.8**	**1,817,000**	**1,817,000**	**86,000**	**1,731,000**	**75.20**	**45.70**	**47.10**	**85,574**
New Jersey [3]	3,100	179.0	555,000	555,000	—	555,000	(X)	56.10	56.10	31,136
Oregon [3]	2,700	159.3	430,000	430,000	—	430,000	(X)	36.30	36.30	15,609
Washington	1,700	94.7	161,000	161,000	27,000	134,000	78.20	57.10	60.60	9,762
Wisconsin	18,000	219.4	3,950,000	3,950,000	220,000	3,730,000	78.20	46.70	48.50	191,395
UNITED STATES	38,500	179.6	6,913,000	6,913,000	333,000	6,580,000	77.40	46.80	48.20	333,476
2010										
Massachusetts	**13,000**	**145.5**	**1,891,000**	**1,891,000**	**112,000**	**1,779,000**	**70.30**	**41.60**	**43.30**	**81,880**
New Jersey [3]	3,100	181.3	562,000	562,000	—	562,000	(X)	55.60	55.60	31,247
Oregon [3]	2,700	107.4	290,000	290,000	—	290,000	(X)	34.50	34.50	10,005
Washington	1,700	63.5	108,000	108,000	27,000	81,000	79.30	56.60	62.30	6,726
Wisconsin	18,000	220.0	3,960,000	3,960,000	80,000	3,880,000	77.60	46.50	47.10	186,628
UNITED STATES	38,500	176.9	6,811,000	6,811,000	219,000	6,592,000	74.10	45.50	46.50	316,486

(X) Not applicable.
[1] Yield is based on total production.
[2] Weighted average of co-op and independent sales. Co-op prices represent pool proceeds less returns for processing non-cranberry products, capital stock dividends, capital stock retains, and other retains.
[3] Small quantities of fresh cranberries are included in processed to avoid disclosure of individual operations.
SOURCE: ***Noncitrus Fruits and Nuts - 2010 Summary***, July 7, 2011, National Agricultural Statistics Service, USDA

United States Cranberry Utilized Production Percent by State, 2010



Cranberry Utilized Production and Value Massachusetts, 2001 – 2010



MAINE CRANBERRIES: Acres, Yield, Production, Price and Value, 2008 – 2010

Year	Acres Harvested	Yield per Acre	Production		Utilization		All Price per Barrel	Value of Utilized Production
			Total	Utilized	Fresh	Processed		
	Acres	Barrels [1]	1,000 Barrels [1]				Dollars	1,000 Dollars
2008	196.7	115.6	22.73	22.73	2.70	20.03	94.20	2,142
2009	198.5	131.2	26.05	24.75	2.23	22.52	49.90	1,234
2010	201.0	145.0	29.14	29.11	3.78	25.33	43.40	1,263

[1] A barrel weighs 100 pounds.
SOURCE: ***Maine Cranberries,*** University of Maine Cooperative Extension, Cranberry Associate.

RUTGERS
New Jersey Agricultural
Experiment Station

CRANBERRY EDITION
APRIL 14, 2011

PLANT & PEST ADVISORY

A RUTGERS COOPERATIVE EXTENSION PUBLICATION

INSIDE

Cranberry Diseases and Fruit Rot Control

Peter Oudemans, Ph.D., Specialist in Plant Pathology and Patricia McManus, Ph.D., Professor of Plant Pathology, University of Wisconsin

Fungal diseases are an important component of cranberry culture. The crop is susceptible to a wide variety of diseases that range in impact from severe to benign (Table 1). Some diseases, such as the cranberry leaf gall, are extremely rare and when they occur may have little or no economic impact. Other diseases can flair-up in certain years and disappear the next. It is very important to understand that although many diseases described from cranberry are found in all growing regions, some diseases such as Fairy Ring are more limited in distribution (Table 1). Other diseases such as Valdensinia leaf spot have not yet been reported on cranberry but represent a significant threat (see article in the cranberry newsletter next month). As stakeholders in the cranberry industry we need to be aware of the micro-organisms that travel with our crop and take precautions not to introduce novel pathogens into areas where they do not currently exist. Valdensinia leaf spot is a prime example of such a disease.

Table 1. Some economically important fungal and fungal-like diseases of cranberry and the distribution of those diseases

Disease	Causal Agent	Distribution
Phomopsis Upright Dieback	*Phomopsis vaccinii*	WA,OR,MA, NJ, WI, MI
Fairy Ring	*Helicobasidium species*	NJ, MA
Cranberry Canker	*Auxin producing bacteria*	WI, MA
Valdensinia Leaf Spot	*Valdensinia heterodoxa*	BC, WA, OR, NS, NB, ME (on blueberry and other Ericaceae)
Cottonball	*Monilinia oxycocci*	OR, WA, MA, WI, ME, AK
Rose Bloom/Red Leaf Spot	*Exobasidium* species	MA, WA, OR
Phytophthora root and runner rot	*Phytophthora* species	MA, NJ, OR, WA, BC, WI
Fruit Rot	See below	See below

SEE CRANBERRY DISEASES ON PAGE 2

Cranberry Diseases from page 1

Each disease has a unique causal agent and some diseases such as fruit rot may be caused by more than one pathogen. Since each pathogen has unique characteristics in terms of life cycle, sensitivity to pesticides, and response to environmental parameters each one must be managed using a series of recommendations that are developed specifically to that disease and causal agent. Each set of recommendations is developed for a specific geographic region and applying recommendations outside of that region is risky and may not provide the expected results. Therefore each time a disease is introduced into a region time and money must be spent learning how to manage the disease and during that time potential yield will lost.

One of the most important first steps that should be taken in developing disease management programs is diagnosis. Improper diagnosis can lead to wasted time and expense. For example, there are several species that can cause Phytophthora root and runner-rot. Each species has distinct temperature optima and fungicide sensitivity and therefore one recommendation does not cover all species. It is often critical to know exactly which pathogen species we are dealing with.

Cranberry Fruit Rot

Cranberry fruit rot is caused by a complex of several fungal species that, with the right environmental conditions, can act individually or in combination to destroy up to 100% of fruit in a cranberry bed. In 2005 a survey was conducted in New Jersey to determine the magnitude of losses due to cranberry fruit rot. In that survey 200 samples were collected from 31 beds planted to the cultivar Stevens. The total area sampled was 130 acres and the total average yield was 412 bbl/acre. Of that yield there was an average of 24% fruit rot which amounted to 9000 bbl. This result demonstrated that the management strategies were not working and required significant revision.

Cultural practices strongly influence environment in a cranberry bed. The open canopies of newer beds tend to be warm, and that may be why diseases such as early rot (*Phyllosticta vaccinii*) are worse in newer beds than in established beds. In the past decade growers have been demanding more from new and older beds alike. New plantings are being pushed hard with nitrogen. This results in plants with lots of leaves that need to be supported by small root systems. More leaves is favorable for fungi, since the fungi like leaves every bit or more than they like fruit. More leaves means more irrigation is required. Lots of water on a warm, sandy bed with soft, rank runners is the perfect storm for disease. In established beds, the new “norm” is 400+ barrels per acre. Such heavy crops mean that berries are packed together deep in the canopy where they remain wet for most or all of the day. In addition to creating an environment ideal for disease, fungicide coverage is more difficult as cultivation practices become more intensive to support a canopy that feeds high yielding beds.

Recommendations for fruit rot management

The current recommended control measures rely on five fungicides: ferbam, mancozeb, chlorothalonil, azoxystrobin and fenbuconazole. All of these fungicides work best when applied before infection occurs and the key to effective fruit rot management is accurate timing of the fungicide applications. We have found that phenology of flowering is the best indicator for timing applications. In Fig. 1 you can see how rapidly control is lost by delaying the first fungicide application. Applications initiated during bloom perform consistently better than those initiated after bloom. In New Jersey the period where fungicide applications are critical range from early to mid-bloom until three weeks post bloom. Maintaining a fungicide residue on the fruit surface during this time will reduce the incidence and risk of fruit rot.

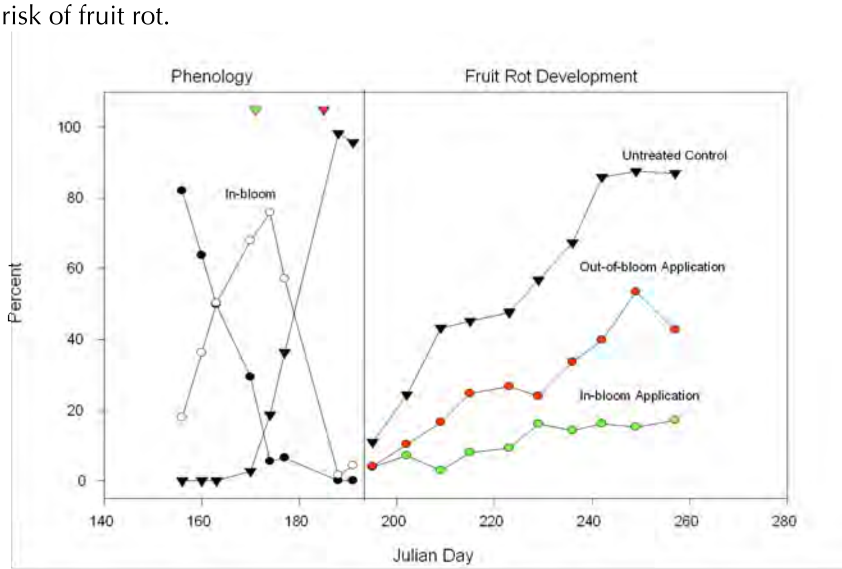


Fig. 1. A comparison of fruit rot development under different treatment timings and an untreated control. Each treatment consisted of two applications of chlorothalonil made 14 days apart. The start date is indicated by a triangle on the phenology side of the chart. The chart demonstrates the importance of timing of fungicide applications to control fruit rot.

See Fruit Rot on page 3

Fruit Rot from page 2

Each of the registered fungicides displays different properties and should be used in a manner that optimizes efficacy and minimizes phytotoxicity. In Table 2 we have summarized the characteristics of each fungicide as it applies to cranberry fruit rot use and control.

TABLE 2. FUNGICIDE USE RECOMMENDATIONS FOR CRANBERRY FRUIT ROT

Fungicide*	REI	PHI	Maximum amount permitted	Suggested use
Abound	4 h	3 days	92.3 fl.oz product	Use at early bloom in combination with Indar. Narrow spectrum fungicide with low efficacy to *Coleophoma*.
Chlorothalonil*	12 h	50 days	3 applications	Use after full bloom. Very effective broad spectrum fungicide. Can be phytotoxic to flowers.
Ferbam Granuflo	12 h	Note**	5 applications	Use during early bloom. Low phytotoxicity. Moderately effective broad spectrum fungicide
Indar 2F	12 h	30 days	4 applications	Use at early bloom in combination with Abound. Narrow spectrum fungicide with low efficacy to *Colletotrichum* species.
Mancozeb*	24 h	30 days	See label	Use during mid –late bloom. Broad spectrum, can inhibit color
Mankocide	24 h	30 days	96 lb	Similar use pattern as mancozeb
Copper products				Not useful for fruit rot control

*Additional trade names:
Chlorothalonil: Bravo 90DG, Bravo 720, Bravo Ultrex, Echo, Equus, Ensign 720, Supanil 720, Terranil 6L, Terranil 90DF.
Mancozeb: Dithane DF, Dithane F-45, Dithane M-45, Manex II, Manzate DF, Penncozeb DF or WP
****Ferbam PHI is 28 days post mid**-bloom

Trouble shooting disease management failures

Most of the recommendations were developed using small research plots to test chemical types and timing to optimize a spray calendar. When scaling up from plot work to commercial fields there are several factors that can lead to control failure. In the table below is a check list of issues to help troubleshoot disease control failures.

Table 3. Factors that can reduce efficacy of a fungicide spray program for cranberry fruit rot

Chemical type and properties	Does the fungicide spectrum of action cover all of the target species? Some fungicides have limited spectrum of action (see Table 2) and will only control certain species. It is important to know which pathogen is causing the disease and if that pathogen is sensitive to the fungicide. Was the interval between applications too long? Each chemical will dissipate at a different rate. This property dictates how frequently a fungicide must be reapplied to maintain the appropriate concentration on the plant surface.
Application	Is the application calibrated to deliver the correct amount of active ingredient per acre? This is a very common mistake. Calculating the size of the area to be treated is sometimes miscalculated and can lead to undesirable effects. If chemigation is being utilized is wash-off time excessive? A general rule of thumb is that if chemigation time allows water to flow off the foliage and wet the ground wash-off is occurring.
Timing	Was the application timed correctly and based on crop development? Applications made to early will dissipate before the pathogen is present. Applications made too late have increasingly minimal effect since the pathogen has penetrated plant and cannot be contacted by fungicide
Pathogen	Is the pathogen you are attempting to control the one that is causing the disease? This is a situation where diagnosis can be critical. Since cranberry fruit rot can be caused by many species of fungi as well as abiotic causes proper diagnosis is critical.
Distribution (in canopy)	Was the fungicide distributed within the canopy? Applications are sometimes made so that they do not penetrate the canopy. In those cases, fungicidal control is greatly diminished in the area where the crop is concentrated.

See Fungicide Efficacy Table on page 6

Insect Update

Cesar Rodriguez-Saona, Ph.D., Specialist in Entomology

Before the season starts, I am providing some general scouting guidelines for cranberry insect pests.

What do you need?

Sampling for Insects

- Sweep net
- Scouting book (record: date, bog, temperature, pests)
- 10X magnifier
- Bags
- Pheromone traps

Monitoring


Lep Larvae, BNLH


SS, BHFW


SFW & SS

Pre-bloom | Bloom | Post-bloom

What to look for?

Immatures

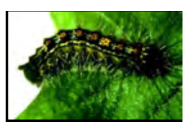

SS
Sparganothis
Fruitworm


SFW
Spotted
Fireworm


BLWM
Cranberry
Blossom worm

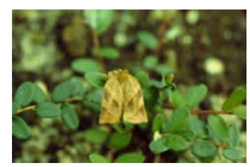

BHFW
Black-Headed
Fireworm

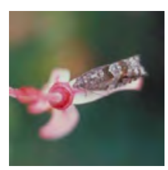

SPW
Spanworm


GM
Gypsy Moth

Adults

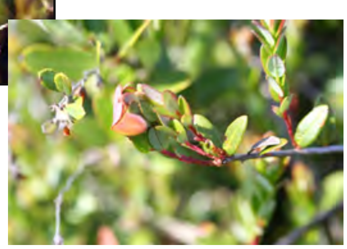

SS
Sparganothis
Fruitworm


SFW
Spotted
Fireworm


BHFW
Black-Headed
Fireworm


BLWM
Cranberry
Blossom worm

Damage



Others - Pests

Blunt-nosed Leafhopper

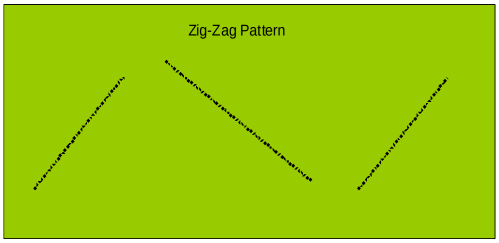
Grubs – Phyllophaga

See Scouting Guidelines on page 5

Scouting Guidelines from page 4

How to Sample?

How to Sweep



Minimum Number of Sweep Sets

1 Sweep Set = 25 Sweeps

1-10 acres	1 sweep set/ acre
10-20 acres	At least 10 sweep sets
More than 20 acres	1 sweep set per 2 acres

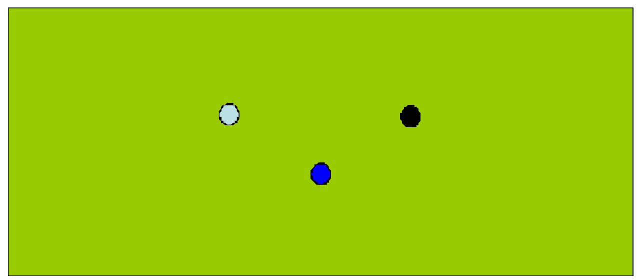
Averill and Sylvia 1998

Action Thresholds

		Average number in sets of 25 sweeps
Black-Headed Fireworm BHFW		1 to 2
Sparganothis Fruitworm SS		1 to 2
Armyworms, blossomworms, gypsy moth	 	4 to 5

Averill and Sylvia 1998

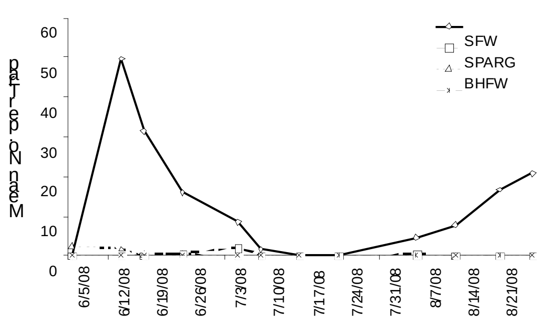
Trap Placement



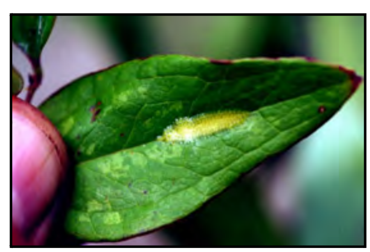
- Bait replaced every 3-4 weeks

- One trap every 10 acres

Flight Activity



Visual Inspection



Reference

Averill, A.L. and Sylvia, M. 1998. Cranberry Insects of Northeast: A guide to identification, biology, and management. University of Massachusetts Cooperative Extension, Amherst, MA. 112 pp.

Weekly Weather Summary

Keith Arnesen, Ph.D., Agricultural Meteorologist

Temperatures averaged near normal, averaging 47 degrees north, 49 degrees central, and 50 degrees south. Extremes were 79 degrees at Downstown on the 6th , and 28 degrees at Belvidere on the 7th. Weekly rainfall averaged 0.81 inches north, 0.67 inches central, and 0.79 inches south. The heaviest 24 hour total reported was 0.73 inches at South Harrison and Seabrook on the 8th to 9th. Estimated soil moisture, in percent of field capacity, this past week averaged 99 percent north, 97 percent central and 96 percent south. Four inch soil temperatures averaged 46 degrees north, 48 degrees central and 48 degrees south.

Weather Summary for the Week Ending 8 am Monday 4/11/11

	RAINFALL			**TEMPERATURE**				**GDD BASE50**		**MON**
WEATHER STATIONS	**WEEK**	**TOTAL**	**DEP**	**MX**	**MN**	**AVG**	**DEP**	**TOT**	**DEP**	**%FC**
BELVIDERE BRIDGE	.95	7.20	1.93	63	28	45.	-3	15	15	97
CANOE BROOK	MISSING									
CHARLOTTEBURG	1.05	13.44	7.75	61	31	45.	0	11	11	98
FLEMINGTON	.33	8.52	2.86	71	32	49.	1	32	32	97
NEWTON	.93	8.50	3.52	64	34	47.	1	15	15	98
FREEHOLD	.57	6.17	.38	77	34	50.	1	41	41	98
LONG BRANCH	.70	6.50	.48	66	34	47.	-2	23	23	98
NEW BRUNSWICK	.69	6.67	1.25	74	34	50.	0	40	40	98
TOMS RIVER	.58	6.03	.30	77	31	47.	-2	37	37	95
TRENTON	.81	5.90	.65	77	36	51.	0	55	53	95
CAPE MAY COURT HOUSE	.78	5.67	.56	72	34	47.	-4	20	19	98
DOWNSTOWN	.62	6.27	1.03	79	34	49.	-2	44	42	95
HAMMONTON	.73	5.77	.47	78	34	49.	-2	49	47	96
POMONA	.74	5.96	.75	76	35	49.	-1	45	45	97
SEABROOK	1.07	6.44	1.83	78	37	53.	2	56	53	96
SOUTH HARRISON	.73	5.47	.49	79	35	49	NA	43	NA	NA

WES KLINE -- GDD BASE 40 PINEY HOLLOW LAST WEEK 12 (ENDING 4/4/11) THIS WEEK 68 (Ending 4/11/11)

* FEBRUARY TOTAL 77

Fungicide Efficacy Table from page 3

Distribution (in field)	Was the chemical applied uniformly to the field? Depending on the equipment being used applications can be extremely variable. This can lead to some areas with excessive residues and others with insufficient residues.
Chemical stability and compatibility	Is the chemical stable in the diluent being used? Are the other components in the tank compatible with the fungicide being applied? For example Abound should not be mixed with emulsifiable concentrates or silicon based adjuvants since these mixtures may promote phytotoxic responses.

Conclusions

Fruit rot control is a critical component to producing a viable, profitable crop. High levels of fruit rot can affect yield as well as quality and create many problems during harvest and delivery. In some regions fruit rot is problematic every year whereas in other areas such as Wisconsin fruit rot occurs occasionally. It is evident that the fungal load is sufficient in Wisconsin to cause significant loss however, the environment dictates if it will be a “bad” fruit rot year or not. It is likely that significant expenditure on fungicides and crop loss to fruit rot could be avoided if the threat of fruit rot could be predicted. Such a predictive scheme could likely be implemented through research. ❏

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Pesticide User Responsibility: Use pesticides safely and follow instructions on labels. The pesticide user is reponsible for proper use, storage and disposal, residues on crops, and damage caused by drift. For specific labels, special local-needs label 24(c) registration, or section 18 exemption, contact RCE in your County.
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2009 Annual Summer Meeting of the American Cranberry Growers Association

P.E. Marucci Center For Blueberry & Cranberry Research & Extension
Rutgers University, Chatsworth, NJ
Thursday August 20th, 2009

Presentation Summaries

American Cranberry Growers Association
2009 Summer Field Day
Thursday August 20, 2009
Rutgers University

P.E. Marucci Center for Blueberry & Cranberry Research & Extension,
Chatsworth, NJ

Parking will be available at the Center"s shop (across cranberry bogs).
Transportation for tours will be provided at the Center.
Restrooms located at the Center, adjacent to Conference Room.

CRANBERRY BOGS:

8:00–8:30 Continental Breakfast (Bog 19)

830 Opening Remarks
Stephen V. Lee, IV President, American Cranberry Growers Association

8:30–9:00 2009 Trials with New Insecticides (Bogs 19-20)
Dr. Cesar Rodriguez-Saona, Extension Specialist, Rutgers University

9:00–9:30 Use of New Fungicide Combinations for Fruit Rot Control (Bog 11)
Dr. Peter Oudemans, Extension Specialist, Rutgers University

9:30–10:00 Update on Chemical Control of Flowering to Enhance Bed Establishment and Reduce Fungal Inoculum (Bog 6)
Dr. James Polashock, Research Plant Pathologist, USDA-ARS, *Dr. Peter Oudemans*, Extension Specialist, Rutgers University

10:00-10:30 Cranberry Breeding Update: Breeding for Fruit Rot Resistance and Maintaining Cultivar Purity (Bog 4)
Dr. Jennifer Johnson-Cicalese, Research Associate, *Dr. Nicholi Vorsa*, Extension Specialist, Rutgers University

CONFERENCE ROOM:

10:50-11:20 Honeybees, wild bees, and the mechanics of cranberry pollination
Dr. Daniel Cariveau, Post-doctoral Research Assistant, Department of Entomology, Rutgers University

11:30–12:00 Pesticide Applicator Safety
Mr. Ray Samulis, Cooperative Extension Agent, Burlington County Extension, Rutgers University

12:00–12:10 Teaching Students Pineland Agriculture and Preparing for the Cranberry Harvest Tour

Ms. Barbara Rheault, Teacher, Mullica Middle School, Elwood NJ

12:10–1:30 LUNCH (POLE BARN)

1:30–2:30 LAB TOURS

Dr. Nicholi Vorsa. Nick is Director at the Marucci Blueberry and Cranberry Research and Extension Center. His research interests involve the areas of plant breeding, genetics, germplasm evaluation and reproductive plant biology.

Dr. Amy Howell. Amy is an Associate Research Scientist at the Marucci Blueberry and Cranberry Research and Extension Center. She works on isolating natural products from cranberries and blueberries that benefit health.

Dr. Peter Oudemans. Peter is an Associate Professor in the Department of Plant Biology and Pathology at Rutgers University and is stationed at the Marucci Blueberry and Cranberry Research and Extension Center. Peter's research program tackles problems in the biology and control of fungal diseases of blueberry and cranberry.

Dr. Cesar Rodriguez-Saona. Cesar is an Assistant Professor in the Department of Entomology at Rutgers University and is stationed at the Marucci Blueberry and Cranberry Research and Extension Center. His research program focuses on the development and implementation of cost-effective reduced-risk insect pest management practices for blueberries and cranberries.

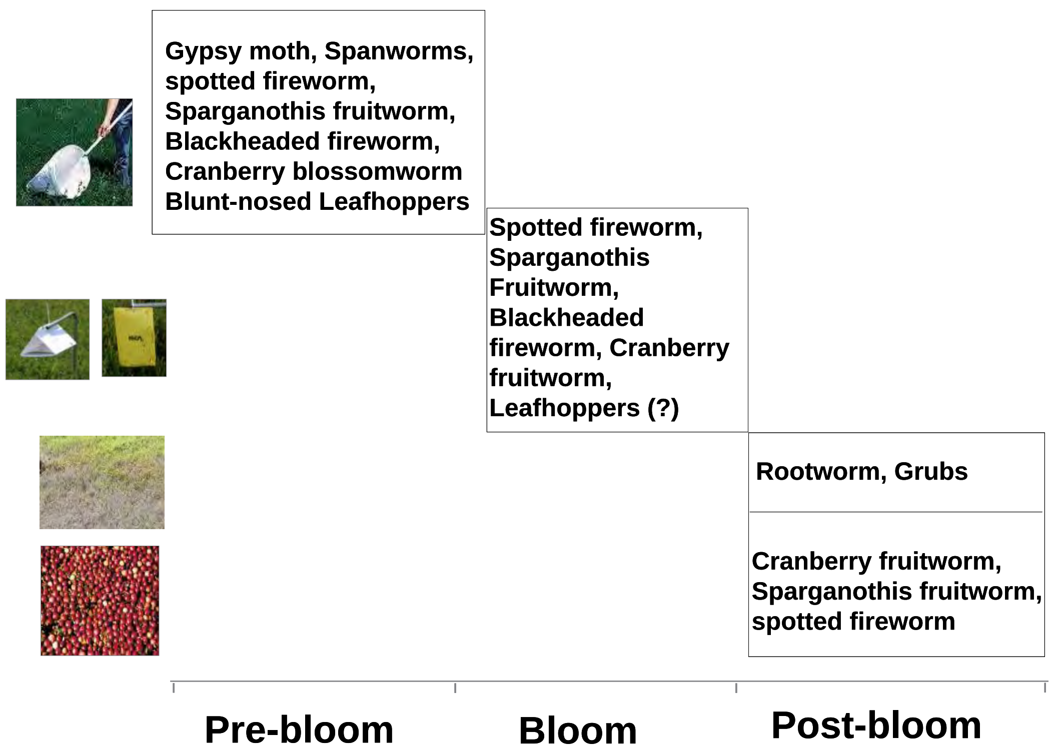
TRIALS WITH NEW INSECTICIDES

Cesar Rodriguez-Saona, Robert Holdcraft, and Vera Kyryczenko-Roth
P.E. Marucci Center for Blueberry & Cranberry Research & Extension,
Rutgers University, Chatsworth, NJ

INTRODUCTION

Not all insects are pests in cranberries. Knowing how to recognize and monitor these pests are key components in insect pest management.

Monitoring for Cranberry Insect Pests



In New Jersey, cranberries have historically been attacked by *Sparganothis* fruitworm, spotted fireworm, blackheaded fireworm, and recently by gypsy moth. Changes in pest management practices due to reduction of organophosphate and carbamate use may cause an increase in secondary pest populations. A major concern among New Jersey growers is the blunt-nosed leafhopper that transmits false blossom. Below is a brief overview of these insects:

***Sparganothis* fruitworm**- Larvae will feed on the fruit surface, inside berries, and on foliage. One larva may feed on several berries. This insect has 2 generations a year.

Adult flight usually peaks towards the last week in June. A second adult flight starts in mid-August and continues through September, these adults will lay eggs, and the newly hatched first instars will overwinter.

Spotted fireworm – High numbers of spotted fireworm larvae are often seen only in cranberry beds where weeds are present in high density. Thus, growers need to monitor for the presence of egg masses on weeds (broadleaf species and grasses). Adult flight typically peaks in the second through third week in June. Larvae from this generation feed on foliage as well as fruit. A second adult flight starts in early August, eggs from the second generation begin to hatch by mid-August, and these larvae will feed on berries and overwinter as second instars. This insect has 2 generations a year.

Blackheaded fireworm – This insect is a sporadic pest in New Jersey. It overwinters on cranberry leaves as eggs. The first-generation larvae are foliar feeders, while the second-generation larvae feed on blossoms and fruit. Growers need to be careful when monitoring for this particular pest during the first generation because, if left untreated, the second generation can cause serious damage. First-generation larvae feed on terminal foliage, webbing them together. Feeding can cause vines to appear as if burned. This insect can be detected by looking for webbing in the upright tips.

Blunt-nosed Leafhopper – This insect is the principal vector of a phytoplasma that causes cranberry false blossom, which threatened the entire cranberry industry in the early 1900‟s. This leafhopper does not move around much, and colonization of bogs occurs slowly. The insect completes one generation a year and overwinters as an egg. Eggs begin to hatch in early May. The nymphs go through five instars in about a month. The adults begin to appear early in July and are most abundant in mid-July. Numbers of this species start to diminish by the first week in August. The adults have a characteristic blunt head and vary from light yellowish-gray to dark brown.

CURRENT STATUS

A few new insecticides have been recently registered for control of insect pests in cranberries. These include: Avaunt, Delegate, and Assail. These have been added to the list of reduced-risk insecticides and organophosphate replacements in cranberries; which consisted of Bt products, the insect growth regulators Confirm and Intrepid, and the neonicotinoid Actara, among others.

Avaunt (Indoxacarb). Avaunt belongs to a new class of insecticides called the oxidiazines. This insecticide has a novel mode of action: it works by inhibiting sodium ion entry into the nerve cells that results in paralysis and death of the targeted pest. Avaunt has broad-spectrum activity and is designated by the EPA as a “reduced-risk” pesticide. This insecticide is effective against some lepidopteran pests in cranberries, including blackheaded fireworm, gypsy moth, and blossom worm, but has low toxicity against *Sparganothis* fruitworm.

Delegate (Spinetoram). This insecticide is similar to SpinTor in that they are both derived from fermentation of a species of bacteria; however, they have different active ingredients. Delegate has both contact and stomach activity, and is highly effective against many lepidopteran larvae: gypsy moth, armyworms, fireworms, *Sparganothis* fruitworm, and spanworms.

Assail (Acetamiprid). This is a new neonicotinoid insecticide with broad-spectrum activity. It is effective against leafhoppers and certain lepidopteran pests (gypsy moth and cranberry fruitworm).

Efficacy of Newly-Registered Insecticides against Major Cranberry Pests in New Jersey

Target Pest	New Insecticides: Efficacy Rating[1]				
	Intrepid[2]	Delegate[3]	Avaunt[3]	Assail[3,4]	Actara[3,4]
Cranberry Fruitworm	++++	++++	++	++++	—
Sparganothis Fruitworm	++++	++++	+	++	—
Cranberry Blossom worm	++++	++++	+++	—	—
Blackheaded Fireworm	++++	++++	++++	—	—
Spotted Fireworm	++++	++++	++	++	—
Gypsy Moth	++++	++++	++++	++++	—
Bluntnosed Leafhopper	—	—	—	++++	++++

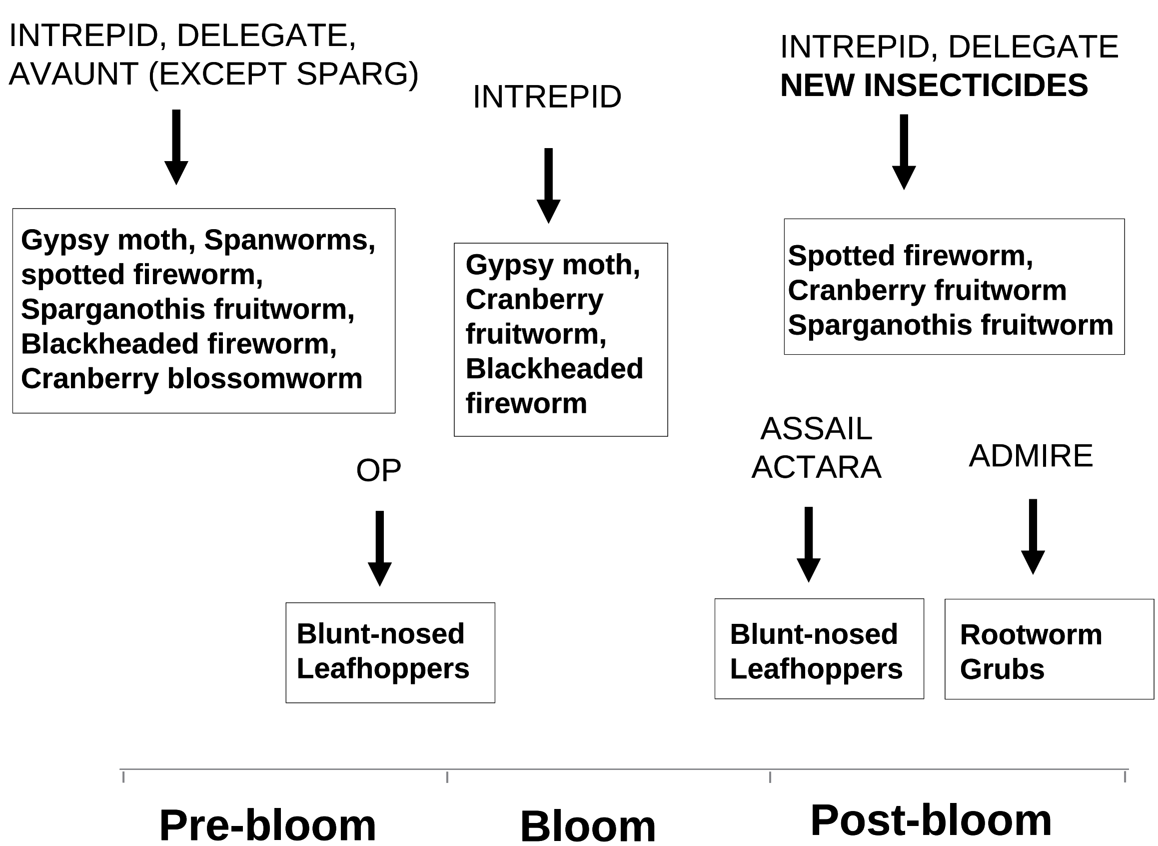
[1] ++++ = excellent, +++ = good, ++ = fair, + = poor, — = not tested or not recommended

[2] Can be used during bloom

[3] Do not use during bloom

[4] Not recommended before bloom

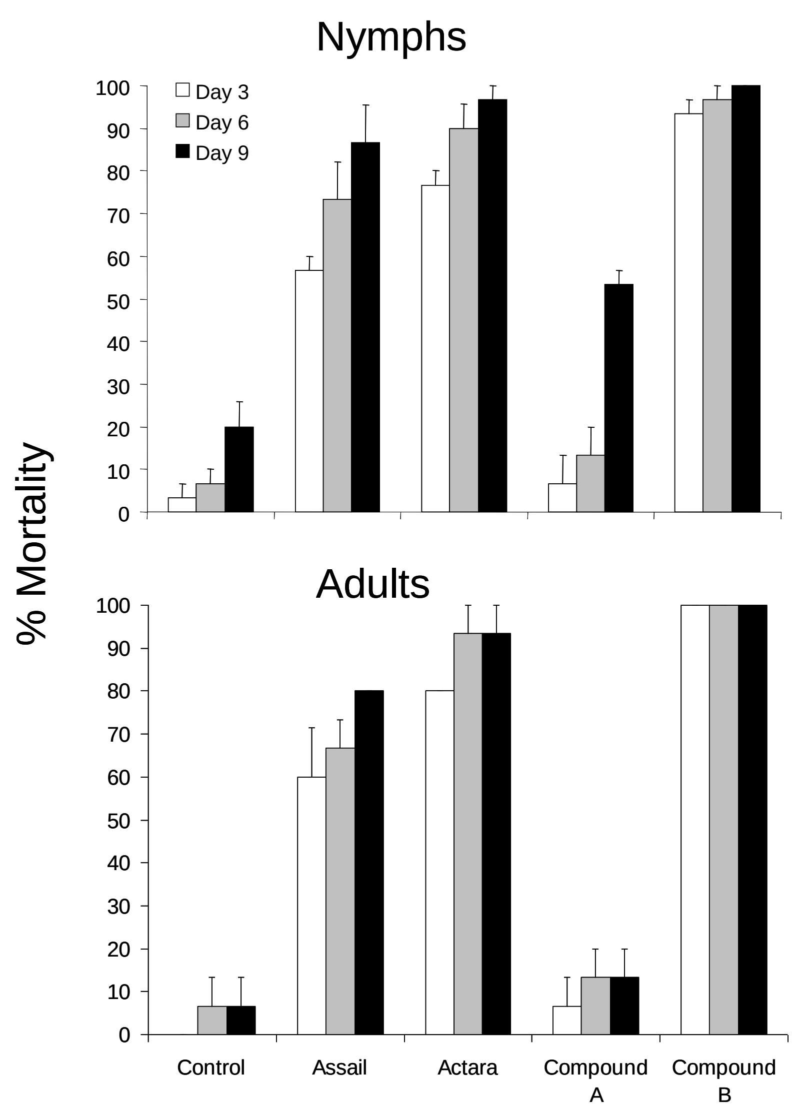
Timing of Control Options



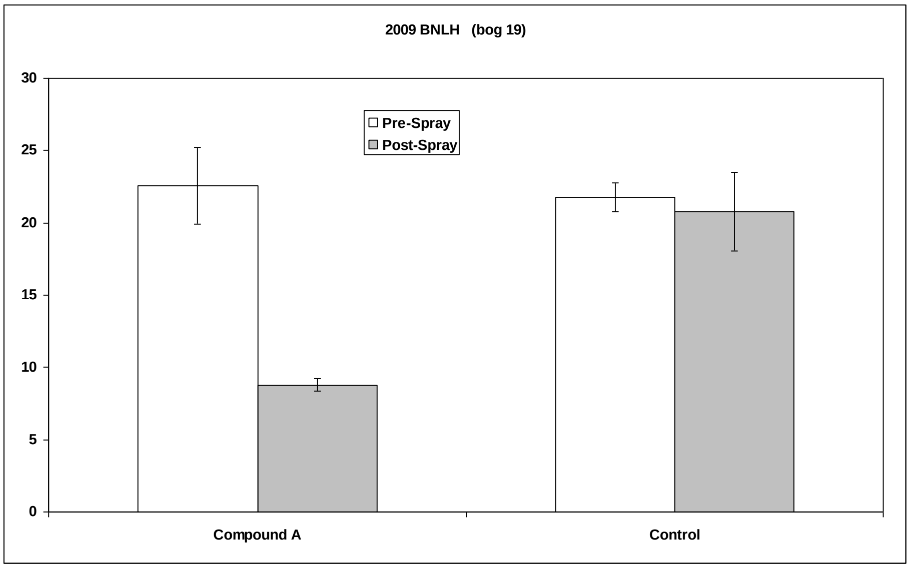
CURRENT RESEARCH

In 2009, the entomology program conducted trials to test newly-registered and unregistered insecticides against leafhoppers and *Sparganothis* fruitworm.

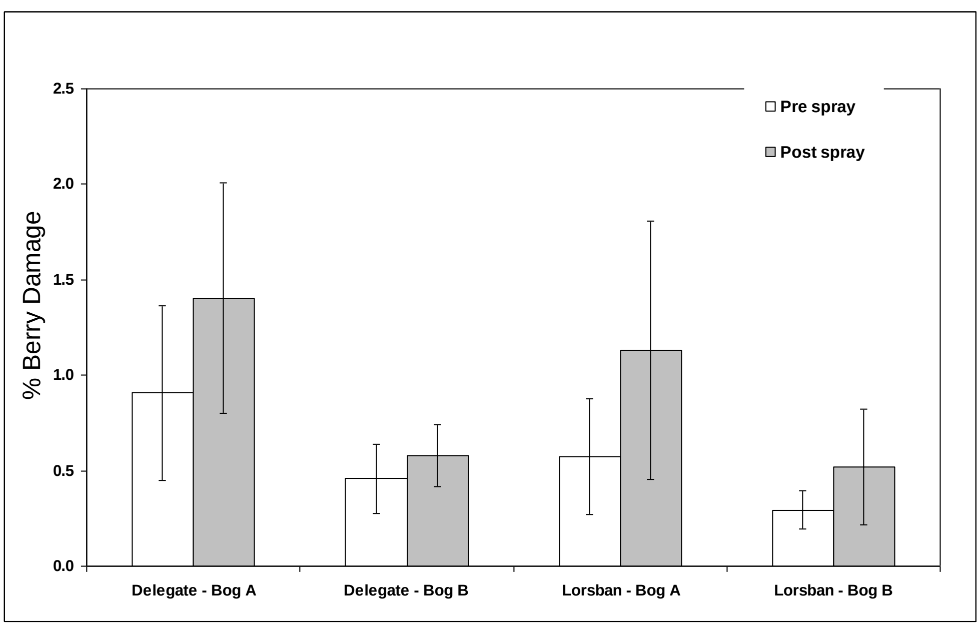
Laboratory trial for blunt-nosed leafhopper control: Base-level toxicity of Assail (4 oz/acre), Actara (3 oz/acre), Compound A, and Compound B were evaluated against leafhopper nymphs and adults in the laboratory on cranberry treated foliage and compared to untreated foliage. Insecticide treated and untreated uprights were inserted in florists‟ water picks, enclosed in a ventilated 40-dram plastic vial, and secured in Styrofoam trays. Mortality was assessed 3, 6, and 9 days after transfer. Assail, Actara, and Compound B provided good control against nymphs and adults. Compound A provided only 50% control of nymphs after 9 days.



Field trial for blunt-nosed leafhopper control: We evaluated the efficacy of a pre-bloom application of Compound A against blunt-nosed leafhopper nymphs. A cranberry bog located at the Rutgers Blueberry/Cranberry Center was divided into 6 plots. Half of the plots received one treatment (Compound A), while the other half were untreated controls. Application was made on 6 June. Sweepnet samples were taken from each plot on 4 June (pre-treatment) and 29 July (post-treatment). Compound A provided 57% control against blunt-nosed leafhopper after insecticide application.



Field trial for Sparganothis *fruitworm control:* This trial evaluated the efficacy of a post-bloom application of Delegate and Lorsban against *Sparganothis* fruitworm. The test was conducted in 4 commercial cranberry bogs. Two bogs were treated with Delegate and two bogs with Lorsban. Both insecticides provided similar control.



Cranberry Fruit Rot Control

Plant Pathology Lab
Peter Oudemans, Chris Constantelos, Donna Larsen, Jennifer Vaiciunas

Cranberry fruit rot is currently one of the most destructive cranberry diseases particularly in warmer growing regions such as New Jersey and Massachusetts. Historically, it has also been one the most economically important factors affecting cranberry production (Shear et al.,1931). The disease is actually caused by a wide variety of fruit infecting fungi. Shear (1907) and Shear et al. (1931) identified over 15 species of fruit infecting ascomycetes (anamorph and/or teleomorph) of both major and minor importance. Subsequently, mycologists described several new species (Weideman and Boone, 1982, Carris, 1990) and there are currently eleven species considered to be economically important (Table 1).

Cranberry fruit rot can be divided into two general classes (Wilcox, 1940). Field rot typically expresses prior to harvest and storage rot is a post harvest disease important for fresh marketed fruit. There is significant overlap among the species causing field and storage rot and typically one species cannot be classed as exclusively causing either field rot or storage rot. On exception is the end rot pathogen *Godronia cassandrae* (*Fusicoccum putrefaciens*) which is primarily a postharvest problem. The causal agent can be determined by culturing rotted fruit on common microbiological media. In many cases more than one fungal species is isolated from a single fruit. Cranberry fruit rot is widespread and occurs at differing levels depending on climatic conditions. It is more of a problem in the Northeast (NJ and MA) than it is in the Northwest (OR, WA, BC). In Wisconsin and Quebec the disease occurs at very low levels and most growers utilize a minimal spray program. Organic production can only occur in areas where fruit rot pressure is low.

Each fruit rotting species has a unique life cycle and mechanism of spread (Oudemans et al. 1998). Composition of the fruit rot community in a single cranberry bed may vary significantly from one year to the next when only rotted fruit are tested. One reason for this may be that the fungi (Table 1) reproduce successfully without infecting fruit and thereby maintain an active population that will cause fruit rot only when the conditions are conducive for that species. McManus et al (2003) compared different growing conditions and harvesting techniques and found that the compliment of fungi isolated from rotted fruit statistically similar. There has been significant research examining overwintering sites for each species and use of molecular diagnostic methods may become very useful in accurately characterizing the fungal fruit rot community in individual cranberry beds (Robideau et al. 2008)

Table 1. Important cranberry fruit rot pathogens				
Latin Name of Fungus	Common name	Type	Syngenta Abound Flowable	Dow AgroSciences Indar 2F Fungicide
Allantophomopsis cytosporea	Black Rot	Storage[1]	?	?
Allantophomopsis lycopodena	Black Rot	Storage[1]	?	?
Phyllosticta elongata	Berry Speckle	Field[1]	?	?
Phyllosticta vaccinii	Early Rot	Field[1]	+	+
Colletotrichum gloeosporioides	Bitter rot	Field[1]	+	+
Colletotrichum acutatum	Bitter rot	Field[1]	+	-
Physalospora vaccinii	Blotch Rot	Field[1]	+	+
Coleophoma empetri	Ripe Rot	Field[1]	-	+
Phomopsis vaccinii	Viscid Rot	Field[1]	?	?
Strasseria geniculata	BlackRot	Storage[1]	?	?
Fusicoccum putrefaciens	End Rot	Storage	?	?
[1]Found in both storage and field rot stages but predominates in one				

From a practical perspective fruit rot is normally treated as a single disease. Management strategies including choice of fungicide and timing of application target fruit rot without regard for individual species. This approach is appropriate when broad spectrum fungicides are used. However, as new chemistries with more limited spectra of action are introduced the particular compliment of species causing fruit rot becomes very important (Fig. 1). Recently, registration of fenbuconazole and azoxystrobin was completed and combinations of these two modes of action provide a greater spectrum of action and improved disease control than either fungicide alone (Oudemans and Vaiciunas, 2008 attached below). It is likely that as horticultural practices and breeding efforts lead to increased crop yields it will become necessary to better characterize the fruit rot community and target specific fungal species.

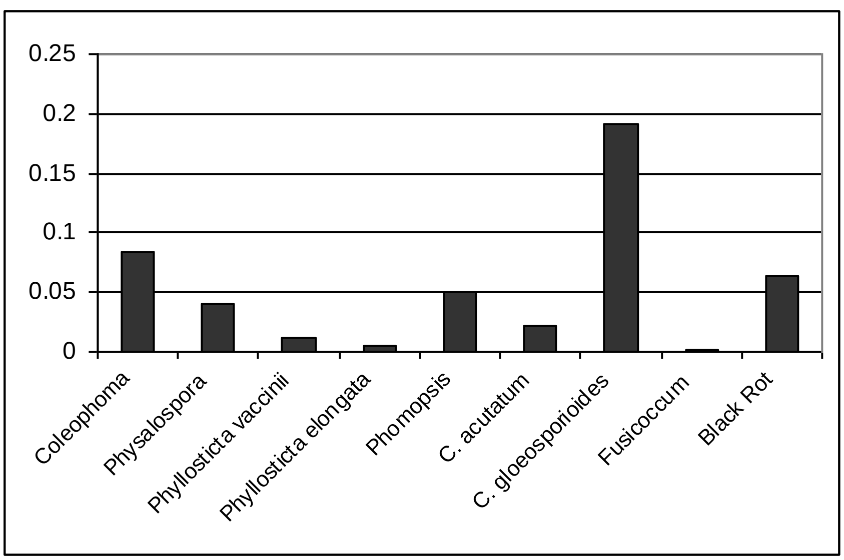


Fig. 1. Frequency fruit rotting fungi isolated from 20 commercial beds in New Jersey,

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Evaluation of selected new fungicides for the control of fruit rot in cranberries, 2007.

Six fungicides were evaluated for their ability to control cranberry fruit rot, a disease complex. Three of the fungicides were being tested for the first time. Proline (prothioconazole) showed activity in 2006 and was being tested again to confirm activity. Indar (fenbuconazole) and Abound (azoxystrobin) are currently labeled for cranberry fruit rot nationwide. Both of these registered materials have limited spectra of action and gaps in activity have been observed. Therefore, a tank mix of these fungicides (at full, labeled rates) was tested to determine if they were complimentary in activity. The study was conducted at the Marucci Center for Blueberry and Cranberry Research and Extension, Chatsworth, NJ in a 0.2ha cranberry bed maintained under commercial conditions, but without fungicide usage. The bed was established in 1972 with the cultivar Early Black. The site was irrigated as needed to prevent frost, heat and drought stress. Insecticide and fertilizer applications were made according to recommended crop management strategies. Plots were 1.2m by 1.2m and arranged in a randomized complete block design with eight replications. Fungicides were applied in water equivalent to 1215 liters/ha with a CO_2 powered sprayer at 207Kpa using a single TeeJet 8002VS flat fan nozzle. Treatments were initiated on 15 Jun 07 when plants were at 50% open bloom and reapplied on 27 Jun and 4 Jul. Cranberry fruit rot was first observed in mid-Jul and disease pressure was high throughout the study. An initial evaluation of fruit rot was conducted 24 Jul by counting fruit on twenty uprights from each plot. Percent fruit rot was expressed as the number of rotted fruit divided by the total number of fruit on twenty uprights. There were no differences among treatments for the total numbers of fruit however; the non-treated control had begun to express fruit rot symptoms. Plots were harvested on 9 Oct. Following harvest, the fruit were separated into two categories (sound and rotted) and the weight of each category was measured. Percent fruit rot was calculated as the weight of rotted berries divided by the total weight of berries multiplied by 100. Yield was measured by taking the weight of sound berries per sq ft and converted to bbl/A. Data were subjected to analysis of variance and a means separation test (Student-Newman-Kuels, 5%). Distinguish, AEC656948 and Omega did not provide any significant level of control as compared with the non-treated control. Vines treated with Distinguish appeared red and unusually erect on 27 Jun and by 4 Jul symptoms were obvious. By harvest time these effects had disappeared. Abound provided an intermediate level of control. As standalone fungicides Proline and Indar provided the greatest levels of control however, the tank mix of Abound and Indar provided statistically similar control. This tank mix did result in a significantly greater yield.

	------% Fruit rot------				Harvest data (9 Oct.)			
Treatment and rate/A	24 Jul		9 Oct		Yield bbl/acre[x]		Avg berry wt[y], g	
Non-treated control	14.9	a[z]	83.2	a[z]	16.1	d	1.02	ab
XXX 480SC 5.7 fl oz….	5.8	b	29.4	c	97.0	b	1.10	ab
XXX 480SC 18 fl oz	7.2	b	76.6	a	26.8	cd	0.97	b
XXX	8.0	b	73.5	a	37.4	cd	1.06	ab
XXX 500SC 1.25 pt	10.6	ab	78.9	a	29.6	cd	0.84	c
Abound 2.08SC 15.2 fl oz	5.5	b	55.8	b	58.6	c	1.10	ab
Indar 75WSP 4.0 oz	6.6	b	27.5	c	108.6	b	1.12	ab
Abound 2.08SC 15.2 fl oz + Indar 75WSP 4.0 oz	3.8	b	14.7	c	175.9	a	1.18	a

[x]Barrels per acre
[y]Weight of 100 berries was taken and the average calculated
[z]Column numbers followed by the same letter are not significantly different at P=0.05 as determined by the Student-Newman-Kuels test

2009 Experiment and Field Demonstration

Experiment 1. Evaluation of combinations of Indar and Abound to test for synergistic activity

Objective: To test Abound and Indar at three concentrations in all combinations to determine if they act in an additive or synergistic manner.

Abound fl.oz./acre	Indar 2F fl.oz./acre				
		0	1	2	4
	0	T1	T2	T3	T4
	3.4	T5	T6	T7	T8
	7.7	T9	T10	T11	T12
	15.4	T13	T14	T15	T16

Update on Chemical Control of Flowering to Enhance Bed Establishment and Reduce Fungal Inoculum

James Polashock and Peter Oudemans

Introduction

New cranberry beds are usually started with rooted cuttings or pressed in vines. Establishment and the time to first production harvest vary depending on such factors as planting density, fertilizer regime and cultivar, but at least 2-3 years is typical. During the first two years, inhibition or elimination of fruiting could be advantageous for several reasons. First, eliminating the fruit load will shift allocation of plant resources to vegetative growth. Second, we have shown that open ground in cranberry beds allows the establishment of undesirable seedlings from dropped and rotted fruit. Thus elimination of fruiting in the early stages of bed establishment will help preserve cultivar purity. Third, many fruit rot pathogens sporulate on infected fruit and then overwinter on vegetative tissue. Thus, eliminating the unharvested fruit could reduce build up of fungal inoculum.

Objective

The objective of this project is to eliminate flowers and/or fruit in establishing cranberry beds. When we first started this project, we tried two approaches 1) „burn‟ flowers and/or young fruit using chemical treatment such as ammonium thiosulfate and 2) prevent flowering and/or fruiting using plant growth regulators such as ProGibb. Our preliminary data suggested approach 2 to be the most viable and treatment in 2009 was limited to the most promising candidate in this category, ProGibb.

Treatments

We selected two different sources of material. The first source is now a 3-year old bed of rooted cuttings of „Crimson Queen‟ and „Stevens‟ (Bog 3). The second source is an established bed of „Stevens‟ (Bog 6). The treatments used in 2008 were as follows: 1) Ethephon, 2) ProGibb, 3) Induce, 4) Ammonium Thiosulfate (ATS), and 5) Sulforix. In 2009, we used only ProGibb (two applications).

Results

Data collected in the fall 2008 showed that across both beds (3-year old and mature) and both cultivars (Stevens and Crimson Queen), that the ProGibb treatment consistently showed no phytotoxicity, increased vegetative growth, and the lowest yields (almost no berries) as compared to the control and all other treatments. Thus, treatment this year (2009) was limited to only ProGibb as this was by far the most promising treatment. The extensive vegetative growth in response to ProGibb treatment was monitored for hardening and susceptibility to winter injury. No winter injury was observed suggesting that there is no negative effect on plant health. Some plots sprayed last year with ProGibb were not sprayed this year to determine if the effects (more vegetative growth and severe inhibition of flowering) linger for more than one year. Ideally, flowering and normal growth will resume one year after treatment.

Conclusions

Based on three years of data, only the gibberellic acid (ProGibb) treatment has the potential to safely accomplish the objective. We have shown that we can 1) dramatically reduce the occurrence of unwanted fruit and 2) dramatically increase vegetative growth (a benefit when establishing new beds) with no ill effects (i.e. no phytotoxicity or increased susceptibility to winter injury or disease).

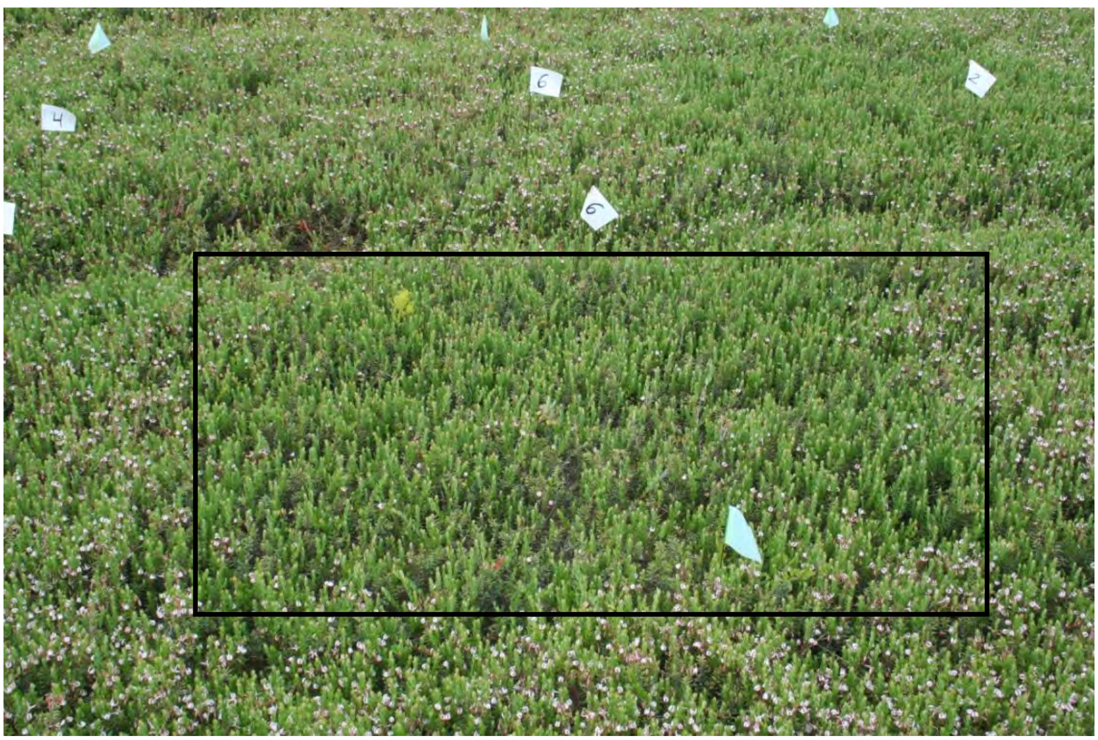

Figure 1. ProGibb Treatment of „Crimson Queen" (boxed area). Note the absence of flowers and increased runner growth.

Honeybees, wild bees, and the mechanics of cranberry pollination.

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Rachael Winfree—Assistant Professor
Department of Entomology
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Cranberry fruit production relies on the transfer of pollen grains from the anthers (male structure) to the stigmas (female structure) of the flower. Pollination in cranberry is carried out almost solely by bees with managed honeybees being the most abundant pollinators. While honeybees are critical to ensure high yields of cranberry, native, wild bees also pollinate and may play an important role in fruit production. Recent declines in honeybee colonies due to *Varroa* mites and Colony Collapse Disorder have highlighted the importance of understanding the role of native bees in cranberry pollination. The goals of this study were to 1) quantify the contribution of honeybees and native bees to cranberry pollination and 2) examine how attributes of cranberry farms and the surrounding landscape influence the abundance and diversity of wild bees.

OBJECTIVE 1: Quantify the contribution of honeybees and native bees to cranberry pollination.

Numerous bee species visit cranberry flowers yet each may differ in their effectiveness as pollinators. Pollinator effectiveness is a product of the frequency at which the pollinator visits flowers (visitation rate) and the average number of pollen grains they transfer on each visit. In the summer of 2009, we recorded the visitation rate of various bee species on 32 cranberry bogs throughout central New Jersey. In addition, we collected bees to determine bee species abundance and variety. We recorded approximately 25 wild bee species visiting cranberry flowers. Honeybees were the most frequent pollinator and accounted for 73% of the visits. Native bees made up 25% of the visits with wasps and flies comprising roughly 2%. Of the native bees 66% were bumblebees (Genus *Bombus*) and 34% were other bee species. In the summer of 2010, we plan to conduct experiments to determine the number of pollen grains deposited per visit by each bee species, and to calculate the contribution that each type of bee makes to cranberry pollination.

OBJECTIVE 2: <u>Determine how landscape factors such as proximity to natural habitat and proportion of surrounding area in cranberry production influence the abundance and diversity of wild bees.</u>

Wild bees that visit cranberry must feed and nest entirely on the landscape within and surrounding bogs. Variation in landscape attributes may influence bee abundance, diversity and subsequently cranberry pollination. To examine landscape factors, we used GIS to locate bogs that 1) ranged in proportion of surrounding landscape in cranberry production and 2) were close or far from woodlands. At these bogs, we conducted visitation rate observations and collected wild bees (as described above). We also collected stigmas to quantify the number of pollen grains deposited per stigma at each of these bogs. This will allow us to directly link landscape attributes to visitation rate, wild bee abundance and diversity, and pollination.

JUST HOW MUCH EXPOSURE DO I HAVE TO PESTICIDES ON THE FARM?

By Raymond J. Samulis, Burlington County Agricultural Agent

Pesticide applicator licensing has been with us for more than 30 years now. Yet we still have many unanswered questions about evaluating our repeated exposure to various pesticides. For acute exposure to pesticides the circumstances are usually obvious. We know when we get spray material in our eyes, see stains on our clothing, get headaches, dizzy, and so on that we have an immediate problem. With organophosphate pesticides, we can get a cholinesterase blood tests at the beginning of the season to see if we are getting in trouble.

I think that the more nagging question regarding pesticide exposure deals with our continual chronic exposure. What happens to us when we are exposed daily, weekly, monthly or yearly to minute amounts of various pesticides?

The amount of our pesticide exposure vulnerability will vary according to the method of application. If we are handgun spraying, weed wiping or tractor spraying our vulnerability to exposure will have a wide range. Likewise, exposure to pesticides from seed treatments generally has a low hazard rate associated with their use. A recent pesticide exposure study of farmers conducted by Iowa and North Carolina has produced interesting results. Overall, 14% of the farmers and farm workers were shown to have high exposure to pesticides on their farms.

This study was able to conclude that the application in this highly exposed category had these things in common:

- Stored pesticides in their homes;
- Repaired their own equipment;
- Delayed changing clothes and washing;
- Applied pesticides within 100 yards of their houses;
- Washed in their houses versus in an outside building;
- Mixed pesticides within 50 yards of a well;
- Mixed work clothing and family laundry together.

It was startling to learn that more than 94% of farmers washed their family laundry in the same machine as their work clothes. This study was also unique in that it studied the change in pesticide use over the years and was less concerned with old, historic pesticide use.

Probably the most useful aspect of the study was that it resulted in production of a simple system to measure your exposure to pesticides over time. This formula ultimately can help you answer the question posed in the title of this presentation.

The formula specifically rates four distinct areas of exposure and comes up with a numerical rating to evaluate problem areas. These areas include mixing and loading, application methods, whether you repair your own equipment, and how extensive is your use of personal protection equipment. In the exposure category, factors range from 9 for handgun spraying down to 1 for granular application. Mixing and loading pesticides are given ratings of 0 through 9 depending upon the frequency of mixing. The repair category is given a 2 X rating to those farmers who repair their own equipment. Finally a range of .1 to 1 is given to personal protection equipment with .1 used for maximum use of equipment to 1 for no use of personal protection equipment.

This information can also be used to calculate a lifelong exposure formula with a few additions.

Let‟s face it, whether acute or chronic, pesticide exposure can cause us serious health effects. It‟s in all of our best interest to use formulas like these to determine ahead of time just how vulnerable we are to needlessly damaging our health.

Maintaining Cultivar Purity

Jennifer Johnson-Cicalese, Nicholi Vorsa, and Karen DeStefano, P.E. Marucci Center for Blueberry & Cranberry Research & Extension, Rutgers University, Chatsworth, NJ 08019

Maintaining cultivar purity is a continual challenge for both the cranberry grower and cranberry researcher. In a production bed, cranberry contaminants, or off-types, can reduce yield, quality and vigor of the bed (see “**A DNA fingerprinting study of Washington State and Newfoundland ‘Stevens’: is ‘Stevens’ becoming more contaminated with off-types”**). These contaminants can come in with vines used to establish a new bed, or as volunteer seedlings, particularly when disease or other problems leave an open area in a bed. Unfortunately, the off-types are often highly vegetative and crowd out more productive vine.

For the cranberry researcher, contaminants can seriously confound results. In 1995, Rutgers cranberry breeding program established two beds containing an extensive germplasm collection, where each plot was propagated from a single stem to ensure 100% genetic homogeneity within each plot. In the past few years, it has become apparent that despite our efforts to maintain purity, these beds now show signs of contamination. The germplasm was collected in 1988 through 1994 from bogs throughout the U.S. (NJ, NY, MA, DE, WV, PA, MI, and WI), and includes both major and minor cultivars, genetic variants that had developed in cultivated beds many decades old, and wild cranberries collected from a diverse range of habitats. Alleys between each 5‟ x 5‟ plot were maintained with regular herbicide applications. This germplasm collection is a valuable resource for our breeding program. Within it we have identified accessions with fruit rot resistance, high sugars, low acids, and other traits of interest which have been used in crosses and new cultivar development.

To re-establish this collection, we examined each plot in September 2007 and selected one piece of vine with fruit attached that looked typical to the plot. These individual vines were rooted in the greenhouse, propagated into 25 plants, and will be replanted in a new 5‟ x 5‟ plot in April 2010. Plants were DNA fingerprinted to confirm their identity and assure that they are the same accession originally planted in 1995. Once established, these new plots will serve as a resource to researchers here at Chatsworth and around the country.

Cranberry – Update on Health Benefits
Amy Howell

Cranberry is well established as a “super fruit,” with a wide array of potential health benefits, the most substantiated being prevention of urinary tract infections. Cranberries contain a number of phytochemicals, among them anthocyanin pigments, flavonol glycosides, organic acids, and complex oligomeric flavonoids known as proanthocyanidins (PACs) or condensed tannins. PACs appear to be particularly bioactive and, in recent years, have gained the attention of the medical and pharmaceutical communities for their wide array of potential health benefits. The PACs in cranberry are of interest in that they have unusual molecular structures when compared to PACs from other foods and have been linked to prevention of bacterial adhesion in the urinary tract, stomach, and oral cavity. Bacterial adhesion to cells is the initial step in many bacterial infection processes. If the initial adhesion step is inhibited, the bacteria are not able to multiply and colonize, essentially preventing infection. The role of cranberry in preventing bacterial adhesion in the urinary tract, gastrointestinal tract, and oral cavity will be reviewed, as well as the emerging research into the benefits of cranberry on markers for heart disease and cancer.

Biology and Management of *Rhizoctonia/Thanatophytum*, the Causal Agent of Cranberry Fairy Ring Disease

The Fairy Ring Team includes:

Rutgers University:
Ms. Jennifer Vaiciunas
Dr. Peter V. Oudemans

Cooperators and Institutions:
Dr. James Polashock, USDA-ARS, Beltsville, MD
Dr. Frank Caruso, University of Massachusetts

Fairy Ring is a re-emerging disease on cranberry. We have recently identified the causal agent and now have the opportunity to develop a new management strategy. Fairy Rings cause not only direct crop losses but also provide an entry point for weed species and promote development of cranberry seed banks which lead to development of rogue cranberry genotypes that can shorten bed life. We are developing improved fairy ring management strategies aimed at reducing spread of the disease to new beds and new cranberry growing areas as well as to investigate control procedures to help arrest the development of existing rings. In the short-term we are attempting to identify fungicide control methods to reduce the expansion of Fairy Rings. Ferbam used at a rate of 0.9lb/100ft2 will be eliminated and replaced by lower impact fungicides used at lower rates. We have developed methods to diagnose the disease and determine how new rings are being formed. The benefit will be that dispersal to new beds and other growing regions will be prevented or reduced. When successful controls are developed it is likely that the life-span of individual cranberry beds will be increased. Long-term objectives that will be initiated under this proposal include an elucidation of the mechanisms for dispersal and investigation of biological control methods.

A CHEMICAL ECOLOGY LAB FOR BLUEBERRY & CRANBERRY ENTOMOLOGY

Cesar Rodriguez-Saona, Extension Specialist, Rutgers Entomology

Plant volatiles serve as a source of airborne chemicals in insect communication. Insects may use plant volatiles to locate food and mates. Females may also use these chemicals to locate oviposition sites. Because these chemicals play an integral role in the insect‟s life, they can be used for insect control. A laboratory for the study of plant volatiles and insect response to these chemicals has been established at the P.E. Marucci Center, Rutgers University in Chatsworth, NJ. The laboratory accommodates equipment for the collection and analyses of plant volatiles, electro-antennographic detection, and insect‟s behavioral response to plant volatiles (repellency and attraction). We are currently studying the response of cranberry fruitworm and cranberry weevil to host-plant volatiles to develop better tools for monitoring these insect pests.

CRANBERRY (*Vaccinium macrocarpon.* 'Early Black')
Black rot: *Allantophomopsis lycopodina*, *Allantophomopsis cytisporea*,
Ripe rot: *Coleophoma empetri*,
End rot: *Fusicoccum putrefaciens*,
Bitter rot: *Glomerella cingulata*,
Viscid rot: *Phomopsis vaccinii*,
Early rot: *Phyllosticta vaccinii*,
Blotch rot: *Physalospora vaccinii*

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Evaluation of fungicides for control of field and storage rot of cranberries, 2010.

Plots (25 ft^2) were established in a bed of 'Early Black' vines located in State Bog, East Wareham, MA operated by the UMass Cranberry Station. The fungicides (Evito 480 SC at 5.7 oz/A, Luna Experience 400 SC at 8 oz/A, Proline 480 SC at 5 oz/A, Fontelis 20 SC at 16 and 24 oz/A, Indar 2F at 12 oz/A, Abound at 15.4 oz/A, a combination of Abound at 15.4 oz + Indar 2F at 12 oz/A and Bravo WeatherStik at 5.5 pt/A) were applied on three dates: 4 Jun (35% open blossoms), 14 Jun (90% open blossoms), and 24 Jun (100% open blossoms, 15% fruit set). Each treatment was replicated eight times in a randomized complete block design. Sprays were applied using a CO_2 sprayer equipped with a single flat-fan nozzle (Tee-Jet 8004) at 40 psi and 300 gal/A. Sprays applied for insect control included Avaunt, Belay, Callisto and Delegate WG. Berries were harvested by hand on 20-21 Sep in a 4-ft^2 area in the center of each plot. Volumes of harvested fruit per replicate varied from 2.0-24.5 oz. Berries were counted and evaluated for the presence or absence of field rot at five days after harvest. Apparently healthy berries were sorted, stored in open paper bags at 38^{o}F for eight weeks, and evaluated for storage rot.

For the first time since 1990, Massachusetts cranberry beds experienced weather conditions on 30-31 Aug that were conducive toward the development of physiological scald in the fruit. State Bog was highly impacted and this section of 'Early Black' vines experienced losses to scald of roughly 25%. Consequently, field rot values are significantly higher than normal values. Scald occurred uniformly across the plots, and every treatment was impacted similarly. Proline and Indar provided the best field rot control, followed by Luna Experience, Bravo and the Abound + Indar combination. All other treatments afforded poor field rot control. Proline provided the best control of storage rot. Luna Experience significantly reduced berry size and yield compared to all other treatments. No phytotoxicity was observed for any of the treatments as expressed by yellow or red vine color.

Treatment	Field rot (%)	Storage rot (%)	Total rot (%)	Cup Count[y]	Berry wt. (oz)	Yield (bbl/a)[z]
Bravo WeatherStik 720SC 5.5 pt..	33.9 c[x]	2.8 bc	35.7 c	103.3 b	0.04 ab	195.0 c
Indar 2F 12 fl oz…………………	24.4 d	3.2 b	26.9 d	99.7 bc	0.05 b	235.6 b
Abound F 15.4 fl oz……………..	60.8 b	3.2 b	62.0 b	103.9 b	0.04 ab	267.7 a
Abound F 15.4 fl oz + Indar 2F 12 fl oz……………….	36.6 c	2.4 bc	38.1 c	102.8 b	0.04 ab	226.6 b
Evito 480SC 5.7 fl oz……………	75.2 a	3.7 ab	76.1 a	96.7 c	0.03 a	237.0 b
Luna Experience 400SC 8 fl oz….	33.1 c	3.8 ab	35.6 c	118.3 a	0.04 ab	107.3 e
Proline 480SC 5 fl oz……………	20.9 d	1.6 c	22.2 d	97.7 c	0.04 ab	235.4 b
Fontelis 20SC 16 fl oz…………..	71.3 a	3.8 ab	72.4 a	105.5 b	0.04 ab	196.3 c
Fontelis 20SC 24 fl oz…………...	68.6 a	4.2 a	69.9 a	103.3 b	0.04 ab	151.9 d
Untreated check………………….	74.0 a	3.5 ab	69.9 a	105.0 b	0.04 ab	179.4 cd

[z]Potential yield as determined in harvested foot squares per plot. Data are expressed in barrels/acre (1 barrel = 100 lb).
[y] Mean value of the number of cranberries in three standard cups filled to the top.
[x]Means followed by the same letter are not significantly different (Student-Newman-Keuls Test, *P*=0.05).

EVALUATION OF FUNGICIDES FOR CONTROL OF
FIELD AND STORAGE ROT OF CRANBERRIES, 2010

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Product	Source	Composition
Bravo Weatherstik	Syngenta Crop Protection, Inc. 1800 Concord Pike Wilmington, DE 19850-5458	Composition previously reported in F&N Tests
Indar 2F	Dow AgroSciences LLC 9330 Zionsville Road Indianapolis, IN 46268	Composition previously reported in F&N Tests
Abound	Syngenta Crop Protection, Inc. 1800 Concord Pike Wilmington, DE 19850-5458	Composition previously reported in F&N Tests
Evito 480 SC	Arysta Lifescience 15401 Weston Parkway Suite 150 Cary, NC 27513	Composition previously reported in F&N Tests
Proline 480 SC	Bayer Crop Science LP P.O. Box 12014 2 T.W. Alexander Drive Research Triangle Park, NC 27709	Composition previously reported in F&N Tests
Luna Experience 400 SC	Bayer Crop Science LP P.O. Box 12014 2 T.W. Alexander Drive Research Triangle Park, NC 27709	Composition previously reported in F&N Tests
Fontelis 20 SC	Dupont Crop Protection Co. Inc. Laurel Run Building Chestnut Run Plaza Wilmington, DE 19898	Composition previously reported in F&N Tests

Reviewer's signatures: ______________________________________ ______________________________________

THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

HYG-3205-10

White Pine Blister Rust on Currants and Gooseberries

Michael A. Ellis and **Leona Horst**
Department of Plant Pathology

White pine blister rust is not a serious disease of currants and gooseberries; however, it is a very serious disease of white pines (*Pinus strobus*). Currants and gooseberries serve as an alternate host for the rust fungus that causes white pine blister rust. Therefore, planting currants and gooseberries in areas where white pines are present can lead to serious losses of white pines. North American white pine species, including bristlecone, limber, sugar, eastern white, southwestern white, western white, and whitebark, are highly susceptible. White pine blister rust causes significant damage in pine forests by forming cankers on the branches of white pines. These cankers ultimately kill the trees. Black currant is the most susceptible of the *Ribes* species.

Figure 1. Symptoms of white pine blister rust on the lower surface of an infected black currant leaf.

To protect white pine forests, several states have enacted laws concerning planting of black currants.

The current Ohio law (Regulation AG-71-85.01) to suppress and control White Pine Blister Rust Disease is as follows:

(A) The European black currant, *Ribes nigrum* L. or any variety of this species is hereby declared to be a public nuisance, and it shall be unlawful for any person to possess, transport, plant, propagate, sell, or offer for sale, plants, roots, scions, seeds, or cuttings of these plants in this state.

(B) Recognized varieties, e.g., "Consort" produced by the hybridization of *Ribes nigrum* L. or a variety thereof with a resistant or immune species, known to be immune or highly resistant to the White Pine Blister Rust fungus, (*Cronartium ribicola*, Fischer) are exempt from the restrictions imposed by paragraph (A) above.

Note: Ohio law does not prohibit the planting of red currants or gooseberries within the state.

Symptoms

On *Ribes* in the spring, tiny yellowish spots become visible on the upper surface of the leaves, while on the underside, orange-yellow, blister-like fruiting bodies appear. By late summer, yellow to brown threadlike growths develop on or near these infection spots on the leaf. Bushes also will have premature defoliation.

On white pine, the symptoms include dead branches, chlorotic foliage, branch girdling by lesions that exude

Figure 2. Close up of telia and some uredia on the lower surface of a black currant leaf infected with white pine blister rust.

resin or sticky yellowish fluid (spermagonia), cankers that are diamond-shaped to elliptic with a dead center surrounded by a band of yellowish-green infected bark, light yellow-orange aecia, and death of the tree.

Causal Organism and Disease Development

White pine blister rust is caused by a fungus, *Cronartium ribicola*. The organism was introduced from Europe in the early 20th century. It has spread throughout the entire range of white pines in North America. The life cycle takes three to six years to complete. The initial infection of black currant bushes occurs in the spring, when aeciospores from diseased white pine land on the leaves of the bush. These spores can travel on the wind several miles. Moisture is needed for the germination of the aeciospores.

After one to three weeks incubation, the plants begin to show the first symptoms of disease. Yellowish spots appear on the top side of the leaves and fruiting bodies (uredia) appear on the underside of the leaves. The fruiting bodies (uredia) produce uredospores which reinfect *Ribes* leaves. This cycle can be repeated many times during a single growing season.

In late summer or early fall, when day length and temperature decrease, telia (another type of fruiting body) replace the uredia on the underside of the leaves. The telia produce teliospores, which germinate in place at night during wet weather and produce basidiospores. After telial formation, at least 60 hours of wet weather with temperatures not exceeding 20 degrees C are required for basidiospore formation, dispersal, and infection of white pine. These basidiospores are carried by the air currents to white pine trees. The basidiospores germinate on wet needles and enter through the stomata.

The only symptom initially is a yellow to reddish spot at the site of infection. Infected needles turn yellow and drop prematurely, but often not before the fungus has grown down the needle and entered the twig. This occurs late in the fall or early in the spring of the next year. About 12 to 18 months after infection, the fungus has grown from the needle into the bark of the stem, where it produces spermagonia. During the first or second year of infection, the spermagonia produce aecia. The aecia produces powdery bright yellow aecidiospores that may live for many months. The aecidiospores are carried by the wind to *Ribes* bushes, completing the cycle.

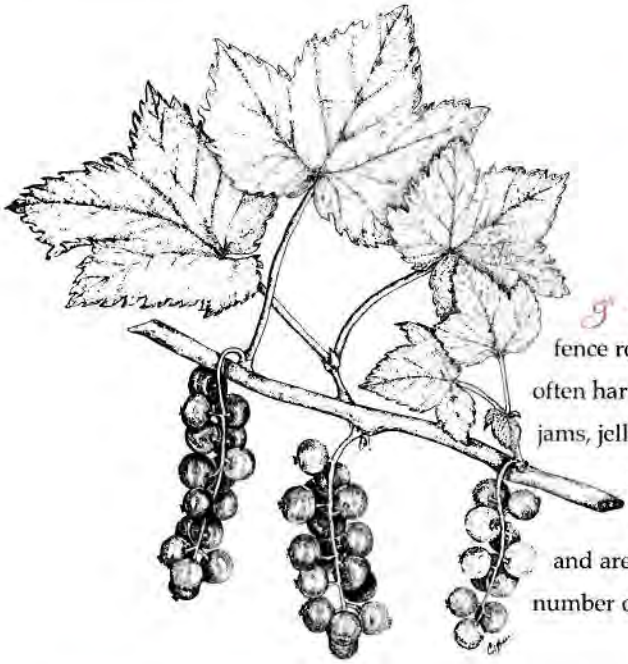
Control

1. Remove susceptible *Ribes* species and infected plants.
2. Plant only disease-free resistant varieties of *Ribes* approved by the Ohio Department of Agriculture. Resistant varieties of Black currant include Consort, Crusader, Coronet, Lowes Auslese, Polar, Titania, and Willoughby. Red currants and gooseberries are not affected by Ohio law and are legal to plant.
3. There are no fungicides labeled on currants and gooseberries for control of white pine blister rust.

A1960

Growing Currants, Gooseberries, & Elderberries in Wisconsin

Teryl R. Roper, Daniel L. Mahr, Patricia S. McManus



Currants, gooseberries, & elderberries are native to Wisconsin woodlands, fence rows, and fields. Fruit of these lesser known crops are often harvested from the wild and are prized for making jams, jellies, pies, and juice. Elderberries are sometimes used in home winemaking. These crops are generally hardy enough to be grown in all areas of Wisconsin and are well adapted for home fruit plantings. A limited number of improved cultivars are available from nurseries.

Site selection and preparation

Gooseberries, currants, and elderberries prefer cool moist locations; they will not thrive in hot dry places. They can be grown in partially shaded areas but should have good air circulation around the plants to reduce leaf and fruit disease problems. Soils high in organic matter are ideal for these crops. Do not plant in poorly drained areas where water stands for more than a day.

If possible, obtain a soil test before planting. Procedures for soil sampling and submitting samples for testing are outlined in Extension publication *Sampling Lawn and Garden Soils for Soil Testing* (A2166), which is available through your county Extension office. Apply and incorporate any phosphorus or potassium recommended from the soil test the fall before planting.

Eliminate quackgrass and other troublesome perennial weeds by frequent cultivation or use of non-residual herbicides such as glyphosate the season before planting. Before using any herbicide, read the package label to make sure the crop you intend to treat is listed.

In the fall or early spring before planting, thoroughly mix additional organic matter with the soil. Well-rotted manure, compost, granulated peat, or other partially decomposed organic matter are beneficial.

Sources of plants

Because of limited demand, recommended gooseberry, currant, and elderberry cultivars may be difficult to obtain. One-year-old plants are best; older plants can be used but are often less vigorous and not as desirable. Check reliable mail-order nurseries for availability. For sources of these plants, see Extension publication *Home Fruit Cultivars for Northern Wisconsin* (A2488) or *Home Fruit Cultivars for Southern Wisconsin* (A2582).

If you wish to start your own plants from a nearby source, currants, gooseberries, and elderberries are easily propagated from cuttings or by layering. These procedures are discussed in Extension publication *Home Propagation Techniques* (NCR274). These plants do not come true from seed and must be vegetatively propagated.

Currants are usually propagated from hardwood cuttings. In winter or early spring, take cuttings 6 to 8 inches long from the matured dormant growth of the previous season. Store cuttings in moist peat moss or sand in a refrigerator or other location cold enough to prevent growth. Do not store in a home freezer.

In early spring, plant the cuttings 6 to 8 inches apart in rows with the top two or three buds above the soil. Press soil firmly around the cuttings and water lightly and frequently. Rooted cuttings often can be transplanted in the spring following one season's growth.

Gooseberries can also be propagated by cuttings but are well adapted to layering. To layer plants, bend down low-growing branches in early spring, pin the branches in place with a hooked wire or weight, and cover them with 2 to 3 inches of soil. Leave the base and tips of the branches exposed. Branches will usually root well in one season and can be cut from the plant and transplanted the following spring. Rooting of layered branches is generally enhanced by covering the soil with sawdust or granulated peat to retain moisture.

Elderberries are easily propagated by cuttings as described for currants. In early spring take 10- to 12-inch cuttings from live portions of the previous season's growth and plant them 10 to 12 inches apart in rows, leaving the top bud exposed. Firm soil around cuttings and water as needed to retain a moist, not soggy, medium for rooting. Cuttings can be transplanted to permanent locations early the following spring.

PLANTING AND SPACING

In Wisconsin, spring planting is preferred for gooseberries, currants, and elderberries. Set dormant plants as soon as they are received from the nursery, or transplant them directly from the propagation bed. Before planting, remove damaged or broken roots or stems and cut back the top portions to 8 to 10 inches, depending on the size of the root system. Plant with the lowest branch at or just below the soil line. Water thoroughly after planting to settle the soil around the roots, and water weekly thereafter if rainfall is inadequate.

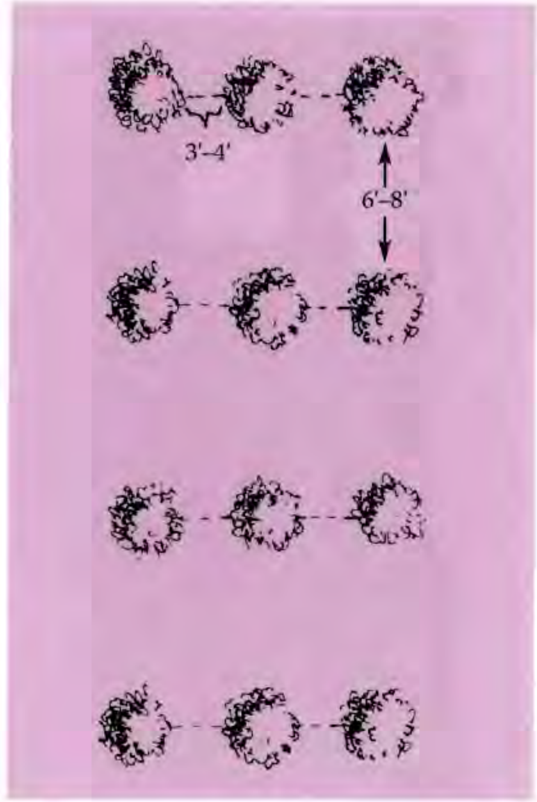


FIGURE 1. Plant spacing for currants and gooseberries

Space currants and gooseberries 3 to 4 feet apart in rows 6 to 8 feet apart. Elderberries should be spaced 7 to 8 feet apart in rows 10 to 12 feet apart to allow cultivation and air circulation in plantings.

POLLINATION

Currants and gooseberries are self-fruitful. Cross pollination with other cultivars is not essential. Elderberries are essentially self-unfruitful. Two or more cultivars should be planted near each other to provide for cross-pollination to ensure good fruit set.

SUGGESTED CULTIVARS

Since only a limited number of nurseries propagate currants, gooseberries, or elderberries, the cultivars suggested here are chosen on the basis of availability as well as their characteristics of good yield, fruit quality, and hardiness. Other unlisted cultivars may also perform satisfactorily in a home planting. The home fruit grower may find testing of other cultivars to be fun and interesting if time and space permits.

Currants

Wilder. Vigorous, red-fruited cultivar; moderately hardy and productive. Berries are somewhat larger than Red Lake. Ripens beginning in early July.

Red Lake. Vigorous, hardy, productive cultivar. Fruit is large, bright red when mature, and of good quality. Mild flavor. Ripens over a 3-week period beginning in early July.

White Imperial. An older cultivar. White, translucent fruit with pink blush is borne in loose clusters. Very rich, sweet flavor better than red currants. Winter hardy. Ripens mid-July.

Gooseberries

Hinnonmaki Red. A European gooseberry. Fruit is large, purplish red, and sweet. The canes are moderately vigorous, but are very spiny. For trial.

Poorman. Hardy and moderately productive. Red fruit is the largest of any American type. Somewhat less thorny than most cultivars.

Pixwell. Hardy and moderately productive. Medium-sized fruit is pink and mild flavored when mature.

Elderberries

Adams. Both Adams No. 1 and Adams No. 2 are suitable. Very large fruit compared to native plants. Plant is 8 feet tall, vigorous, with strong canes. Considered hardy. Ripens early August.

Johns. Exceptionally vigorous plant, growing 6 to 10 feet tall. Less productive than Adams, but fruit and fruit clusters are larger. Moderately hardy. Ripens 10 to 14 days after Adams.

Nova. An outstanding cultivar. Fruit is large and sweet. Plant is 6 feet tall, moderately hardy, and very productive. Use York as pollinizer. Ripens in August, before York. Originated in Nova Scotia.

York. More productive than Adams cultivars and as hardy. Largest berry of all cultivars; juicy, sweet, purplish black. Excellent 6-foot-tall ornamental with white flowers, black fruit, and showy fall foliage. Last to ripen in mid- to late August.

FERTILIZER

If the site was prepared properly and phosphorus and potassium were added based on the soil test, no additional phosphorus or potassium fertilizer should be required. Currants, gooseberries, and elderberries will benefit from applications of nitrogen. Young plants should receive 1 to 2 tablespoons of a high nitrogen fertilizer like ammonium sulfate, ammonium nitrate, or urea annually in the spring. Older plants should receive 3 to 4 tablespoons of high nitrogen fertilizer in the spring. Nitrogen can also be supplied by aged manures.

You can judge the need for fertilizer by looking at the bush. If the bush is very vigorous, producing a lot of new growth, reduce the nitrogen by half or eliminate it altogether. If growth is moderate but the plants still appear thrifty, apply the recommended amount. If few new canes are produced and growth appears poor, increase nitrogen application by half. For more detailed fertilizer use suggestions, refer to Extension publication *Fertilizing Small Fruits in the Home Garden* (A2307).

PRUNING

Growth and fruiting habit of currants and gooseberries are similar. Thus, pruning practices are essentially the same for both.

Prune when plants are dormant—usually in early spring just before growth begins. Wherever possible while pruning currants and gooseberries, remove canes drooping on the soil or canes which shade the center of the plant. After the first season of growth, remove all but six to eight of the most vigorous shoots from currants and gooseberries. After the second season, retain four or five 1-year-old shoots and three or four 2-year-old canes. Following the third season, keep three or four canes each of 1-, 2-, and 3-year-old wood. When plants have finished the fourth season, remove all 4-year-old canes, and repeat the renewal process annually as described above for the third season.

With elderberries simply prune out weak or broken canes, leaving six to eight vigorous canes to a plant.

Old neglected currant, gooseberry, and elderberry plants can be renovated by removing old canes and thinning out newer shoot growth to initiate the sequence described for new plantings. Mature gooseberry and currant plants should have eight to ten bearing canes and four to six new shoots to replace the oldest canes removed each year. Six to eight mature canes to a plant are generally adequate for elderberries.

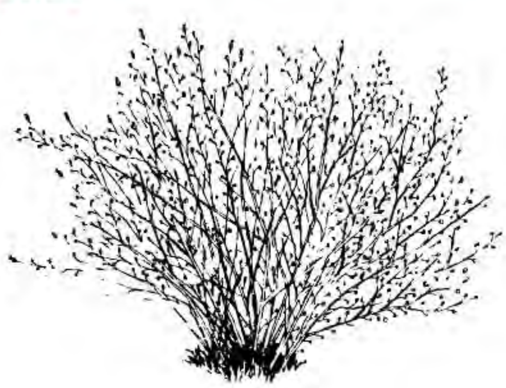
WEED MANAGEMENT

Currants, gooseberries, and elderberries do not compete well with weeds. Weed management begins by controlling perennial weeds before planting the bushes. After planting, frequent shallow cultivation will keep weeds out of the planting. Grasses are particularly competitive and must be controlled.

Mulches will aid in suppressing weeds as well as retaining soil moisture. Suitable mulches include shredded bark, bark chips, wood chips, sawdust, compost, straw, or lawn clippings. Apply mulches 3 to 4 inches deep around the plants. Time of application is not critical, but check the

FIGURE 2. Pruning currants and gooseberries

Before



After

mulch depth annually and replenish the mulch as needed. Don't get mulches too deep or you'll create a habitat for rodents.

Grass can be planted in the aisles between the rows. A grass walkway will let you harvest fruit following rains. Cultivate along the grass edges to keep the grass from invading the bushes.

INSECT PESTS OF CURRANTS AND GOOSEBERRIES

Under most conditions insects are not perennially serious pests of currants and gooseberries. However, certain insects occasionally will become abundant enough to cause serious damage if left unmanaged.

Currant aphid

This insect overwinters in the egg stage on plant stems. Eggs hatch in early spring, and the insects feed by sucking out the plant juices, which results in stunted and distorted new growth. As leaves continue to develop they will be crinkled, with down-turned edges. Areas between veins on the upper leaf surface may be reddened. As the aphids feed, they excrete excess sugar and water in small droplets called honeydew. Ants may feed on the honeydew, and a black fungus—sooty mold—often grows on it. The aphids themselves are small (up to about 2 mm) and green, and usually are found in colonies. Other aphid species also occasionally feed on currants and gooseberries.

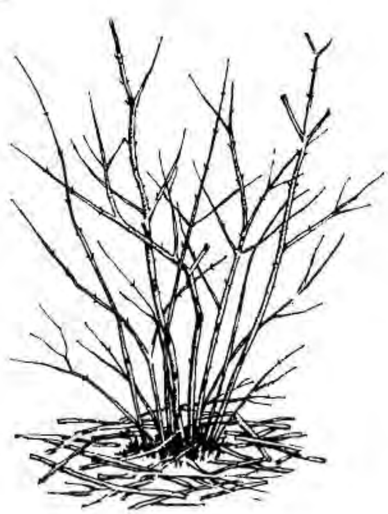
Aphids are often kept under good natural control by predators such as lady beetles and lacewings, small parasitic wasps, and even some insect diseases. In some areas or during certain years, these natural controls may not be adequate, and you may choose to use a chemical spray. Dormant sprays are effective, as is malathion or rotenone applied when the aphids are first seen. Insecticidal soap is also effective, but spray coverage must be thorough.

Currant borer

The damaging stage of this insect is a pale, yellow, worm-like larva, which tunnels through the pith of the cane. A member of the family called clear-winged moths, the wasp-like adult lays its eggs on the canes in early June. After hatching, the worm enters the cane and feeds all season. It overwinters in the larval stage in the cane,

FIGURE 3. Pruning elderberries

Before



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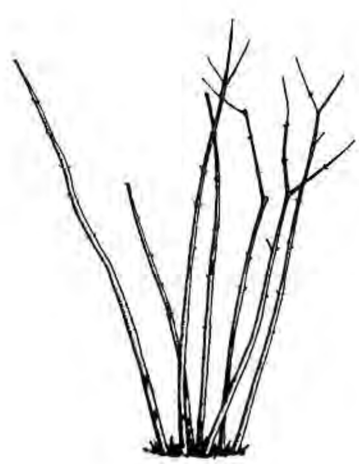


emerging as the adult moth the following spring. Feeding damage will kill the cane, and the first symptom is yellowing foliage on individual canes in late spring. Red currants are most frequently attacked.

Cut out and destroy infested canes as early as possible.

Imported currant worm

This is the most serious insect pest of currants and gooseberries, with the latter being the favored host. Foliage is consumed by several small, spotted, caterpillar-like larvae. The adults are sawflies about the size of a house fly. There are two generations per year, with damage occurring in spring and again in late summer.

Malathion and rotenone will control this insect. Start looking for damage shortly after the leaves have fully expanded. Usually the second generation is less severe than the first and does not require treatment.

Currant stem girdler

These adult sawflies make numerous punctures in canes during egg laying in spring. The damage causes new shoots to droop and wilt in late spring. Further damage occurs as the larvae tunnel through the canes. This insect also attacks poplar and willow trees, and damage is usually more severe near stands of these trees.

The best control is the removal and destruction of infested canes at the first sign of wilting.

Fourlined plant bug

This insect is yellowish green with four dark stripes on the back. It is quite active, and it runs and flies readily. It feeds by sucking plant juices from leaves and young stem growth. Damage to young leaves results in deformed and brown foliage. Older leaves will be spotted with many tiny light spots. This insect feeds on numerous wild hosts and damage is seen most frequently when such plants are allowed to grow near currants and gooseberries.

In areas where plant bugs have been a problem, they can be controlled by an early-season application of malathion.

Gooseberry fruitworm

The larval stage of this insect is a greenish worm with darker stripes along the sides. The worms feed by hollowing out the insides of fruit of both currants and gooseberries, with each worm consuming several berries. The adult is a moth.

Malathion or rotenone will control this insect. Make two applications 10 days apart, starting at early fruit development.

Currant fruit fly

Infested fruit drops early and has dark spots surrounded by a red area. Small white maggots will be found in such fruit. Late-maturing varieties are preferred by this insect.

Removal and burial or destruction of dropped fruit will keep populations from building. The insecticide program for gooseberry fruitworm will also control fruit flies.

San Jose scale

These insects are small, grayish disk-shaped specks about 2 mm across with a raised spot in the center. They are most frequently found on the canes. For most of its life, the scale insect is incapable of movement, and merely sits and sucks out the plant juices. Heavily infested plants will have canes encrusted with scales. In such cases, single canes or even entire plants will be killed.

Dormant sprays of lime sulfur or superior oil will control San Jose scale.

Insect pests of elderberries

Because elderberry is a native plant, there are several native insects and mites that feed on it. Although most of these are checked by natural controls, occasionally some plant damage can occur. Pyrellin, a combination of rotenone and pyrethrins, is registered for controlling several of the following elderberry insects.

Aphids

Certain species of aphids are occasionally found feeding on elderberry. Although feeding may cause stunted and distorted leaves, usually only a few branch tips are involved. If aphids become numerous, wash them from the plants with a strong spray of water, prune out and destroy the infested terminals, or spray with Pyrellin.

Cecropia moth

The larval stage of this insect is a large caterpillar that can remove much foliage during feeding. They are most abundant near wooded areas. Control by hand removal and destruction.

Elder shoot borer

The larval stage of this insect is a worm that bores in the stems and shoots. The adult moth lays eggs in July and August in canes at least 1 year old. Eggs hatch the following April or May. The larvae feed first within the unfolding leaf whorls, then bore into new lateral shoots. When partially grown, they migrate to the ground shoots, entering these at the bases and feeding upwards into the shoots. When the larvae are fully grown in mid-June, they leave the ground shoots and tunnel into dead canes to pupate, leaving small piles of frass (sawdust) on the ground at the base of the old wood.

To control, prune out infested shoots or canes. Eliminate dead canes to discourage pupation. Remove old canes with holes or with piles of frass at their bases. Destroy all prunings.

Diseases of currants and gooseberries

The most common diseases of currants and gooseberries are caused by fungi. Symptoms of fungal diseases include leaf spots, stem cankers, and shoot dieback. Signs of the fungal pathogens, such as fruiting bodies, are often visible when infected plants are viewed with a hand lens. The other major group of pathogens that attack currants and gooseberries are viruses. Typical symptoms of virus diseases include yellowish to pale green mosaic patterns on leaves, and malformed or stunted shoots, leaves, and flowers. Viruses do not form fruiting bodies. Fungal diseases are managed by pruning to enhance drying of foliage, and removal of prunings and plant debris to reduce primary inoculum. Virus-infected plants cannot be cured. However, virus-free plants can be obtained from reputable nurseries. Wild plants in the genus *Ribes* harbor many of the same fungi and viruses that infect cultivated varieties and may be reservoirs for pathogens.

Powdery mildew

Powdery mildew is a common fungal disease that is generally more serious on gooseberry than on currant. The fungus overwinters in pruned or broken twigs. In the spring spores are released and infect leaves and shoots. Signs of the fungus —white patches on the surface of leaves, shoots, and berries—first appear in May or June on lower parts of the bush. The patches enlarge, merge, and develop white, powdery masses of spores which can start new infections. Eventually the fungus turns reddish-brown and small, spherical, black spore-containing bodies develop. Severe infection will cause stunting and dieback of shoots. Infected berries are off-color and rough.

Powdery mildew infections are favored by humid conditions. Spacing bushes to enhance air movement and rapid drying should reduce disease. Removing prunings and other plant debris in the fall will reduce the amount of fungal inoculum available the following spring. Sulfur-containing fungicides are effective against powdery mildew but can damage plants, especially if used in hot weather. Repeated applications of sulfur may also harm beneficial microbes, insects, and earthworms.

Anthracnose

Anthracnose is a common leaf spot disease of both currant and gooseberry. The anthracnose fungus overwinters in leaf and twig debris. One type of spore (ascospore) is ejected from debris and carried by air currents to newly emerging tissue. A second type of spore (conidium) is splashed by rain to new tissue. Because fungal spores come from the ground, the first infections of the year are often on lower parts of the bush. Early season infections produce spores that cause additional infections. Thus, leaf spots occur throughout the season. Spots are dark brown or black and are scattered over either leaf surface. Spots enlarge (up to about ⅛ inch), become somewhat angular in shape, and sometimes have a purplish border. Spore masses appear as glistening, gray, slimy droplets under wet, humid conditions. In some cases, leaves turn yellow with green zones surrounding the spots. Leaf yellowing is more common on gooseberry than on currant.

Spores of the anthracnose pathogen can germinate at temperatures between 35° and 82°F, although 40° to 60°F is optimal for ascospores while 55° to 70°F is optimal for conidia. Spores do not germinate at temperatures above 85°F, so new infections do not occur during very hot weather. Moisture is required for infection.

To reduce primary infections, remove prunings and plant debris in the fall or in the spring before plant growth resumes. Copper-containing fungicides, such as Bordeaux mixture, are effective against anthracnose. Lime sulfur is also effective and will simultaneously control powdery mildew.

Leaf spot

Leaf spot is sometimes called Septoria leaf spot, named for the fungal pathogen. The fungus overwinters on leaves on the ground. Ascospores are discharged in the spring (usually late May) and infect leaves. Leaf spots appear by mid-June as small, dark spots that resemble anthracnose infections. However, as the spots enlarge, the centers turn light tan, and the borders turn brown. Small black spore-containing bodies appear scattered over the spots. Anthracnose spots do not have these black, pinpoint-sized fruiting bodies. Under wet conditions, spores are released from the bodies and are splashed to leaves where further infection may occur. Severely infected leaves turn yellow and drop. Leaf drop is more common with currant than gooseberry.

Minor diseases

White pine blister rust. Plants in the genus *Ribes*, including currant and gooseberry, are hosts for part of the life cycle of the white pine blister rust fungus. Black currant is more susceptible than red currant. The disease is usually not serious on currant and gooseberry but is devastating to white pine, the alternate host. Symptoms on currant and gooseberry appear in the spring as small, yellow spots on the undersides of leaves. Spores are shed from the spots and incite new infections. During late summer and fall, a different type of spore is formed and is carried up to a few hundred feet to white pine trees. The following spring, spores are released from white pines and can be carried up to 350 miles to *Ribes* plants. Separating currant and gooseberry from white pine by at least 1,000 feet can reduce infections but is often not practical.

Cane blight. Cane blight is caused by a fungus, and in severe cases can cause entire shoots or bushes to wilt and die. Symptoms are most evident just before fruit ripens. The wood and pith of affected canes are dark. Later in the season on current year's growth, or on 2-year-old infections, black wartlike bodies form in parallel rows along the length of the shoot. Removal of infected canes will minimize further infections.

Botrytis. Infections by the ubiquitous fungus *Botrytis cinerea* cause a dark-colored dieback of shoot tips and gray mold rot of berries. Infection and disease development are favored by wet, humid weather, especially in low areas with poor air circulation.

Cluster cup rust. Cluster cup rust produces striking symptoms on wild *Ribes* species or in neglected home plantings where sedge, the alternate host, is found. Damage is generally minor. The reddish rust is most common on leaf blades and petioles. The leaf is thickened where the cluster cup later appears.

Diseases of elderberries

Tomato ringspot virus

Tomato ringspot virus infects a wide range of plants, including elderberry. The virus is spread by nematodes in the genus *Xiphinema* and by pollen transfer. Symptoms are not distinct, but infected plants are weakened, have reduced productivity, and may die. Soils should be tested for the presence of *Xiphinema* nematodes before establishing a planting of elderberry.

Fungal cankers

Stem cankers are caused by any of a number of different fungi that commonly attack woody plants. If a canker girdles a stem, the tissue above the canker will usually die. Conditions that stress plants, such as winter injury, drought, and flooding, may predispose plants to infection. Infected shoots should be removed from a planting to prevent further infection.

Other diseases

Powdery mildew fungi attack elderberry, as do numerous leaf-spotting fungi. These diseases seldom warrant special attention other than removing as much plant debris as possible in the fall to prevent the pathogens from overwintering. Root rots may occur in poorly drained soil. Verticillium wilt affects a wide range of plants including elderberry. Plants should not be established in sites where tomatoes or related plants were grown during the past 5 years.

Related publications

Fertilizing Small Fruits in the Home Garden (A2307)

Home Fruit Cultivars for Northern Wisconsin (A2488)

Home Fruit Cultivars for Southern Wisconsin (A2582)

Nurseries

This list of nurseries is provided as a convenience for our readers. It is not an endorsement by Extension, nor is it exhaustive. The plant materials listed in this bulletin may be available from other equally suitable nurseries.

Bear Creek Nursery
P. O. Box 411
Northport, WA 99157
(509) 732-6219

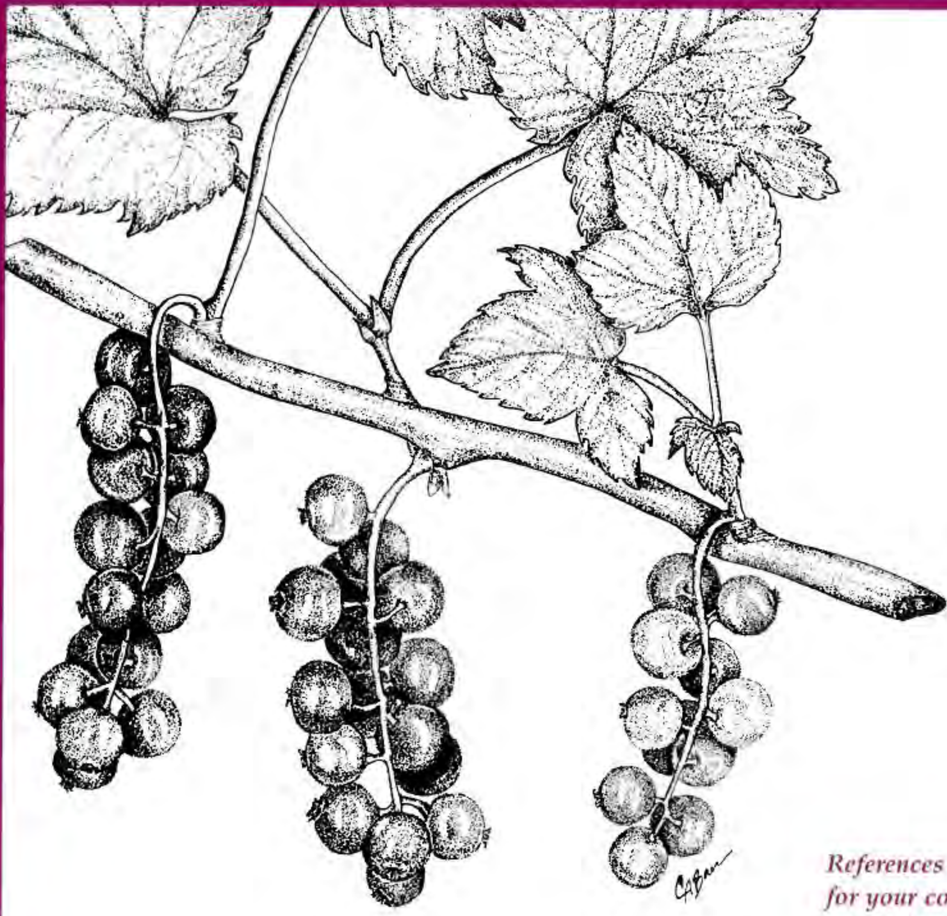
Indiana Berry & Plant Co.
5218 W 500S
Huntingburg, IN 47542
(800) 295-2226

J.W. Jung Seed
335 South High Street
Randolph, WI 53957
(800) 247-5864

McKay Nursery
P.O. Box 185
Waterloo, WI 53594
(920) 478-2121

Miller Nurseries
5060 West Lake Road
Canandaigua, NY 14424
(716) 396-2647

St. Lawrence Nurseries
325 State Highway 345
Potsdam, NY 13676
(315) 265-6739



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UW Extension

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A1960 GROWING CURRANTS, GOOSEBERRIES, AND ELDERBERRIES IN WISCONSIN

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CHAPTER 9

Gooseberries and Currants

CONTENTS

INTRODUCTION

Decisions to commercially produce specialty small fruit crops such as gooseberries and currants should be driven by availability of market outlets for the fruit. A market should be secured before plants are set in the ground. Fresh fruit sales are options for direct marketers, though most consumers are unfamiliar with the fruit and their uses. Consequently, processing the crop into jams, jellies, fresh juice products, and wine may be the best way to utilize these crops. In Europe, significant fresh and processing markets exist, which may be an indication of the undeveloped market potential in this country. Growers near populations of people who are already familiar with the crop may have a ready market.

Successfully producing these unique fruit involves knowledge of cultivars, their horticultural characteristics and requirements, and successful pest management.

TYPES OF PLANTS

Currants and gooseberries are two closely related species within the genus *Ribes*. This genus is diverse with more than 150 known species and hundreds of cultivated varieties (cultivars). Currants and gooseberries can be easily distinguished by the presence or absence of thorns; gooseberries usually have thorns, while currants do not.

Ribes plants are long-lived perennial shrubs that are cold-hardy, some to USDA Zone 2. Species and cultivars vary in plant size and form but are usually upright to spreading in habit (3 to 6 feet). Disease and insect resistance is variable. The fruit is versatile and nutritious and varies in presentation, flavor, shape, size, texture, and color.

CURRANTS

Most cultivated currants are of European origin, though many native North American species also exist. Currant color types include red, white, pink, and black. Plants are thornless and fruit is small (pea sized) and produced and harvested in a grapelike cluster called a “strig.” Cultivars may be classified under several species; however, keep in mind that some debate exists as to which species different types of plants belong. Species are *Ribes rubrum* (most red currants and some whites), *R. petraeum* (white), *R. vulgare* (pink, white, and red), and *R. nigrum* and *R. ussurienses* (black). Native currants, sometimes considered more closely related to gooseberries, belong to the species *R. odoratum*, the Buffalo Currant, with some selections known as Clove Currant (for example, the cultivar Crandall) because of the fragrance of their blossoms. Because of their tart flavor, currants are seldom eaten out of hand but are used for processing into juices, jams, and jellies. Black currants are noted for their strong (to some, offensive) odor and astringent flavor, yet they are highly prized in Europe for juice products and their high nutrient content. Vitamin C concentrations can be as high as 250 milligrams per 100 grams of juice, even after 6 months of storage.

GOOSEBERRIES

Cultivated forms of gooseberries are divided into two major types, European (*Ribes grossularia* var. *uva-crispa*) and American (*R. hirtellum)*. European types are native to North Africa and the Caucasus Mountains of eastern Europe and western Asia, while the American types are native to the northern United States and Canada. Within the European types, fruit size varies widely, from pea sized to small egg sized. Color varies widely as well, with fruit colors in shades of green, pink, red, purple, white, and yellow. This diversity is due to the historical popularity of the European gooseberry. Over the past two centuries, hundreds of cultivars have been developed with a focus on prize-winning fruit size and color.

Native American gooseberry species have smaller fruit size and less flavor, but they are more resistant to diseases when compared to European cultivars, which are noted for powdery mildew and leaf spot susceptibility. This problem has limited the culture of most of the European types in this country. However, disease resistance is improving through additional breeding with American types, and several new promising European cultivars have recently been introduced in the United States and Canada. In comparison, most known American cultivars in the trade today have had some historical infusion of European genetics to improve size and flavor, which can be traced to a handful of crosses made in the 1800s. All gooseberry cultivars have varying degrees of thorniness. Fruit is produced in small groups or singularly on stems and are picked individually.

JOSTABERRIES

Lastly, the jostaberry is an interspecies cross between gooseberries and black currant. Its fruit is larger than currants, similar to gooseberries, and black in color. The stems are thornless. Fruit quality has not gained wide appeal for either fresh or processed use, but it has inspired renewed breeding efforts, with new and improved crosses being developed. It has a vigorous growth habit and is resistant to white pine blister rust. Disease (mildew) resistance is similar to that of black currants.

LEGALITY OF CULTURE

The history of *Ribes* production in America is of significant interest. Cultivated currants and gooseberries were first introduced in America in the Massachusetts Bay colony in 1629. By the mid-1800s commercial acreage of currants and newly developed European and American gooseberry crosses such as Downing and Houghton were common in the eastern United States. In 1899, reported production in the United States reached nearly 7,000 acres. In the early 1900s, *Ribes* species were implicated in the spread of white pine blister rust (*Cronartium ribicola*), a devastating disease for white pine trees brought into this country on imported nursery tree stock.

Ribes, in particular black currants, are a secondary host to this disease, which requires both pine and *Ribes* to complete its life cycle. Red currants and gooseberries exhibit varying degrees of susceptibility. In 1912, federal and state governments introduced restrictions on importing, planting, and cultivating *Ribes* species to protect the lucrative timber industry. Soon after, a sweeping federal law was passed banning only black currants, while some northern states passed outright bans on all *Ribes* species. A program of eradication of both native stands and domestic plantings was begun, with Civilian Conservation Corp (CCC) crews doing much of the work.

The federal law was rescinded in 1966, but today laws regarding *Ribes* culture remain on the books in many states. While some states allow all species to be cultivated, others continue full or partial bans geographically or by selected species, namely black currant. Laws banning *Ribes* species range from being well to poorly enforced, or in some instances agencies responsible for enforcement no longer exist as originally designated. Restrictions often vary by township within a state. For information on state laws, contact your state's Department of Agriculture or a cooperative extension office. Cultivars resistant to white pine blister rust are now available and should be selected.

The early *Ribes* industry was dealt a great setback because of these bans and has yet to recover. Variable and often confusing legal issues are still an effective roadblock to development of a viable industry. Nevertheless, the threat of white pine blister rust remains a reality today, and site selection in new plantings should take into account the presence of nearby susceptible pine species, identifiable by the characteristic of five needles per needle cluster. Most commonly this means consideration of native or planted stands of white pine in the area, but several other susceptible species may be cultivated in nearby nursery operations or your neighbor's yard as ornamentals.

CULTURE

Overall, cultural requirements are similar for all *Ribes* species, and they can be grown successfully in most of the Mid-Atlantic.

GENERAL

Ribes are adapted to cooler climates; therefore, excessive summer heat can be a limiting factor to culture. Temperatures above 85°F can cause currant leaves to begin to flag and extended direct sunlight can cause leaf sunburn. Temperatures of 95°F sustained for three or more days may cause most of the fruit to drop from the plant, especially if the fruit is nearly ripe. Partial shade, a soil mulch, and adequate water are essential in drier, hotter areas. American gooseberries are more tolerant of direct light and warm temperatures than European types.

Currant and gooseberry plants can be very productive at maturity, with yields of 4 to 6 quarts per plant considered good (by weight, gooseberries produce 8 to 10 pounds per plant and currant, 5 to 8 pounds per plant). Black currant yields are usually 50 percent less. Red currants and gooseberries reach economic bearing capacity in 3 to 4 years, and black currants in 4 to 5 years. With care, the life of currant plantings is about 8 to 15 years, and that of gooseberry plantings is 15 to 20 years. The fruit ripen over a several-week period and, depending on variety, can remain on the plant for extended periods of time in cool weather, allowing harvest schedule flexibility.

SITE SELECTION

Unlike other fruit crops, currants and gooseberries can tolerate partial shade. Northern to northeastern exposure is often ideal because the air and soil will be cooler and moister and plants will be protected from direct sunlight. Full sun exposure in cooler or mountainous climates, however, is desirable and leads to increased yields.

Air circulation and movement is an important consideration in site selection, as foliar disease can be a problem in many cultivars. Consider summer prevailing winds and align rows to take advantage of air movement.

Currants and gooseberries require approximately 1,000 to 1,200 chilling hours to break dormancy, so plants bloom early in the spring. Avoid low areas where late spring frosts can injure the blossoms. Though tolerant to cold, temperatures below 28°F can cause damage to flowers and reduce yields. An additional advantage of cooler, northern slopes is slow spring warmup and delayed plant growth, which can further reduce frost risk.

Plants have shallow, fibrous roots and should be situated where irrigation can be provided. They should be grown beyond the canopy of shade trees, away from competition for moisture.

Though currants and gooseberries are not excessively damaged by white pine blister rust, their proximity to susceptible pine species (those with five needles per needle cluster) should be considered. Locate plantings at least 1,500 feet away from valuable ornamental plantings, commercial nurseries, commercial pine crops or native stands.

SOILS

Currants and gooseberries are fairly tolerant of a wide range of soil conditions and less than perfect sites. They perform best in well-drained silt to sandy loam soils with an organic matter content greater than 1 percent and good water-holding capacity. Planting in light sandy or heavy clay soils should be avoided, as well as areas in which water stands for any length of time. If your area is poorly drained, improve the site by tiling or building raised beds. Both heavy and light soils can be improved by additions of organic matter. The ideal soil pH is slightly acidic, from 5.5 to 6.5. Micronutrient deficiencies may occur at a pH greater than 7.0. Saline or salty soils near coastal areas should be avoided.

CULTIVARS

Several factors should be considered when choosing a cultivar. Adaptability, availability of nursery stock, productivity, ripening time, fruit size, appearance, flavor, ease of harvest, and disease resistance are just a few important considerations.

Selection for cold-hardiness is usually not an issue, though bloom time and bloom hardiness should be considered in areas where late spring frosts commonly occur. More importantly for the Mid-Atlantic, relative tolerance to summer heat, foliar disease, and insect pressure should be considered. Documentation of the performance of cultivars in our region is limited, and test plantings of cultivars are strongly recommended before larger plantings are committed.

Currants

Most currants are self-fruitful; therefore, only one cultivar is needed for fruit production, unless otherwise noted in cultivar descriptions. However, currants will produce better and larger fruit crops when more than one cultivar is planted. A few cultivars may be locally available through nurseries and garden centers, but specialty mail order nursery suppliers are the primary source of stock. See Appendix C for a listing of nurseries that carry *Ribes*.

Red Currants

Cascade
- Early.
- Fruit is large, medium dark red, and produced on short strigs.
- Plants are erect to slightly sprawling and of medium productivity and vigor.
- Berries are susceptible to sunscald and should be picked promptly.

Detvan
- Midseason.
- A selection from Slovakia.
- Plants are very large, robust, and upright.
- Fruit is large and produced on very long strigs, often with as many as 25 to 30 berries per strig.
- Should be planted on at least 5-foot row centers.
- Very high yielding.
- Good resistance to gray mold (also called runoff).

Jonkeers van Tets
- Popular early to midseason selection from Holland.
- Fruit is dark red and soft, has very good flavor, and is on medium-sized strigs.
- Plants bloom early and are heavy producers.
- Growth habit is not uniform.
- Plants are mildew and aphid resistant, but gray mold can be a problem for fruit production in wet years.

Red Lake
- Mid- to late season.
- Fruit is large, firm, light red, subacid, and is on easy-to-pick long strigs with high juice content.
- Easily found in nurseries.
- Plants are productive, upright, dense and hardy.
- Has a low tolerance to frost.
- Susceptible to mildew.

Rovada
- Late season.
- Fruit is large and produced on long, compact strigs.
- Dependable bearer and productive.
- Blooms late, so frost can be less of a problem than with other cultivars.
- Resistant to mildew and other leaf diseases.

Tatran
- Late season.
- A sister selection of Detvan, with many similar characteristics.
- Plants are robust and upright.
- Fruit is very large and produced on long strigs of 25 to 30 berries.
- Very high yielding and resistant to runoff.
- Should be planted at least 5 feet apart both within the row and between rows.
- Canes become very heavy with fruit and may need some support.

Wilder
- Mid- to late season.
- Fruit is large, dark red, subacid, and produced on large compact clusters.
- Plants are productive, large, and upright to spreading.
- Resistant to leaf spots.

White and Pink Currants

White and pink currants are more difficult to find. They grow like red currants but have a less acidic, sweeter, unique flavor. The fruit is small, white to yellowish to pinkish, and opaque to translucent.

Blanka
- Mid to late season.
- Known for heavy yields and dependability.

- Produces long strigs of large, opaque, off-white fruit.
- Plants are vigorous and spreading and easy to grow.

Pink Champagne
- Midseason.
- Quality and flavor are good.
- Fruit is a translucent pink color.
- Yields are generally low.
- Plants are vigorous, upright, and resistant to leaf diseases.

Primus
- Late season.
- Has white to yellowish fruit on upright, vigorous plants.
- Similar to Blanka in fruit quality, but yields may be slightly lower.

White Imperial
- Midseason.
- One of most commonly available white varieties.
- Lowest acidity of currant cultivars.
- Produces small fruit on long strigs.
- Yields are moderate.
- Plants have a spreading growth habit.

Black Currants
Black currants are prized for their strong aroma, flavor and high vitamin C content. Some varieties, particularly those that are purely *Ribes nigrum*, are highly susceptible to white pine blister rust. Resistance has been developed in cultivars through crossing of *R. nigrum* and *R. ussurienses*.

However, juice and processing quality of initial crosses (Consort, Coronet, Crusader) are considered substandard as compared to standard nonresistant cultivars. Recent backcrosses (crosses back to a parent), such as the cultivar Titania, have retained near immunity to white pine blister rust. These backcrosses also have improved commercial traits such as tolerance of adverse weather at flowering, and suitability for machine harvest. In addition, they have a long hang time, even fruit-ripening within clusters, high yield, improved resistance to mildew and leaf diseases, and better juice quality. Black currants nonresistant to white pine blister rust, though sometimes listed, are not recommended and usually are in the target group still prohibited by law.

Ben Lomond
- Known for even ripening and high yields of large, firm fruit that have a long hang time and high vitamin C content, despite high pectin levels.
- Plants are compact yet spreading and have good frost tolerance at flowering.
- Plants have variable resistance to mildew and slight resistance to white pine blister rust.

Ben Sarek
- Early to midseason.
- Known for strong set of very large fruit, ease of hand harvest, and tolerance to frost and cold injury.
- Growth habit is very compact.
- Recommended for small-scale growers with limited land area.
- Has slight to moderate resistance to white pine blister rust.

Black September
- Late season variety.
- Fruit is large and firm with a mild flavor.
- Yields are poor.
- No resistance to white pine blister rust.

Consort
- Early to midseason.
- Fruit is medium to small with medium firmness.
- Juice quality is fair.
- Does not machine harvest well.
- Plants are self-fertile with dependable set but are rated fair in productivity.
- Susceptible to leaf spot and mildew.
- Resistant to white pine blister rust.

Coronet and Crusader
- Similar to Consort but both require pollinators.
- Yields and quality are poor.
- Resistant to white pine blister rust.

Tisel
- Midseason.
- New cultivar that is a progeny of Titiana.
- Productive.
- Fruit ripens evenly and has very high vitamin C levels.
- Has reported immunity to white pine blister rust and also is resistant to mildew.
- Not yet available in the United States.

Titania
- Midseason.
- Fruit is large and of high quality.
- Yields are high.
- Plants are vigorous, growing up to 6 feet tall, come into full production by the third year, and are well-suited for machine harvest.
- Nearly immune to white pine blister rust, but is susceptible to a cane blight disease, possibly from the genus *Botryosphaeria*.

Current Breeding Efforts
A few Russian seedling selections are being increased in number for distribution and will become available in the near future. These selections vary in resistance to mildew and white pine blister rust. Many of these selections are large fruited and, in general, much more palatable for fresh use than black currant cultivars currently available.

Gooseberries
American gooseberry cultivars are more foliar-disease resistant, more productive, healthier, and more adaptable to varied climatic conditions than European cultivars, which have the advantages of large fruit size, good color, and sweet flavor. Lack of disease resistance and marginal hardiness has limited European cultivar use in North America and a stringent disease management program is required to grow them. Despite the huge number of European cultivars in existence, few are commonly available in the United States. Newer cultivars with American genetic disease resistance are being developed and introduced; however, at this time, few new commercial American cultivars are on the market. Most currently available have been around for many years. While the true genetic lines are somewhat blurred between American and European gooseberries, a distinct separation of the two types still remains.

The following cultivars are of American origin:

Captivator
- Late season.
- American-European hybrid.
- Fruit is large, pink to red, teardrop shaped, and sweet.
- Yields are moderate.
- Plants are mildew resistant with few thorns.

Oregon Champion
- Midseason.
- Fruit is small to medium in size, round to oval, and pale white to greenish yellow at maturity.
- The fruit has a thin skin and is juicy and tart.
- Plants are large, vigorous, upright to spreading, and productive.
- Plants are somewhat susceptible to mildew.

Pixwell
- From North Dakota.
- Fruit is of medium size, pink, in clusters, and of fair quality.
- Plants are vigorous, productive, hardy, and have few thorns.
- Recommended for home garden use.
- Best if used slightly underripe.
- Mildew resistant.

Poorman
- Early to midseason.
- Fruit is red, of medium size, and oval shaped.
- Fruit ripens over a long period and is of high quality.
- Flavor is sprightly sweet.
- Plants are vigorous, the largest of American cultivars, productive, upright, dense with few short thorns, and mildew resistant.

Tixia
- Midseason.
- Red fruit is large and relatively mild in flavor.
- Plants are vigorous, have few thorns, and are resistant to mildew.

Welcome
- Released by the University of Minnesota.
- Fruit is a dull red and of medium to large size.
- Plants are hardy and have few spines.

The following cultivars are of European origin:

Careless
- Midseason.
- Fruit is large, oval, and pale green to milky white when ripe with a smooth transparent skin.
- Plants are moderately vigorous, upright to spreading, and very susceptible to mildew.

Clark
- Mid- to late season.
- Fruit is very large, red, and of high quality.
- Plants are thorny, dense, short with branches close to the ground, moderate in vigor, and productive.
- Thought to be a natural American-European cross.
- Plants are very susceptible to mildew.

Hinnonmaki Red and Hinnonmaki Yellow
- Developed in Finland.
- Fruit is red and green yellow, respectively.
- Hinnonmaki Red fruit is medium size, while Hinnonmaki Yellow fruit is smaller.
- With both, the skin is tart, but the flesh is sweet, aromatic, and has very good flavor.
- Both are thorny.
- Hinnonmaki Red is also known as Leppa Red (erroneously).
- Plants are short, moderate in vigor, and upright to slightly spreading.
- H. Red is more mildew resistant than H. Yellow.
- Sometimes characterized as an American type.

Industry
- An older, large, red-fruiting cultivar with slightly hairy fruit.
- Finding a source of this cultivar may be difficult.
- Plants are very susceptible to mildew.

Invicta
- Midseason.
- Fruit is large and pale green with a bland flavor.
- Used for processing, where it provides an even color and flavor.
- Plants are large and productive and have numerous spines.
- Resistance to mildew is good, but resistance to other leaf spots is not.

SITE PREPARATION

Site preparation should begin by eradicating perennial weeds in the planting area to the fullest extent possible. This can be achieved by applying translocated herbicides in mid- to late summer or by diligent cultivation. A soil test should be taken to determine the soil pH, phosphorus, and potassium levels and needs. These nutrients should be amended to moderate levels, with available phosphorus brought to a range of 50 to 75 pounds per acre and potassium to 150 to 200 pounds per acre. Lime should be added to bring the soil pH to 6.1 if pH levels are below 5.5. Along with lime, phosphorus can be incorporated in the fall; however, potassium and nitrogen (25 to 35 pounds per acre) should be incorporated in the spring to avoid the loss of nutrients to leaching. Currants and gooseberries are sensitive to the chloride contained in muriate of potash (0-0-60), so another form of potassium, such as sulfate of potash, should be used. If plants are to be planted in the fall, nitrogen should not be applied until the following spring.

Currants and gooseberries respond well to organic amendments, which improve aeration and drainage and also increase water-holding capacity in all soil types. Organic matter can be applied in the fall or spring before planting. Well-aged manure at 4 to 5 bushels per 100 square feet (1,750 to 2,200 bushels per acre) is a good option; other suitable sources are finished compost, leaves, rotted hay or straw, shredded peat, or sawdust. Any additions should be free of weed seeds and insects.

For larger plantings, a cover crop (green manure) can also be grown and turned in to increase organic matter. See Chapter 2 for more information on green manure crops. Two or possibly three green manure crops can be grown during the course of one growing season if the first crop is planted early. At blossom, till or disk down the cover crop and replant immediately. A winter cover (e.g., cereal rye, vetch) should be sown after fall site preparation. At least 3 weeks prior to spring planting, overwintered cover crops should be burned down with herbicides and/or mowed or chopped and incorporated. Be sure to disk or rototill organic materials deeply into the soil to ensure adequate breakdown and soil loosening. If large amounts of non-decomposed materials are added, ammonium nitrate can be applied at 1 pound per 100 square feet (450 pounds of ammonium nitrate per acre) to aid in decomposition. A different nitrogen source can be used, applied at an equivalent rate (150 pounds of actual nitrogen per acre).

In areas of questionable drainage, permanent raised beds 3 to 4 feet wide and 4 to 6 inches tall should be formed. A second option to improve drainage is to install drain tiles at least 25 inches deep near the row.

SPACING AND PLANTING SYSTEMS

Plant spacing is dependent on cultivar vigor and growth habit, site fertility, planting system, and equipment size. In general, red or white currants and gooseberries should be planted 3 to 4 feet apart in rows a minimum of 6 to 8 feet apart. Black currants are more vigorous and should be spaced 4 to 5 feet apart in rows 8 to 12 feet apart. Avoid overcrowding plantings because adequate air circulation and movement are critical in reducing foliar disease incidence. Equipment access is also an important preplant consideration, and adequate room must remain between rows when plants mature.

Plants can be established as freestanding bushes at the above spacing or planted at closer densities to form a hedgerow—a common practice for black currant production. A third, less common method is to keep plants pruned as a tree form or as a standard with a trunk kept at a chosen height and supported by a trellis. This is sometimes practiced with gooseberries, which increases air circulation and reduces disease. In this system, spacing is the same as that of freestanding bushes.

While trellising the plants is not a requirement, it improves fruit exposure and makes harvesting easier, especially with gooseberries. A simple series of horizontal wires placed about 6 inches apart to which canes can be tied will suffice.

OBTAINING PLANTS

Plants should be one or two years old, vigorous, and well rooted. Reliable disease-free stock can be purchased from a nursery, or nonpatented stock can be easily propagated by means of layering and by cuttings (see section on propagation). Only disease- and insect-free stock should be propagated and planted. Nursery-grown plants will usually come as bare-root stock. Request that the plants be shipped as close to the planting date as possible.

After receiving the plants, check the roots for moistness, moisten if necessary, and store plants in a plastic bag in cold storage (separate from apples or other sources of ethylene, as this is lethal to plants) until the site is ready to plant. If storage is necessary for longer than two weeks, plants can be heeled in with roots covered with soil in a temporary outdoor trench.

PLANTING

Because *Ribes* plants break dormancy early, very early spring planting is recommended. A plant that has just leafed out can easily tolerate 20°F, so do not be afraid to plant as soon as the soil can be worked. If dormant nursery stock is available, fall planting should be used; however, avoid nitrogen fertilizer application, which may decrease winter hardiness. In addition, plants should be mulched to reduce winter frost heaving effects.

Avoid excessive root drying and exposure as plants are set out. The roots of bare-root plants should be soaked in a bucket of clean water 2 to 3 hours prior to planting. Plants should be set about an inch deeper than they were growing in the nursery. Covering one to three buds on the lower part of canes will encourage a larger root system and increase renewal cane production. Avoid excessive planting depths. Damaged and straggling root parts should be trimmed; the roots should be spread out, covered with soil, and pressed firmly to remove air pockets. Water the plants to settle the soil, but avoid "water logging."

ESTABLISHMENT

Newly set plants should be pruned back to 6 to 10 inches above the ground, depending on root system vigor. This will encourage development of new canes. With fall planting, this pruning should be delayed until spring. When practical, blossoms or any set fruit should be removed the year of planting. This helps plants to become well established and make better vegetative growth.

CULTIVATION AND MULCHING

Mechanically cultivate or hand hoe from early spring until harvest to control weeds between rows. Practice level, shallow cultivation to avoid harming roots. After planting and throughout the life of the plants, maintain an organic mulch of straw, decomposed hardwood sawdust or bark, pine needles, compost, or other suitable material around the base of each plant or as a band over the row. Mulching helps to conserve soil moisture, cools the soil, and suppresses weeds. The mulch should be 2 to 4 inches deep, with additional annual applications made to maintain this depth as decomposition occurs. Fresh or undecomposed materials such as woodchips or sawdust can tie up available nitrogen as they break down, and additional nitrogen above recommended rates may be needed. Signs of nitrogen deficiency include yellowing older leaves and poor growth. Rodents may infest mulched areas and should be controlled before winter sets in.

FERTILITY

Currants and gooseberries are heavy feeders and respond to a regular fertilizer program. Established plants should be fertilized each spring as growth begins. Depending on site fertility and plant vigor, fertilizer applications can be made only once in early spring or split to encourage better growth. Because the plants have shallow roots and fertilizer may quickly leach below the root zone, splitting applications, especially in light textured soils, is recommended.

Both currants and gooseberries are sensitive to chloride. Therefore, when applying a balanced fertilizer such as 10-10-10, use a fertilizer made with potassium sulfate rather than potassium chloride. You may need to blend your own. Keep in mind that some fertilizers and certain mixtures absorb moisture very quickly, so the blend should be applied immediately after it is mixed. Other potassium-containing fertilizers that can be used are potassium magnesium sulfate (Sul-Po-Mag), if magnesium is also needed, and potassium nitrate. For second-year plantings, apply approximately 4 to 5 ounces of 10-10-10 fertilizer per plant (or an equivalent rate of a similar fertilizer). A broadcast application should be made, spread under the branches and just beyond the drip line. In third-year plantings, rates should be increased slightly. Fourth-year and mature plantings should receive a maximum of 6 to 8 ounces of 10-10-10 fertilizer per plant (0.6 to 0.8 ounces of actual nitrogen per plant or 25 to 50 pounds of actual nitrogen per acre). Depending on growth, up to double these rates may be needed where fresh sawdust or bark chip mulch is used (using fresh mulch materials is not recommended).

When available, manure or other composted materials with a high nitrogen content are the best nutrient sources for *Ribes,* which respond well to the slow release nature of organic nitrogen sources. These materials can be substituted for all or part of the fertilizer requirement. They should be applied in early spring to allow time for nutrient movement into the root zone. In general, inorganic nitrogen additions can be reduced by one-half or more with the use of manure. Both manure and chemical fertilizers applied in summer or early fall can make plants more susceptible to winter injury.

NOTES ON SOD ROW MIDDLES

A permanent sod such as creeping red fescue or orchardgrass may be grown between rows. This area should be lightly cultivated and fertilized prior to sowing or drilling seed for best results. Sod eliminates the need for cultivation between rows and provides a clean walking area for hand-picking. Sod should not be allowed to grow closer than one foot from the drip line and should be kept closely mowed and irrigated. Avoid legumes in a sod seed mix because they may provide untimely nitrogen. Plantings under sod culture tend to be more prone to frost injury as compared to cultivated soil since bare soil warms more quickly in the spring and releases more heat on cold nights.

IRRIGATION

For quality fruit, currants and gooseberries require about one inch of water per week from bloom to the end of harvest. This ensures good plant growth, high yields, and large berry size. In most areas, rainfall is usually adequate, especially if mulch is being used. However, if rainfall is insufficient, supplemental irrigation is advised. Drip or trickle irrigation is preferable to overhead irrigation, which can increase foliar disease problems. During prolonged dry periods after harvest, plants should be watered periodically until late August or early September. Add enough water to moisten the soil to 6 to 8 inches deep, allowing it to dry out somewhat before watering again. Roots can be injured by overirrigation.

As with strawberries, sprinkler irrigation can help to prevent frost injury during bloom. As temperatures fall just below freezing, low volumes of water are applied using special low-delivery nozzles. A protective film of ice forms over the plant and blossoms and, as water is converted to ice, heat is released, which protects blooms and newly set fruit. Trickle systems are not useful for frost protection. See Appendix A for additional information on frost protection.

POLLINATION CONSIDERATIONS

Since currants and gooseberries (except for a few black currants) are self-fruitful, cross-pollination by a second cultivar is not needed. However, cross-pollination can result in bigger fruit and a larger harvest. Larger plantings may benefit from inclusion of multiple cultivars and nearby placement of beehives to facilitate pollination. Bumble bees and solitary bees are more efficient in most cases due to the early bloom when weather is colder and honey bees are not as active. As always, only insecticides not harmful to bees should be used during bloom.

PRUNING AND TRAINING

Currants and gooseberries should be pruned in the dormant season—during late winter and early spring. Red currants and gooseberries are similar in their fruiting characteristics; black currants are different and should be pruned accordingly.

Red, White, and Pink Currants and Gooseberries

Plants of these types produce most of their fruit from short spurs located on one- , two- , or three-year-old canes. Spurs decline in productivity by the fourth year. Hence, older canes should be removed at ground level. In pruning for bush production, a goal for a mature plant is to have nine to twelve main stems (three to four each of one-, two- , and three-year-old canes). All stems older than three years should be removed. This is called renewal pruning and will keep the bushes productive. A seasonal pruning schedule should follow this pattern:

- At planting: After planting, head back plants to 6 to 10 inches tall to encourage root and basal shoot growth.
- After the first season: During late winter or early spring, remove all but six to eight of the most vigorous shoots, making pruning cuts close to the ground.
- After two seasons: Leave four or five new one-year-old shoots and keep three or four of the two-year old-canes.
- After three seasons: Leave three to four canes from new one-year-old growth, and keep three or four each of the two- and three-year-old canes.
- Mature plantings: After the fourth and following years, remove the oldest canes and keep three to four new one-year-old canes to replace the older canes you removed.

When pruning, also remove branches that lie too close to the ground. Heading back is not necessary; however, removal of diseased tips and weak or otherwise damaged branches is advised. Excessively crowded and vigorous canes should be thinned to create an open center to increase light exposure for fruit bud formation and to increase air circulation. Do not make the common mistake of leaving the bushes too thick. Plants may also be thinned in summer by removing many of the side branches on the canes so that the canes are better able to support a heavy fruit load and to facilitate harvest.

Pruning red currants to a tree or standard form is also possible. This requires judicious removal of suckers and stem growth and/or the use of grafted plants. Trellising or some means of support is usually required. The advantages of this system are increased yields and air circulation. Disadvantages are increased hand labor in pruning and training, cost of wire support, and decreased plant longevity. This method is recommended for those who have had experience with dwarf tree fruit systems or are interested in specialized or unique methods of production or ornamental aspects. Trellising of large red currant plants reduces wind damage in early spring.

Black Currants

Black currants produce best on one- and two-year-old wood. They do not fruit on spurs as do red currants and gooseberries. Strong one-year-old shoots and two- and three-year-old stems that have an abundance of strong one-year-old shoots are the most productive.

Because of their bearing habit, black currants can be pruned by two different methods. These two methods can be used in both free-standing and hedgerow systems.

Method 1

In a method similar to pruning red currants and gooseberries, plants should have two- and three-year-old canes, along with one-year-old shoots, with a total of 10 to 15 canes per mature bush. Black currants are somewhat more vigorous than red currants; hence the number of canes kept is higher. The proportion of one-year-old canes kept to older canes is also different, with approximately one-half of all canes kept being one-year-old canes. Remove all shoots more than three years old at ground level.

Method 2

An easier method of pruning black currants takes advantage of its fruiting habit. This system uses only one-year-old canes and an alternate-year production system.

- Year 1: Plants are pruned to the ground immediately following the harvest, then lightly fertilized and watered. Small immature canes may be allowed to grow. This will usually provide 12 to 18 inches of growth by dormancy. These canes do not set flower buds.
- Year 2: The previous year's canes remain vegetative and additional canes are produced.
- Year 3: A large crop is produced. Plants are again pruned to the ground after fruiting.

The cycle repeats with vegetative growth only the next year. As plants are out of production for a season, the planting should be divided into differently pruned blocks to ensure a crop each year. This method greatly simplifies pruning of black currants and reduces insect and disease carryover. The hedgerow planting system is ideal for this time-saving pruning method.

Black currants can also be trained as a standard. This requires diligent pruning to promote one-year-old shoot production on older wood.

HARVEST

Black currants, jostaberries, and gooseberries are harvested as individual berries; red, white, and pink currants are picked in whole strigs. Red currants are smaller and more tightly bunched than black currants. Gooseberry fruit is borne singularly or in small clusters on spurs.

Fruit is harvested in midsummer. Currants ripen over a two-week or longer period, while gooseberries take from 4 to 6 weeks to ripen, depending on weather. Once a berry fully ripens, it can be left on the bush for a week or more without becoming overmature; but in some varieties, fruit acidity can drop. This allows fruit that matures more slowly to ripen and condenses harvest to two to three pickings. Red currants turn red long before they are fully ripe. They should be allowed to remain on the plant as long as possible to develop additional flavor and sweeten with time.

Gooseberry harvest generally requires the use of gloves, especially with thornier varieties. If desired, a canvas may be spread out under the bush and fruit knocked off onto it. Berries can be harvested when they are full size but not yet ripe. This is preferred for pies and jam. For fresh and juice use, fruit should be allowed to reach full ripeness and color expression.

Both types of fruit can be frozen and kept for later use.

PROPAGATION

To increase your plantings, currants and gooseberries are easily propagated by means of cuttings or layering, as long the varieties you intend to propagate are not patented.

Cuttings should be taken during the dormant season from new one-year-old wood. Make cuttings 6 to 8 inches long, with the bottom and top cuts made near nodes. Stick in rooting media in the late fall or take later and keep in moist sand, sawdust, or peat moss in a cool place (refrigerator) until they are set in early spring. Cuttings should be set about 6 inches apart in a well-drained nursery bed. They should be inserted so that one to two buds extend out of the soil. Fall stuck cuttings should be mulched with straw or stuck through black plastic. They should be cut and placed as soon as the plants are dormant, which will allow several weeks for rooting to start before the ground freezes.

Gooseberries—in particular the European types—can also be propagated by layering. This can be done using a "stooling bed" (mound layering) or by individual branch layering (ground layering). Stool beds require the use of a stock plant that should be cut back before growth starts in the spring. By early summer a large number of vigorous shoots will have been produced. Soil is mounded around these shoots about halfway to the tips, with care taken to work the soil down among the shoots. The covered parts of the shoots usually become rooted by fall. Cut the newly rooted plant from the parent in the spring and plant in a permanent site or in nursery rows.

Branch layering is similar to mound layering and is accomplished by bending down branches while they are still attached to the plant and partly covering them with soil. Pegs may be necessary to hold down the stems. This can be done fall or spring. Plants are kept covered for one growing season. Roots and shoots form along the branch; several plants can often be obtained from one branch. These can be dug and separated after the growing season.

PEST MANAGEMENT

Both currants and gooseberries can be affected by several insect and disease problems. Powdery mildew and leaf spot (anthracnose) are two common disease problems. Careful site selection, choosing resistant cultivars, and proper pruning often give adequate control; chemical use is an additional means of management (see Table 9.1).

DISEASES

Botrytis (Runoff), Dieback, and Fruit Rot

Symptoms: The gray fuzz characteristic of botrytis on other crops covers the leaves and fruit. Tips of branches turn dark and die. Fruit drops from the plant before ripening.

Causal Agent: The fungus *Botrytis cinerea.*

Epidemiology: The fungus has a wide host range and can survive on either living or dead tissue. It overwinters in dead leaves and plant debris and on stems. Inoculum is produced from fruiting structures on canes, from dead leaves, and from mummified berries in the spring.

Controls: To help control the disease, choose a planting site with good air movement and prune out weak canes to speed the drying of plants. Also eliminate weeds to aid in quicker drying of foliage and fruit and harvest fruit before it is overripe. Fungicides should be applied during bloom, with additional applications made during harvest, if necessary. Refer to Table 9.1 for fungicide recommendations.

Anthracnose Leaf Spot

Symptoms: Dark-brown or black spots that appear on the leaves at any time during the growing season. The spots grow larger over time to a size of about 1/8 inch, remain dark, and may develop a purplish margin. Eventually leaves turn yellow and drop from the plant. The spots look like fly specks on berries. Berries may split open and drop from the plant.

Causal Agent: *Drepanopeziza ribis.*

Epidemiology: The fungus overwinters in old leaves on the ground. Spores are produced on the dead leaves and are released, infecting new leaves. A different type of spore is later produced that is spread by splashing rain. Wet spring weather aids in disease development.

Controls: Rake away and destroy affected leaves. Mulch can be applied in the fall after the leaves drop to bury them. Any practice that aids in plant drying will be helpful. Fungicides may be applied.

Septoria Leaf Spot

Symptoms: Spots on leaves develop in early summer. Septoria leaf spots are similar in appearance to anthracnose leaf spots, except that septoria leaf spots develop a light center as the spots enlarge. Leaves drop from the plant.

Causal Agent: *Mycosphaerella ribis* (anamorph *Septoria ribis*)

Epidemiology: The fungus overwinters in old leaves on the ground.

Controls: Good sanitation and practices that improve foliage drying. Fungicides may be applied.

Powdery Mildew, Gooseberry Mildew, American Gooseberry Mildew, and American Powdery Mildew

Symptoms: Powdery, "frosty" patches on shoots, branch tips, and young leaves, eventually causing dead tissue in the affected area or deformation of leaves and shoots. On the fruit, white patches may occur, but eventually the mildew turns a dark brown, making the fruit rough and unmarketable. Infected fruit might also split open. In severe cases, infection decreases fruit production the following year.

Causal Agent: *Sphaerotheca mors-uvae* is referred to as American gooseberry mildew since it originated in the United States. *S. mors-uvae* causes more severe symptoms on *Ribes* than other types of powdery mildew. *Sphaerotheca macularis* is another species of powdery mildew that occasionally affects *Ribes* in the United States and causes similar symptoms. Control for both species is the same.

Epidemiology: *S. mors-uvae* affects gooseberries and black currants. The fungus overwinters in buds and infects the shoots produced from those buds in the spring. Spores are produced on infected foliage and spread by wind. The fungus grows most prolifically under conditions of high humidity.

Controls: Because mildew is most problematic under conditions of high humidity, any cultural control that decreases humidity in the vicinity of the leaves will be helpful. Avoid damp planting sites; growing *Ribes* in shady locations to decrease heat stress may make the occurrence of powdery mildew more likely. Do not use closer plant spacings than those recommended above. Keep plantings well pruned and well weeded. Captivator, Glendale, Hinnomaki Yellow, Hinnomaki Red, and Poorman are resistant.

White Pine Blister Rust and Currant Blister Rust

Symptoms: In the spring, small, yellow spots appear on the leaves. Yellow-orange fruiting bodies ("rust") are visible on the leaf undersides. Damage to *Ribes* plants is of little concern; the main concern is the damage and death of susceptible five-needled pine species (in the east, primarily white pine).

Causal Agent: *Cronartium ribicola.*

Epidemiology: Initial infection occurs in the spring when fungal spores from diseased white pines land on the leaves of the *Ribes* bush and germinate. After 1 to 3 weeks, fruiting bodies on the undersides of the leaves produce spores that infect more *Ribes* tissue. A second type of spore is produced in late summer and fall that can be wind-carried great distances. These spores then infect white pines. After 1 to 2 years, spores are produced from the pine tree, starting the cycle over. Black currants are the most susceptible *Ribes* species.

Controls: Resistant black currant varieties are listed in the section on cultivars. Avoid planting near white pines.

Currant Cane Blight

Symptoms: Shoots wilt and die. The whole plant may be affected. Pith is discolored, ranging from light tan in young infected shoots to black in mature canes that are nearly dead. Canes may become hollow and snap off.

Causal Agent: *Botryosphaeria ribis*, though identification is not yet certain.

Epidemiology: Disease cycle is thought to be similar to that of *Botrysphaeria dothidea*, which causes *Botryosphaeria* cane blight on blueberries. Inoculum survives the winter and is probably produced in dead, infected canes and shoot tips in the spring and early winter.

Controls: Remove infected branches and dead shoot tips in the spring, wilting canes in the summer, and entire plants if dead or severely infected. No effective fungicides have been identified.

INSECTS

Aphids, Various Species, especially Currant Aphid, *Cryptomyzus ribis (Homoptera: Aphididae)*

Symptoms of Damage: Foliage is distorted, crinkled, curled, and sometimes reddened, brought about by aphid feeding on the leaf undersides.

Identification: Small (less than 1/10 inch), slow-moving, pear-shaped, yellow-green insects with cornicles (tubes) extending backwards from their posterior.

Life Cycle: Aphids overwinter as tiny, glossy, black eggs on the stems. Green female aphids hatch from these eggs about the time the leaves appear and give birth to live aphids. Winged forms are produced when overcrowding occurs, allowing the aphids to distribute themselves more easily. Male and female forms are produced in the fall and mate, after which the females deposit eggs for overwintering.

Monitoring and Control: Especially troublesome on red currants. Predatory insects are helpful in control, and aphid populations may decrease later in the season once populations of predators build. Insecticides as listed in Table 9.1 may be applied.

Currant Fruit Fly (Gooseberry Maggot, Currant Maggot), *Euphranta (formerly Epochra) canadensis* (Diptera: Tephritidae)

Symptoms of Damage: A dark spot on the berry possibly surrounded by a reddened area. White larvae may be found in affected fruit. Infested berries usually drop prematurely, but when they don't, harvested fruit can be contaminated.

Identification: Adults are a fly about 1/3 inch long. Their bodies are yellow with shading and their wings are banded.

Life Cycle: Adults emerge from soil in the spring and lay eggs under the skin of fruit. Eggs hatch in 5 to 8 days, and larvae then feed in the fruit for 11 to 16 days. Larvae may continue to feed once berries have fallen to the ground. Larvae enter the soil and pupate over the winter.

Monitoring and Control: Early varieties may escape damage. Collecting and destroying fallen fruit regularly before larvae hatch may have some effect on populations. Monitor for adults—usually found in shady areas of the plant—starting at petal fall. Treat if adults are seen.

Currant Borer, *Synanthedon tipuliformis* (Lepidoptera: Sesiidae), also Known as Currant Stem Borer, Clearwing Borer, and Clearwinged Moth

Symptoms of Damage: Withering or yellowing of leaves. Affected canes may die. Watch for a dark hollow stem pith when pruning, as this is evidence of damage. They are particularly troublesome on red currants.

Identification: The 1/2-inch-long adult resembles a wasp, though this pest is actually a moth with clear wings and a wingspan of about 3/4 inch. The larva is white with a light-brown head.

Life Cycle: Adult moths emerge from the canes in the spring and lay their eggs on the canes in early summer. In a little more than a week, the larvae hatch and enter the cane where they feed while tunneling through the pith. They overwinter as larvae, cause little damage while feeding briefly during the spring, pupate, and emerge as adults.

Monitoring and Control: These branches should be pruned below the damage and destroyed. Adults fly well and can be seen hovering around the canes. Insecticides should be applied to target adults and young larvae before they enter the canes. Insecticides applied after the larvae are protected inside the cane will have no effect.

Imported Currant Worm, *Nematis ribesii* (Hymenoptera: Tenthredinidae)

Symptoms of Damage: Damage is from the larvae, which have voracious appetites and can completely defoliate a plant in a few days.

Identification: Adults are sawflies the size of a housefly. The head and thorax are dark, and the abdomen is a yellow-red. The caterpillar larvae are green with black spots in early instars but become a solid light green in their last instar.

Life Cycle: Adults emerge from the soil soon after bud break. Translucent white eggs are laid along the leaf veins, from which the larvae hatch in 7 to 10 days. They feed on the leaves for 2 to 3 weeks and then pupate in litter on the ground. A second generation of adults appears in midsummer, but it tends to be much lower in numbers, possibly because of predation by natural predators. This second generation overwinters as pupae.

Monitoring and Control: Watch for larvae starting just after bloom as the fruits start to enlarge. Cultural control involves being observant of growing conditions and keeping plants vigorous. Insecticides may be applied, if necessary.

Gooseberry Fruitworm, *Zophodia convolutella* (Lepidoptera: Pyralidae)

Symptoms of Damage: Hollowed-out berries that change color prematurely and dry up or fall to the ground. Clusters of berries and part of the stem may be wrapped in a silken webbing.

Identification: The adult is a grayish moth with a wingspan of about an inch. Larvae are about ¾ inch long with a brownish head and green body with dark stripes along the sides when fully grown.

Life Cycle: Shortly after fruit set, adults emerge from cocoons under dead leaves on the ground, where they overwintered. The female lays eggs on the fruit. The larva enters the berry and feeds on the pulp. The larva may eat several berries and web them together. After the larva is fully grown, it moves down to the ground and pupates.

Monitoring and Control: Hand-picking infested berries provides some control. An insecticide may be needed starting at early fruit development and again 10 days later.

San Jose Scale, *Quadraspidiotus pernicious* (Homoptera: Diaspididae)

Symptoms of Damage: In cases of light infestations, plant vigor may be decreased from the scale removing plant juices. In severe infestations, canes or plants may be killed.

Identification: Small, gray, circular specks about 1/10 inch across, usually on the canes.

Life Cycle: The scale insect overwinters under its shell on the plant's branches. In the spring, the males emerge as tiny yellow-winged insects and mate with females. The females give birth to live young (crawlers), which move to a new location, begin feeding, and form their own shells. The scale insects reach maturity in 25 to 30 days. Two generations occur per year.

Monitoring and Control: Superior oil at bud break will help.

See Chapter 3 for general guidance on using pesticides safely.

WEEDS

Good weed control begins years before planting. Begin by identifying perennial weed problems in the field. Eliminate these weeds before planting by rotating to crops in which the target perennial weed can be controlled and by using herbicides registered for the crop that control the target weeds. After harvest of these preceding crop(s), spend extra effort to continue control strategies. Early to mid-fall applications of glyphosate products or Banvel can be very effective. Use caution when applying residual herbicides including Banvel and Stinger, as carryover can affect crops the following year. Use cover crops to aid in suppressing weed growth.

A permanent sod such as hard fescue between the rows is effective in controlling weeds in established plantings. Within-row weeds can then be controlled with appropriate herbicides or landscape fabric.

Herbicides labeled for use in bearing and nonbearing currants and gooseberries are Casoron, certain glyphosate products (Roundup, Touchdown, and others), Gramoxone Max 3SC and Gramoxone Inteon 2.76SC, Scythe, Rely, and Surflan AS. Devrinol 50DF is labeled for use on bearing and nonbearing currants. Fusilade DX, Select 2EC, Gallery 75DF, and Snapshot 2.5TG are labeled for use only on nonbearing currants and gooseberries (plants that won't be harvested for at least one year). Other formulations with the same inactive ingredients may exist that are labeled for the same uses.

Glyphosate products and Gramoxone, Scythe and Rely are nonselective postemergence materials. Glyphosate products are translocated within and therefore kill the entire plant, even though only a portion of the plant may have come in contact with the herbicide. Fusilade and Select are selective postemergence materials that are also translocated in the plant, but are effective only on grasses. Gramoxone and Scythe are nontranslocated contact herbicides, and kill only the portion of the plant with which they come in contact. Because of this feature, the roots of treated weeds survive, and control of perennial weeds is only temporary. Good coverage is a necessity, as untreated portions of the leaves and stems will continue to live. Rely is partially translocated. Casoron, Gallery, Surflan, Devrinol, and Snapshot are preemergence materials, so they must be applied before weeds have germinated. Gallery is effective against annual broadleaves, while Surflan and Devrinol are effective against annual grasses and certain annual broadleaves. Casoron and Snapshot are effective against both annual grasses and annual broadleaf weeds. Casoron also controls some perennials. Before use, always consult the herbicide labels for precautions, reentry intervals, and preharvest intervals.

Remember that weeds compete with each other, not just with crop plants. Therefore, controlling a particular weed or group of weeds may allow another weed species to take over, requiring adjustments to your control strategies.

Table 9.1. Pesticides for *Ribes* disease and insect control.

The information below is correct to the best of our knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Read the text for information on cultural practices to minimize pest incidence. If control cannot be achieved with a particular material, resistant populations could exist. Use a material in a different activity group, denoted by different designations in the "Group" column. Materials from different activity groups have different modes of action, See Table 3.2 for limits on states in which these cannot be used, use status (general versus restricted), chemical names of active ingredients, and reentry intervals. See Table 3.1 for toxicity to nontarget organisms. Information was current as of October 1, 2009.

Pest	Timing of Treatment/Comments	Group[a]	Product Labeled Rate/A[b] (Days to Harvest)
DISEASES			
Botrytis	During bloom, with additional applications made during harvest, if necessary. Omega can be used only during bloom due to its long days-to-harvest limitation.	17	Elevate 50 WDG, 1.5 lb (0), ***or***
		7, 11	Pristine, 18.5–23 oz (0), ***or***
		2	Rovral 4F, 1–2 pt (0), ***or***
		9, 12	Switch 62.5WG, 11–14 fl oz (0), ***or***
		29	Omega 500DF, 1.25 pt (30)
Anthracnose leaf spot	At bud break.	M	Lime sulfur (0), 2.5 gal per 100 gal of spray solution, applied at 100–160 gal/A
	When disease symptoms appear, then as needed. Rally is labeled for anthracnose on gooseberries only.	3	Rally 40W, 5.0 oz (0)
Septoria leaf spot	When disease symptoms appear.	11	Abound, 6.2–15.4 fl oz (0), ***or***
		11	Cabrio EG, 14 oz (0), ***or***
		7, 11	Pristine, 18.5–23 oz (0)
Powdery mildew	Prebloom or postbloom.	NC	Stylet oil, 3–6 qts/100 gal, ***or***
		M	Lime sulfur, 1.5 qt (0)
	As needed.	3	Rally 40W, 5.0 oz (0), ***or***
		7, 11	Pristine, 18.5–23 oz (0), ***or***
		11	Abound, 6.2–15.4 fl oz (0), ***or***
		11	Cabrio EG, 14 oz (0)
White pine blister rust	When pustules are visible on leaf undersides	NC	Stylet oil, 3–6 qts/100 gal
INSECTS			
San Jose scale	At bud break	—	Superior oil, see label for rate (—)
Aphids	Whenever aphids are found.	*1B*	Malathion 57EC, 3.2 pt (3), ***or***
		—	M-Pede, 1–2% v/v (0), ***or***
		4A	Provado, 3.0–4.0 fl oz (3), ***or***
		4A	Actara, 3.0–4.0 oz (3), ***or***
		4A	Assail 70WP, 1.0–2.3 oz (1), ***or***
		3	Brigade WSB, 5.3–16.0 oz (1), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0)
Imported currant worm	Target adults starting soon after bud break, then larvae as fruits start to enlarge.	*1B*	Malathion 57EC, 3.2 pt (3), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0)
Currant fruit fly	As adults are noted, starting at petal fall. Delegate is for suppression.	*5*	Spintor 2SC, 4–6 fl oz (3), ***or***
		5	Delegate WG, 3–6 oz (3), ***or***
		3	Pyganic EC 5.0, 4.5–18 oz (0)

CONTINUED

Table 9.1. Pesticides for *Ribes* disease and insect control, continued.

Pest	Timing of Treatment/Comments	Group[a]	Product Labeled Rate/A[b] (Days to Harvest)
Currant borer	Late spring to early summer. Pyganic should target adults and Bt products should target larvae before they enter the cane. Insecticides will have no effect once larvae are protected inside the cane.	*3* *11* *3*	Pyganic EC 5.0, 4.5–18 oz (0), ***or*** Bt products, various rates (0), ***or*** Danitol, 10.67–16 fl oz (21)[c]
Gooseberry fruitworm	Target adults at early fruit development and again 10 days later.	*3* *3*	Brigade WSB, 5.3–16.0 oz (1), ***or*** Pyganic EC 5.0, 4.5–18 oz (0)

a. Fungicide groups are listed in normal type; insecticide groups are italicized. Chemistry of fungicides by activity groups: 2 = dicarboximides; 3 = imidazoles or triazoles; 7 = carboxamides; 9 = anilinopyrimidines; 11 = strobilurins; 12 = phenylpyrroles; 17 = hydroxyanilides; 29 = activity group not named, chemical group = 2,6-dinitroanilines; M = chemical groups with multisite activity; NC = not classified. Fungicides with two activity groups listed contain active ingredients from two activity groups. Chemistry of insecticides by activity groups: *1B* = organophosphates; *3* = pyrethrins and synthetic pyrethroids; *4A* = neonicotinoids; *5* = spinosyns; *11* = Bt microbials.

b. Some pesticides may be phytotoxic to plants. If in doubt; test a small area of the field first. Be sure sprayer is calibrated properly.

c. Labeled for currants only.

Forest Nursery Practices In the South

James N. Boyer and David B. South

ABSTRACT. Southern forest nurseries produce 80 percent of the bare-root seedlings grown in the United States (nearly 1.3 billion out of 1.6 billion in 1980). Loblolly pine (Pinus taeda L.) *alone accounts for most of the reforestation in this country. Responses by southern nurserymen to a questionnaire were compiled in order to document the practices currently employed to produce southern pine seedlings. In comparison with forest industry nurseries, public nurseries tend to be older and larger, are less mechanized, employ more handweeding, use less cover crops, and produce a greater number of species. The most notable changes occurring in the past 50 years include increased production, a change in the favored species produced, increased chemical pest control, increased mechanical harvesting, and a shift in nursery site selection to sandier soils.*

In 1980, more than 1.6 billion bare-root seedlings were produced in the United States (American Association of Nurserymen 1981, USDA Forest Service 1982). Of this amount, approximately 80 percent (nearly 1.3 billion) were produced in southern forest nurseries (Table 1).

Today, loblolly pine accounts for 60 percent of the bare-root seedlings planted in the United States (Table 1). Together, loblolly and slash pine (*P. elliottii* Engelm. var. *elliottii*) outnumber, by more than 2 to 1, all other species combined. In total, southern pines account for nearly three-fourths of the reforestation in this country. Therefore, it is important to document the practices employed to produce southern pine seedlings. The purpose of this paper is to present various practices employed in southern pine nurseries and to discuss how these have changed over the past 50 years.

THE NURSERIES

Early in 1981, a questionnaire on 1980 practices and production was sent to 63 forest nursery managers in the 13 southern states. Returns were received from 1 federal, 23 state, and 27 forest industry nurseries (Table 2). Questionnaires were not returned for 7 state and 5 industry nurseries. Nearly all the responding nurseries are located in the Coastal Plain (Figure 1).

Between 1923 and 1933, 19 experimental and commercial nurseries were located in 10 southern states (Wakeley 1935). Of these, most were federal or state nurseries and none were still in production in 1980. The oldest nurseries included in this questionnaire were the Miller State Nursery in Alabama (established in 1934) and the Ashe Federal Nursery in Mississippi (established in 1936). Of the state and federal nurseries included in the questionnaire, 44 percent had been established by 1952 and all but one were in existence by 1960. Conversely, only 37 percent of forest industry nurseries were in operation before 1970, with 41 percent coming into existence after 1974. Today, more than half of the nurseries are operated by the forest industry.

The size of southern nurseries (number of seedlings produced annually) has increased dramatically in the past 50 years. Prior to 1934, most nurseries produced less than one million seedlings. Today seedling production ranges from 8.5 to 51 million; the median value is 17 million. On the average, state and federal nurseries produce approximately 22 million seedlings each, while industry nurseries average 18 million seedlings.

Another contrast between public and industry nurseries is that half of the public nurseries produce hardwood seedlings while only 3 out of 27 industry nurseries produced hardwoods. In addition, public nurseries tend to produce a greater number of species than industry nurseries.

SEEDLINGS PRODUCED

Seedlings produced at 50 nurseries totaled over 1 billion in 1980 (Table 3), with more than 98 percent being pine. Loblolly pine was by far the most abundant species produced in the South, followed by slash pine; each of the remaining species made up 2 percent or less of the total. Loblolly pine accounted for three-quarters of the total number of seedlings, and loblolly and slash pines together constituted 88 percent of the total. Only 1 percent of all seedlings were hardwoods. Not included in the survey were approximately 3.5 million containerized seedlings grown at various installations throughout the South.

Table 1. Production of bare-root forest tree nursery stock raised in the South.[1]

	Number	Percent
Loblolly pine	965,620,000	59.9
Slash pine	167,214,000	10.4
Other pine	116,707,000	7.2
Other species	34,766,000	2.1
Total in South	1,284,307,000	79.6
Total outside South	328,686,000[2]	20.4
GRAND TOTAL IN U.S.	1,612,993,000	100

[1] *Some of these figures for the South include estimates of non-questionnaire nurseries from the American Association of Nurserymen, 1981.*
[2] *Figure from USDA Forest Service, 1982.*

Table 2. Number, ownership, and size of participating southern nurseries.

Ownership	Size[1] Small	Medium	Large	Total
Federal	—	—	1	1
State	4	12	7	23
Forest industry	8	15	4	27
Total	12	26	12	51

[1] *Annual production: small = less than 12 million; medium = 12 million to 30 million; large = more than 30 million seedlings produced.*

Fifty years ago, the nurseries in the South produced fewer than 15 million seedlings, and fewer than 9 thousand acres per year were regenerated in 1931, 1932, and 1933 (Williston 1980). During those years, the most commonly produced species were longleaf (*P. palustris* Mill) and slash pines. Of the 9 million plantable seedlings produced at the Stuart Nursery in 1934, 45 percent were longleaf pines, 35 percent were slash pines, and 20 percent were shortleaf (*P. echinata* Mill) pines; no loblolly pines were grown.

Out of 53 southern nurserymen surveyed in 1982, 23 used Whitfield seeders, 20 used Love-Øyjord seeders, six used Stanhay seeders, and two used Planet Junior seeders. In addition, for the first time in the South, precision sowing with

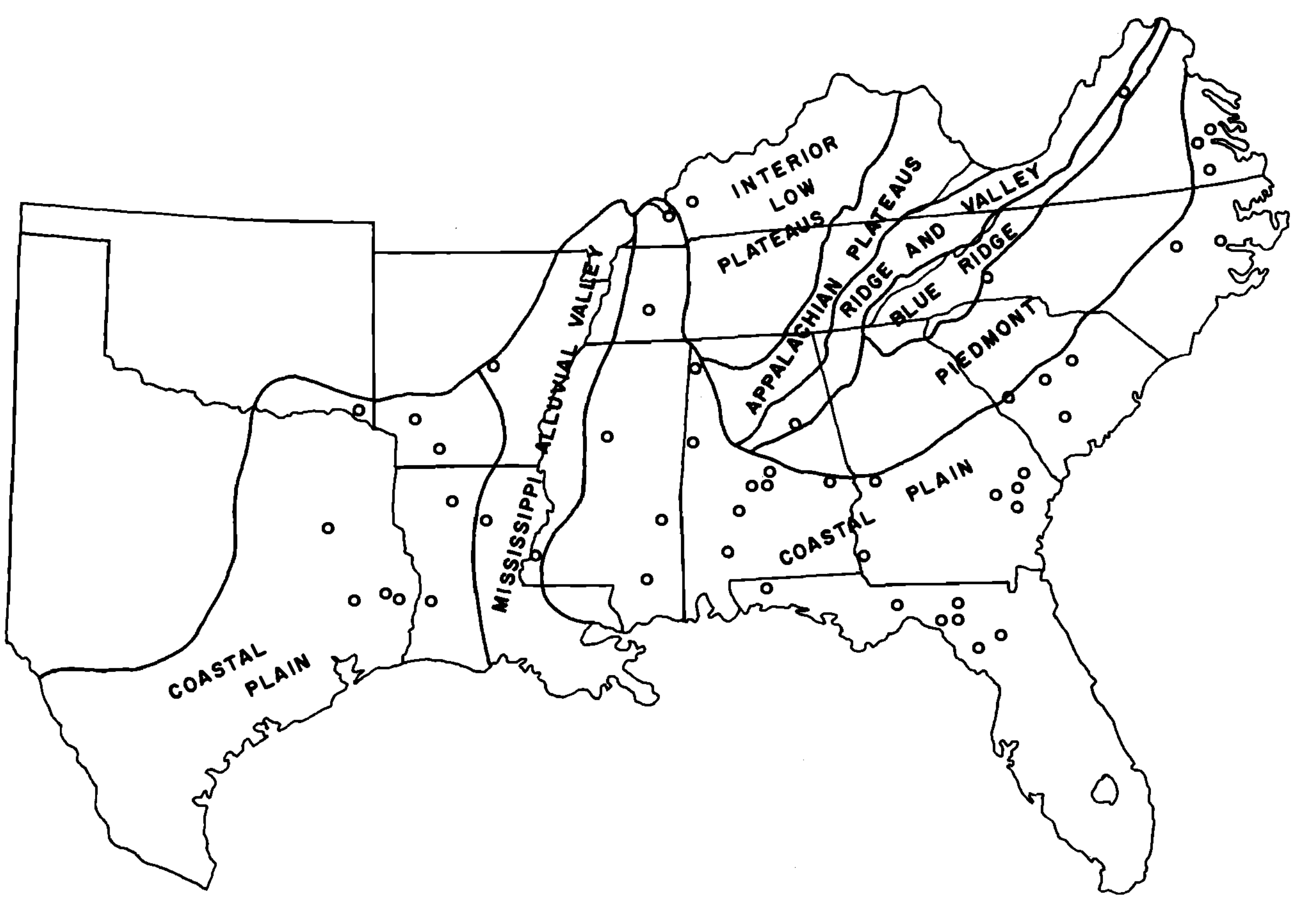

Figure 1. Locations of responding nurseries.

Table 3. Number of forest tree seedlings produced at southern nurseries in 1980.

Species	Industry	State & Federal	Total
		Thousands	
Loblolly pine (Quest.)	381,518 (27)[1]	382,102 (20)	763,620 (47)
Loblolly pine (Non-Quest.)[2]	79,500 (5)	122,500 (6)	202,000 (11)
Total loblolly pine	461,018 (32)	504,602 (26)	965,620 (58)
Slash pine	106,245 (11)	60,969 (11)	167,214 (22)
White pine	95 (1)	22,545 (5)	22,640 (6)
Shortleaf pine	500 (1)	12,414 (9)	12,914 (10)
Longleaf pine	293 (4)	10,000 (9)	10,293 (13)
Sand pine	7,725 (7)	450 (1)	8,175 (8)
Virginia pine	2,800 (2)	4,058 (7)	6,858 (9)
Scotch pine	—— (0)	1,220 (3)	1,220 (3)
Spruce pine	7 (1)	150 (1)	157 (2)
Pond pine	30 (1)	—— (0)	30 (1)
Pines not listed by species	—— (0)	54,420 (3)	54,420 (3)
	578,713 (32)	670,828 (29)	1,249,541 (61)
Black locust	—— (0)	3,059 (6)	3,059 (6)
Sweetgum	1,495 (3)	227 (5)	1,722 (8)
Sycamore	861 (2)	382 (3)	1,243 (5)
Oaks	448 (2)	366 (4)	814 (6)
Green ash	427 (2)	220 (1)	647 (3)
Cottonwood	—— (0)	610 (2)	610 (2)
Yellow-poplar	—— (0)	601 (4)	601 (4)
Dogwood	—— (0)	492 (1)	492 (1)
Black alder	—— (0)	410 (1)	410 (1)
Black walnut	—— (0)	147 (3)	147 (3)
Hardwoods not listed by species	—— (0)	3,568 (7)	3,568 (7)
	3,231 (3)	10,082 (12)	13,313 (15)
Redcedar	—— (0)	1,807 (3)	1,807 (3)
Baldcypress	—— (0)	290 (2)	290 (2)
Arizona cypress	10 (1)	21 (1)	31 (2)
	10 (1)	2,118 (5)	2,128 (6)
Others (Non-Quest.)[2]	8,857 (4)	10,468 (7)	19,325 (11)
GRAND TOTALS	590,811 (32)	693,496 (31)	1,284,307 (63)

[1] *In parentheses is the number of nurseries producing the species.*
[2] *An estimate was made of total production and loblolly pine production at southern nurseries for which a questionnaire was not returned.*

specially designed vacuum-operated seeders was conducted operationally at two nurseries during 1982.

The desired seedling density was determined in the early 1930s by May (1933). When sown by drills on soils of average quality, the desired density was 20 to 24 seedlings per square foot for longleaf pine and 24 to 30 per square foot for slash and loblolly pines. The desired seedbed density for slash and loblolly pines has changed little in 50 years, as nurserymen in 1980 reported similar densities. However, nurseymen today grow longleaf seedlings at lower densities in order to produce stock which has large root-collar diameters.

Abbott and Fitch (1977) found that seedlings were harvested by hand at two-thirds of the nurseries in the United States in 1974. In our questionnaire, 82 percent of responding nurserymen reported using machine lifters (13 nurserymen used a Grayco lifter, 9 used a Mathis lifter, 4 used a Love lifter, 2 used a Whitfield lifter, and 12 used lifters made at the nursery). The discrepancy in these findings may be explained in part by changes since the previous questionnaire and in part by the fact that the greatest proportion of large nurseries are located in the South (Abbott and Fitch 1977). Southern nurseries average much higher production than nurseries in other parts of the country (American Association of Nurserymen 1981). Most older nurseries have either a Grayco metal chain lifter or a Mathis-type belt-lifter; newer nurseries often have Love or Whitfield belt-lifters.

SOILS, MULCHES, COVER CROPS AND ORGANIC AMENDMENTS

Of the 51 nurseries, 21 are situated on sandy loam soils; 17 are on sands or loamy sands; 8 have sandy clay loam soil; and only 5 have loam or silt loam soils. The older state nurseries were usually established on finer textured soils, while the newer industry nurseries are commonly located on sands and loamy sands. This trend is in part due to the increased usage of mechanical lifters after 1960. Of the nurseries established after 1960, most have textures with more than 75 percent sand.

Soil texture has a direct effect on the trafficability of nursery soils. This was evident from response to a question which asked for the time required before a tractor could enter the field after a saturating rain. The median response for nurseries on soils with greater than 88 percent sand was one day, while three days was the median response for nurseries with less than 50 percent sand. This is especially important in years with frequent spring rains, which delay practices such as fumigation and sowing (*e.g.*, 1983).

In discussing soil texture, Wakeley (1935) stated that "Fairly sandy soils frequently meet all forest-nursery requirements if they are underlain by less pervious soils. The cost of enriching such soils with various fertilizers is offset by greater ease of working, and most species of pine develop better root systems in light than heavy soils."

A mulch of some type was used at all but one of 50 nurseries. Most used either hydromulch (and other wood fiber products), pinestraw, sawdust, or bark. Hydromulch was used at industry nurseries more than any other mulching material, while the majority of nurserymen at public nurseries favor pinestraw. Burlap is no longer used but was popular in the early 1930s because it was easy to apply and provided effective protection against birds.

Industry nurseries have a somewhat greater percentage of their land in cover crops than do public nurseries. Industry nurseries had 57 percent of their land, or 860 of 1,508 acres, in cover crops. Median percentage in cover crops for individual industry nurseries was 51 percent. The 24 state and federal nurseries had 48 percent of their land, or 1,010 of 2,091 acres, in cover crops. Median percentage for individual public nurseries was 46 percent.

There were several different reasons nurserymen had for using cover crops, with many reporting more than one reason. Nearly all reported using cover crops for organic matter maintenance. Approximately half used them for erosion protection and soil stabilization. Other reasons were much less common. Wakeley (1935) mentioned that growing crops such as cowpeas (*Vigna unguiculata* (L.) Walp.), soybeans (*Glycine max* (L.) Merr.), and showy crotalaria (*Crotalaria spectabilis* Roth) tended to improve the physical character of the soil.

Nearly two-thirds of the nurseymen used either a 1:1 or 2:2 rotation (seedlings to cover crops). Nurserymen at nearly all industry nurseries used one of these two rotations. However, the 2:1 rotation was the one used most at state and federal nurseries (Table 4). Most nurserymen grew a summer cover crop of either sorghum-sudan (*Sorghum* spp.) or millet (*Panicum ramosum* L.) (Table 5). Of the nurserymen that grow a winter cover crop, rye (*Lolium* spp.) is by far the most popular.

Two-thirds of responding nurserymen applied some sort of organic amendment to their soil. A greater proportion of industry nurseries receive organic amendments than do public nurseries. The predominant amendment was sawdust (Table 6). Few state and federal nurserymen used anything else. However, many industry nurserymen used bark or woodchips. Amendments are most often applied every other year.

Of the 33 nurserymen who stated the amount of organic amendments applied, 7 used more than 200 cubic yards (30 tons of dry weight) per acre, 17 used 100–150 cubic yards, and 9 used less than 100 cubic yards. Wakeley (1954) stated that "Soils very low in organic matter may require annual or alternate-year applications of 10, 20, or

Table 4. Crop rotation employed at southern forest nurseries in 1980.

Rotation Seedlings : Crop cover	Industry (25)		State & Federal (22)		Total (47)	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1:1[1]	14	56	6	27	20	43
1:2	3	12	1	5	4	9
1:3	1	4	0	—	1	2
2:1	0	—	8	36	8	17
2:2	7	28	3	14	10	21
3:1	0	—	2	9	2	4
4:1	0	—	2	9	2	4

[1] *Crop ratios indicate years in seedlings to years in cover crops.*

Table 5. Cover crops grown at southern forest nurseries in 1980.

Summer crop[1]	Industry (25)		State & Federal (22)		Total (47)	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Sorghum-Sudan	12	48	10	45	22	47
Millet	9	36	4	18	13	28
Corn	5	20	4	18	9	19
Soybeans	0	—	5	23	5	11
Sudan	3	12	2	9	5	11
Sorghum	2	8	0	—	2	4
Field peas	0	—	1	5	1	2
Other	0	—	2	9	2	4
None	1	4	1	5	2	4
Winter crop[1]	**Industry (26)**		**State & Federal (24)**		**Total (50)**	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Rye	15	58	7	29	22	44
Wheat	5	19	0	—	5	10
Oats	2	8	3	13	5	10
Ryegrass	1	4	1	4	2	4
Vetch	0	—	1	4	1	2
Field peas	0	—	1	4	1	2
Other	0	—	1	4	1	2
None	8	31	12	50	10	40

[1] *Some nurserymen listed more than one crop.*

even 40 tons of compost or organic supplements per acre."

Twenty nurserymen responded when asked how much they spend on organic amendments. Five spend under $100 per acre per application, six from $100 to 190 per acre, five from $200 to 300 per acre, and four reported costs in excess of $500 per acre.

Pine bark has a high lignin content which makes it desirable as an organic amendment due to its slow rate of decomposition. Sixteen nurserymen responded when asked the price of bark at their location. Five reported that they could obtain bark free, while two reported a cost of $0.25 per cubic yard. Five reported costs of $1.00 to 2.00 per cubic yard. The remaining four reported costs of $3.00, $3.57, $6.05, and $7.50 per cubic yard. A recent survey conducted in Georgia indicated that bark could be purchased and delivered 60 miles for $2.26 per cubic yard (Ames and Baxter 1982).

When asked if 2 percent organic matter content was a reasonable goal for their nursery soil, more than three-quarters of the nursery managers replied that it was realistic and practical. When asked what cost per thousand seedlings could be justified for organic amendments, 16 stated $0.25 to $0.50, while 13 indicated $1.00 to $2.00.

IRRIGATION

Fourteen of 45 nurserymen monitor soil moisture. However, of this number, eight use what they termed a visual or feel method. Only three used tensiometers, and two used electric probes. In

Table 6. Organic amendments applied at southern forest nurseries in 1980.

	Industry (27)		State & Federal (23)		Total (50)	
Material[1]	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Sawdust	14	52	13	57	27	54
Bark	11	51	1	4	12	24
Wood chips & shavings	6	22	0	—	6	12
Animal manure	1	4	1	4	2	4
Sludge	0	—	1	4	1	2
None	7	26	10	44	17	34
Frequency of Application						
Annually	4	15	2	9	6	12
Every 2 years	12	44	5	22	17	34
Every 3 years	2	7	2	9	4	8
Every 4 years	2	7	4	17	6	12
None	7	26	10	44	17	34

[1] *Some nurserymen listed more than one material.*

1980, none of the 45 responding nurserymen monitored stem xylem water potential.

There is a disparity of opinion as to how much water trees need. Opinions ranged from 0.5 inches per week to greater than 5 inches per week. Wakeley (1935) stated that "In a rainless week water equivalent to at least 1 inch of rainfall should be applied artifically, even though there have been abundant rains earlier in the season."

Of the 51 responding nurserymen, 36 were satisfied with their irrigation distribution. However, nurserymen were almost evenly divided on the need for night watering for more uniform distribution (less wind) and to reduce evaporation. Nurserymen listed four disadvantages to night watering; inability to spot problems, labor, increased disease, and cost. Of these, the most common concerns were not being able to spot problems in the system and labor constraints. Fifty years ago it was considered preferable to water at night because the higher humidity and lower temperatures reduce the rate of evaporation resulting in more water soaking into the ground (Wakeley 1935). In fact, some nurserymen were concerned that watering during the hottest part of the day could injure seedlings.

MORTALITY

In the early 1930s, mortality was usually high. When sown under conditions conducive to vigorous germination, 50-percent mortality could be expected (Wakeley 1935). In 1980, average seedling mortality was much less. At industry nurseries, average mortality was 12 percent, ranging from 0.5 to 40 percent with a median of 10 percent. Mortality at state and federal nurseries averaged 11 percent with a range of 0 to 35 percent and a median of 8 percent. From the total number of seedlings produced at each nursery and the percent mortality at the nursery attributed to the specific factors, an estimate was made of the total number of seedlings killed by each factor (Table 7). "Weeds and handweeding" accounted for the most seedlings primarily because one state nursery claimed nearly 30 million trees lost to weeds. Aside from that case, early heavy rain caused the greatest mortality (more than 33 million seedlings). Birds were no great problem in 1980 but were a leading cause of mortality 50 years ago.

WEEDS AND WEED CONTROL

Wakeley (1935) stated that "The history of a dozen nurseries in the southern pine region indicates that crabgrass and bermudagrass are about equally widespread and troublesome. Coco grass, also called nutgrass, although less common, is fully as serious in some nurseries and is perhaps the hardest of all to eradicate." Today, these weeds are still the most troublesome (Table 8) and nutsedge (coco grass or nutgrass) is still the hardest to control.

The most common sources of new weed seeds are areas adjacent to the seedlings and mulch. However, only two industry nurserymen listed mulch as a major source of weed seed. This can be attributed to the fact that most industry nurs-

Table 7. Factors contributing to seedling mortality (listed in order of total number of nurserymen reporting).

Factor[1]	Industry (27)			State & Federal (24)			Total (51)	
	Trees lost	Nurserymen reporting	Mortality median	Trees lost	Nurserymen reporting	Mortality Median	Trees lost	Nurserymen reporting
	Thousands	*Number*	*Percent*	*Thousands*	*Number*	*Percent*	*Thousands*	*Number*
Early heavy rain	13,950	17	3.2[2]	19,281	13	4.0[2]	33,231	30
Postemergence damping-off	5,480	11	1.7	7,353	6	1.0	12,833	17
Herbicides	4,468	5	2.4	2,035	7	1.5	6,683	12
Rain splash	3,606	6	1.8	2,079	5	1.0	5,685	11
Heat or water stress	4,363	5	4.0	4,935	4	4.5	9,298	9
Nutrient deficiency	1,814	6	1.0	814	3	1.0	2,628	9
Preemergence damping-off	3,165	6	1.2	4,264	1	5.0	7,429	7
Fusiform rust	1,724	6	1.2	295	1	1.0	2,019	7
Wind	5,159	6	1.5	—	0	—	5,159	6
Birds	1,032	2	2.7	1,074	4	0.8	2,106	6
Weeds & weedling	882	1	3.8	33,381	4	6.5	34,163	5
Insects	319	2	0.7	4,512	3	2.0	4,831	5
Irrigation problems	302	3	1.0	885	2	3.0	1,187	5
Nematodes	1,463	1	3.0	—	1	—	1,463	2
Other[3]	11,112	12	—	269	1	—	11,381	13

[1] *Nurserymen listed more than one factor.*
[2] *Median for percent mortality due to factor (only for those nurserymen reporting the factor; i.e., no 0's).*
[3] *Other includes hail, mechanical, soil pH, root rots, and poor germination.*

Table 8. Most troublesome weeds in southern nurseries according to reports from nurserymen.

Weed[1]	Industry (26)		State & Federal (21)		Total (47)	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Crabgrass	16	62	14	67	30	64
Nutsedge	27	65	12	57	29	62
Bermudagrass	12	46	5	24	17	36
Purslane	7	27	7	33	14	30
Morningglory	9	35	4	19	13	28
Sicklepod	9	37	2	10	11	23
Goosegrass	7	27	4	19	11	23
Carpetweed	4	15	4	19	8	17
Fennel	6	23	0	—	6	13
Clover	2	8	1	5	3	6
Barnyardgrass	2	8	1	5	3	6
Florida pusley	2	8	0	—	2	4
Broomsedge	2	8	0	—	2	4
Cocklebur	2	8	0	—	2	4
Crowfootgrass	1	4	1	5	2	4
Flathead sedge	2	8	0	—	2	4
Spurge	0	—	1	5	1	2
Others	7	27	12	57	19	40

[1] *Nurserymen listed more than one species.*

erymen use hydromulch, while most state and federal nurserymen use pinestraw as a mulch. Of the 15 nurserymen who use pinestraw mulch, only 2 fumigate the mulch for weed control.

Overall, there was a wide range of weed-control practices. State and federal nurseries had much greater expenditures for both handweeding and mineral spirits. There was not a great deal of difference between the two groups in herbicide usage, except that public nurseries used a greater variety of herbicides while industry nurseries for the most part used just two or three.

In the past, costs for handweeding in southern pine nurseries were high. The first of several handweedings could require 1,600 to 1,900 man-hours per acre.[1] Cost of handweeding ordinarily composed 20 to 40 percent of the total production cost (Wakeley 1935). Today, handweeding in southern pine nurseries usually costs only 2 to 4 percent of the production cost. Total handweeding required at 16 industry nurseries was less than 50 man-hours per acre, while 13 state and federal nurseries required more than 100 man-hours per acre. The amount spent on handweeding at industry nurseries ranged from $16 to $1,554 per acre, with a median value of $155 per acre. At public nurseries, costs ranged from $42 to $1,755 per acre, with a median value of $489 per acre.

Seven of the 27 industry nurserymen reported applying mineral spirits for weed control. The average rate was 25 gallons per acre, with a range of 20 to 30 gallons. The range of total gallons per acre applied over the season was 28 to 437, with a median of 130 gallons per acre. Price per gallon for mineral spirits ranged from $0.68 to $1.70, with a median of $1.25. Eight of the 24 state and federal nurserymen applied mineral spirits to control weeds. The average rate was 24 gallons per acre, with a range of 17 to 35 gallons. The range of total gallons per acre applied over the season was 43 to 550 with a median of 84 gallons per acre. Average cost for mineral spirits at public nurseries was $1.02 per gallon, with a range of $0.64 to $1.39 and a median of $0.90 per gallon.

All 51 nurserymen reported using herbicides. Goal® and Modown® were used most often (Table 9). Roundup® was typically used on a spot-application basis. Nearly half of 47 responding nurserymen reported seeing some herbicide injury to seedlings. Chemical weed control was not used fifty years ago, although certain chemicals such as zinc sulphate had been tried (Wakeley 1935).

FUMIGATION

Today, many nurserymen use methyl bromide as a soil fumigant. Of the 51 responding nurserymen, 45 fumigate with a methyl bromide-chloropicrin mixture at an average rate of 357 pounds per acre. While the proportion applying methyl bromide and the rates applied were nearly identical for the two nursery classes, the costs of application differed significantly. For industry, the average cost to fumigate was $781 per acre, with a range of $450 to $1100. For state and federal agencies, the average cost was $520 per acre, with a range of $205 to $850. The difference in cost results from state agencies doing their own fumigating while industries contract the work.

Most nurserymen (24 out of 40 responding, or

[1] Personal communication from J. T. May—notes taken from A. D. Read's "Southern Reforestation."

Table 9. Herbicides used at southern forest nurseries in 1980.

Trade name[1]	Common name	Industry (27)		State and Federal (24)		Total (51)	
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Goal	oxyfluorfen	22	82	15	63	37	73
Modown	bifenox	15	56	19	79	34	67
Roundup	glyphosate	7	26	8	33	15	29
TOK E25	nitrofen	5	19	8	33	13	26
Devrinol	napropamide	3	11	6	25	9	18
Treflan	trifluralin	1	4	5	21	6	12
Caparol	prometryn	1	4	4	17	5	10
Destun	perfluidone	0	—	2	8	2	4
Eptam	EPTC	0	—	1	4	1	2
Toxaphene	toxaphene	1	4	0	—	1	2

[1] *Some nurserymen listed more than one herbicide.*

60 percent) fumigate prior to each seedling crop. The remainder fumigate once for each two or three seedling crops. Eighteen of the nurserymen used spring fumigation; 17 used fall fumigation; and the remaining 12 fumigated part of the nursery in the fall and part in the spring. The main reason for spring fumigation is to reduce the interval between fumigation and sowing, thus reducing time for recontamination. The main reasons for fall fumigation are because there is more time available for the workers and because soil conditions are more favorable.

Methyl bromide fumigation did not exist in the 1930s. However, fumigation with formaldehyde or steam was available, although seldom used (Wakeley 1935).

There are several reasons why most nurseries are fumigated. These include perennial weed control, annual weed control, black root rot control, nematode control, damping-off control, insurance against pathogens, and increasing the availability of certain nutrients. Three nurseries reported no use of fumigation.

The type of methyl bromide fumigant used most in southern nurseries is the formulation with 2-percent chloropicrin. This formulation is used twice as much as the formulation with 33-percent chloropicrin. The formulation with 33-percent chloropicrin is often used at nurseries with disease problems. Very few nurserymen use any fumigant besides methyl bromide. Of the eight industry and public nurserymen who reported using an alternative fumigant, seven used Vorlex®.

DISEASES AND FUNGICIDES

Nursery diseases mentioned by Wakeley (1935) included "preemergence damping-off," "top damping-off," and "brown-spot." He suggested that "preemergence damping-off" was caused by covering seed with more than one-fourth inch of soil. He suggested that "top damping-off" could be controlled by keeping the soil acidic and not overwatering. Bordeaux mixture was recommended for control of "brown spot." It is interesting to note that he did not mention fusiform rust as a problem in nurseries.

Four out of 44 responding nurserymen reported a preemergence damping-off problem, whereas 14 out of 47 responding nurserymen reported a post-emergence damping-off problem. Twenty out of 51 nurserymen reported problems with black root rot. Ten nurserymen listed the problem as "slight" or "occasional," while six gave frequencies of from 1 to 12 percent, and two said the problem was "severe," but only in black walnut. Two nurserymen did not specify a level. Nine nurserymen reported problems with foliar blights. Nearly all said the problems were "slight" or "occasional." Twenty-nine out of 48 nurserymen listed their fusiform rust level the past two years as less than 1 percent or none.

In 1980, Fermate® was by far the most commonly used fungicide in southern nurseries. There was a wide range in the total number of applications reported, from a low of only 2 to a high of 54 Fermate applications over the season. The average of 23 was very close to the median (22). All nurserymen indicated fusiform rust as the pest they were controlling with Fermate. All reported that Fermate was effective when properly applied.

Bayleton® and Captan® were the next most common fungicides. Nearly half of the industry nurserymen used one to five applications of Bayleton over the season. All reported that Bayleton was effective or very effective for fusiform rust. None of the public nurseries, however, used Bayleton. About one third of both industry and public nurserymen used one or two applications of Captan for damping-off and root rot. Nine out of 50 responding nurserymen used Benlate® for several different pathogens, and 16 reported using a total of 9 other fungicides.

FERTILIZATION, ROOT-PRUNING AND TOP-PRUNING

In 1935, use of inorganic fertilizers on a commercial scale had just begun (Wakeley 1935). Two decades later, this was a common practice and was often the only economical way of correcting serious nutrient deficiencies (Wakeley 1954). In 1980, responses to questions on fertilization practices were quite varied. In general, sandy nurseries with low organic matter required frequent applications of nitrogen and potassium while less frequent applications were used on fine textured nurseries. Top dressings of nitrogen were usually in the form of ammonium nitrate or ammonium sulfate. In the fall, potassium was often applied in hopes of conditioning pine seedlings to harden-off. However, there have been few data on loblolly pine to support this practice. Wakeley (1954) suggested setting up tests at each nursery to evaluate effects of fertilizer treatments on seedling growth and field performance; however, only a few tests of this type have been carried out.

Top-pruning and root-pruning apparently were not used in the 1930s (Wakeley 1935), but, by the 1950s, these practices were being discussed as possible methods of "conditioning" seedlings for outplanting (Wakeley 1954). In 1980, root-pruning and top-pruning were practiced operationally at several nurseries throughout the South.

OUTLOOK

Our survey represents an attempt to document some of the practices occurring in forest nurseries in the South and provide a review of 1980 nursery management practices. During the past 50 years, some practices have changed dramatically while others have remained fairly constant. Future changes in nursery management practices will involve producing the maximum number of seedlings with a limited amount of seed from second- and third-generation seed orchards. The value of improved seed requires that nurserymen utilize nursery techniques which maximize seed efficiency. With a bare-root nursery, this would involve improved methods of handling and sowing seed. In addition, more tailoring of seedlings to specific sites and planting methods likely will occur. Cultural practices will likely be based more on research results than on myths, as is often now the case. Regardless of what the future may bring, the southern forest nurseryman will continue to provide the majority of seedlings for reforestation in the United States.

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Practices for Forest Nursery Seeds and Seedlings: Predation Potential by Birds/Mammals and Risk to Non-Target Organisms

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This document addresses the need for Proline in forest tree nurseries and especially for the use on pine seed and seedlings to prevent fusiform rust, pitch canker and Rhizoctonia foliage blight. The comments apply directly to southern nurseries; as Director I represent the members of the Auburn University Southern Forest Nursery Management Cooperative (SFNMC). Data are present from surveys collected together in a Southern Journal of Applied Forestry article titled "Seedling production trends and disease control practices at southern nurseries, 1981-91" (Carey and Kelley, 1993) and from a more recent membership survey summarized in a Nursery Cooperative Technical Note (Carey, 2002). Little has changed since these articles as far as total productions, the percentages by species, fungicide treatments or production per acre. The Advisory members of the SFNMC participated in an e-mail survey in March 2006; their responses to specific questions concerning fungicides usage were summarized and included. About 1.1 billion conifer seedlings are produced in the South each year and this is about 80% of US forest seedling production. There are about 40 nurseries in the Nursery Cooperative and average production is about 30 million seedlings per nursery per year.

I. Seed Size & Acres Sown

Seed size ranges from 8000 – 15,000 seed per pound depending upon the families' genetic makeup. An average of 12,000 seed per pound of loblolly pine will be used which makes up 90% of the nearly 1.1 billion pine seedlings produced annually in the southern U.S. (Enebak, 2010). One hundred pounds of loblolly pine seed will sow approximately 2 acres of nursery which will produce 600,000 seedlings per acre. Due to the tractor paths in between the bed rows and the riser lines used for irrigation pipes, the actual surface area covered with either seed or seedlings is 60% of any given acre of land (Figure 1). With minor adjustments to grower spray booms (Figure 2) it would be possible to use/require banded applications within a nursery to limit the amount of active ingredient (ai) of pesticides used for herbicides, insecticides and fungicides. With only 60% of an acre being seedling crops, the active ingredient per acre should be reduced by 40% for the foliar treatments.

II. Diseases Controlled

The use of Proline, both as a seed treatment and foliar spray on forest-tree nurseries, has been shown in greenhouse and field trials to control the three most important diseases in forest settings. Pitch canker, a conifer disease caused by the fungus *Fusarium circinatum*, can cause significant seed and seedling mortality in nurseries and later after outplanting in the field (Carey and Kelley, 1994). In the southern U.S., infection and seedling losses have been reported on loblolly, slash, longleaf (*Pinus palustris*), shortleaf (*Pinus echinata*) and Virginia (*Pinus virginiana*) pine (Dwinell et al, 1985). The fungus is also considered one of the most threatening diseases in many areas of the world (Ganley et al, 2009), particularly the South African nurseries (Storer et al, 1998, Viljoen and Wingfield, 1994). There are no fungicides registered for the control of pitch canker on either seed or seedlings and nursery growers are forced to use either bleach or hydrogen peroxide to disinfect seed. By treating seedlings in the nursery, non-industrial private landowners, forest industries and land management organizations are ensured that every seeding outplanted on their property is disease-free and the fungus is not getting established into new areas.

The second most important stem disease on conifers is fusiform rust (Anderson et al, 1986; Powers et al, 1981). This disease is both a nursery and field problem. Without fungicide treatments in the nursery, historical seedling infection rates are over 60% (Czabator, 1971). These seedlings either die in the nursery, are culled (thrown away), or are outplanted where they serve to infect other hosts in the field, thereby increasing both the incidence and the severity of fusiform rust on the owners' property. Seed treatments have been one of the most effective methods in controlling fusiform rust with rust incidence less than 0.1%. A savings of 34.5 million seedlings is realized by reducing rust incidence from 2.5% with Ferbam (Rowan, 1977) to 0.01% on an average annual production of 1 billion seedlings. At an average value of $50/1000 seedlings, this reduced rust incidence is a savings of $1,725,000 per year. While savings is important to nursery producers, fungicide treatment in the forest-tree nursery ensures that every seedling that is outplanted is fusiform rust-free and the fungus is not getting spread and established into a new area. Proline offers another fungicide for the use of fusiform rust control.

One of the potential concerns noted by EPA with Proline registration is the rate on seed treatments. We have no data on disease control with a rate lower than listed (20 fl oz/100 lbs seed). While this rate is higher than other crops currently listed, the rates tested on the seed are needed to ensure disease control throughout the germination period that lasts up to 7 weeks in the nursery. At the time of sowing in April, basidiospores from the fungus responsible for fusiform rust are present in the environment and nurseries need to maintain disease control while the seed are germinating until they can begin a foliar application regime. Due to the environmental conditions that favor basidiospore production into late June, it is possible that up to 5 foliar applications will be needed in nurseries to control fusiform rust. We do not have data to suggest that a lower rate as a seed treatment, or fewer applications (4 vs. 5) would be effective at controlling fusiform rust infection for that period of time.

Rhizoctonia foliage blight is the third most important disease in forest tree nurseries. Longleaf and loblolly pines are particularly susceptible to Rhizoctonia foliage blight. The disease is caused by a species of *Rhizoctonia* spp. or binculeate forms of sexual states belonging to the genera Thanatephorus or Ceratobasidium. Rhizoctonia foliage blight can cause significant pine mortality in nursery beds and typically occurs in late July when the seedling canopy closes in (Carey and McQuage, 2003). Symptoms of dead and dying needles and seedling mortality appear in patches within the bed where moisture and temperature favor infection. Many times the disease is not observed until seedlings are top-clipped to maintain seedling shoot:root ratios and heights. Varying degrees of resistance among seedling families can be found, with U.S. gulf coastal seedlots more susceptible than Piedmont sources, and the disease is rarely observed on slash pine. Rhizoctonia foliage blight is not distributed uniformly throughout a nursery and is generally limited to isolated foci and the disease is also more severe in second crop fields post soil fumigation. While there are fungicides registered for Rhizoctonia foliar blight, they are not always efficacious and result in 8-10% culls (Carey and Kelly, 1994; Carey and McQuage, 2004). The use of Proline reduced infection from 18% in the control to less than 0.1%. Losses due to Rhizoctonia foliage blight was $4,000 per acre in the non-treated nursery sections. Worse than the culled seedlings are those infected seedlings which are shipped to the field where they die after outplanting and move the fungus into the forest.

III. Minor Use Crop

Based on FIFRA definitions, Forest Tree Nursery Seedlings is a minor use crop as the area in production annually across the United States for the crop is approximately 2,500 acres and is well under the 300,000 acre minimum. There are sufficient economic incentives to the forest seedling industry to support the initial registration of Proline for such use (Carey and Kelly, 1983). In addition, there are insufficient efficacious alternative registered pesticides available for the use of Proline (Starkey and Enebak, 2009; Starkey and Enebak 2011). Also, Proline will play a significant part in managing pest resistance (especially with the obligate fungal pathogen fusiform rust) and Proline will play a significant part in an integrated pest management program in forest tree nurseries as the soil fumigant MBr is being phased out and soil-borne fungi become more of an issue.

Based on the Southern Forest Nursery Management Cooperative's annual production survey (Enebak, 2010), if every acre of every tree species was treated for every potential disease for the maximum recommend amount of fungicide, 386 gallons of Proline (Table 1) would be used on an area of 1500 acres (60% of 2500 production acres) across 12 southern states. These 12 southern states contain over 515,000,000 acres of which 1.1 billion seedlings will be used to reforest over 2,200,000 acres of land. The planting of these seedlings would reforest approximately 1/3 of the State of Maryland to forests for the next 25-40 years. The annual usage of 386 gallons is currently on the high end of the spectrum as seedling production has been down the previous couple of years (Enebak, 2011).

IV. Standard Operating Procedures that Minimize Potential Predation of Seeds, Seedlings and Offsite Movement to Non-Target Organisms.

The following steps are Standard Operating Procedures used in all forest-tree. There are about 40 nurseries in the Nursery Cooperative and average production is about 30 million seedlings per nursery per year. Forest nursery seed is the most expensive portion (over 50%) of the seedling cost to the consumer averaging 0.05 cents per seedling. Therefore, seed efficiency (a seedling from every seed sown) is the primary goal of forest-tree nurseries.

- ✓ **Sowing Depth:** Pine seed is sown in nursery beds using either a vacuum precision sower or gravity-fed Oyjard sower to a minimum depth of ¼ inch on the seedling beds. Seed are covered with soil after sowing and lightly packed.
- ✓ **Bed Glue:** After sowing, nursery beds are sprayed with a soil stabilizer such as Agrilock®. This keeps the beds in place, minimizes soil erosion of the nursery beds, increases moisture infiltration and creates a 1/4”-1/2” semi-solid layer to keep soil covering the seed.
- ✓ **Bed Mulches:** After sealing the beds with soil stabilizer, the nursery beds are covered with bark mulch to reduce soil temperatures, seed predation, and soil splash and also for moisture retention.
- ✓ **Nursery Margins:** Within most forest-tree nursery operations, there is some distance between the property margin (under control of the organization) and the crop production area (Figure 3). This typically has been 150’ or so that is not/never in seedling production. Recently, however, with the new soil REDs coming on line in 2012 many nurseries have increased the distance between the property line and crop production area to allow the continued use of soil fumigation. These areas are generally left fallow or kept mowed.
- ✓ **Fallow Areas & Weed Control:** The non-crop areas around forest-tree nurseries are kept either vegetation free or mowed (Figure 4). Weeding and/or mowing is part a nursery’s Integrated Pest Management program that it: 1) decreases Lygus bug feeding on seedlings that use surrounding weeds as egg laying sites, 2) keeps weeds from producing seeds that get blown into production areas, 3) decreases hiding/resting sites of small mammals that use long grass/weeds for foraging, and 4) keeps vegetation from becoming attractive to foraging mammals like deer and rabbits. Thus, the risk to mammal predations in the fallow areas with weed control is minimal.
- ✓ **Seed Treatments:** In addition to fungicide treatments like Proline on seed, forest-nursery seed is coated, prior to sowing, with a repellant to deter bird and small mammal (mice, voles, moles) predation before germination.

- ✓ **Weed Control:** Due to the nature of forest-tree seedling production and the need to produce quality, pest-free seedlings, there is a tremendous effort put forth in weed control. This includes soil fumigation with combinations of methyl bromide and/or chloropicrin, followed up with applications of herbicides at the time of sowing and bi-weekly applications to control weeds like spurge, nutsedge, morning glory, and sickle-pod. Thus, within a crop production area it is common practice to find the seedling crop and nothing else (Figure 4). Nursery managers are fastidious about weeds in their nursery beds and simply do not allow a non-seedling plant to be present. In addition, most forest-tree nurseries do not contain bodies of water (ponds, streams, lakes, ditches) within a nursery that could serve as a source of run-off contamination from the nursery to other property that may contain listed and non-listed aquatic plants (Figures 4, 5 & 6).
- ✓ **Drift Mitigation:** Seedlings are grown within a nursery for less than one year, sown in April, lifted and outplanted in the field in December. The ideal seedling after 9 months in the nursery is 18” in total length, with a 12” shoot and a 6” root system (Figure 6). Thus, any treatment within a nursery uses a 3 or 9 bed boom system that is no more than 18” from the ground at the end of the growing season and usually is lower than that during the rest of the season (Figure 2). Drift from any pesticide application at this height is at an absolute minimum.
- ✓ **Fences:** Forest-tree nurseries are routinely fenced to keep mammals (people and deer) out of the area. In many cases, a 7-8’ high deer-proof fence is used to ensure that browse damage does not occur on hardwood seedlings.
- ✓ **Other Treatments:** If a deer-proof fence is not part of a nursery’s hardwood seedling production area, the nursery will spray the foliage of hardwoods with thiram to discourage mammal pressure and the resulting browse/seedling damage.
- ✓ **Another Factor to Consider - Feeding Habits:** White-tailed deer and cottontail rabbits are the most common herbivores associated with forest-tree nurseries. Of the seedlings produced in nurseries throughout the southern U.S., 97% of the 1,100,000,000 seedlings produced annually are conifers. Conifers are not a preferred food host to either white-tailed deer or cottontail rabbit. Thus, the majority of the crop production area treated with Proline is not a feeding host to the most common mammals associated with forest-tree seedlings. The other type of seedlings produced are various hardwood species that include *Quercus* spp, *Fraxinus*, spp, *Acer* spp, *Populus* spp, *Juglans* spp, *Carya* spp and *Plantanus* spp which make up the remaining 3% of the seedlings grown annually. These tree species can serve as feeding hosts to white-tailed deer and cottontail rabbits, and, depending upon the mammal pressure: 1) are sprayed with thiram to repel predation and, most importantly 2) are not hosts to either Pitch Canker, Rhizoctonia foliage blight or Fusiform rust. Thus, the risk to mammal predation of treated conifers is minimal.

V. Reported Seed Loss Factors of Seed and Seedlings in Forest-Tree Nurseries

How effective are these steps in reducing seed and seedling predation?

- ✓ In a comprehensive nursery pest disease survey (Boyer and South, 1984) there were 2,100,000 seedlings/seed lost to bird predation in 51 nurseries examined (Table 1). **Only 6 nurseries (out of 51)** reported bird predation. Looking at this another way, **45 nurseries out of 51 <u>did not have bird predation</u>**. In that same survey, 51 nurseries **<u>reported zero mammal predation</u>** on 2,166 production acres. Thus, there is even less predation by mammals in forest-tree nurseries than birds.

- ✓ In another survey of slash pine in a Florida nursery that specifically monitored seed loss over the entire growing season of 6,865 seed sown in 1982, **not a single seed was reportedly lost to either bird or mammal predation (Haack R.A. 1988)**.

How similar are production systems today than when the surveys were conducted?

- ✓ Production systems are similar except for the widespread adoption of soil stabilizers (Agrilock®) by nurseries in the early 1990's. Prior to that, only bark mulch was used to cover sown seed.
- ✓ The Southern Forest Nursery Management Cooperative is a research-based organization whose goal it is to solve nursery seedling production issues. If seed predation by mammals or birds were an issue, we would know about it and we would be working on a solution to solve the problem.

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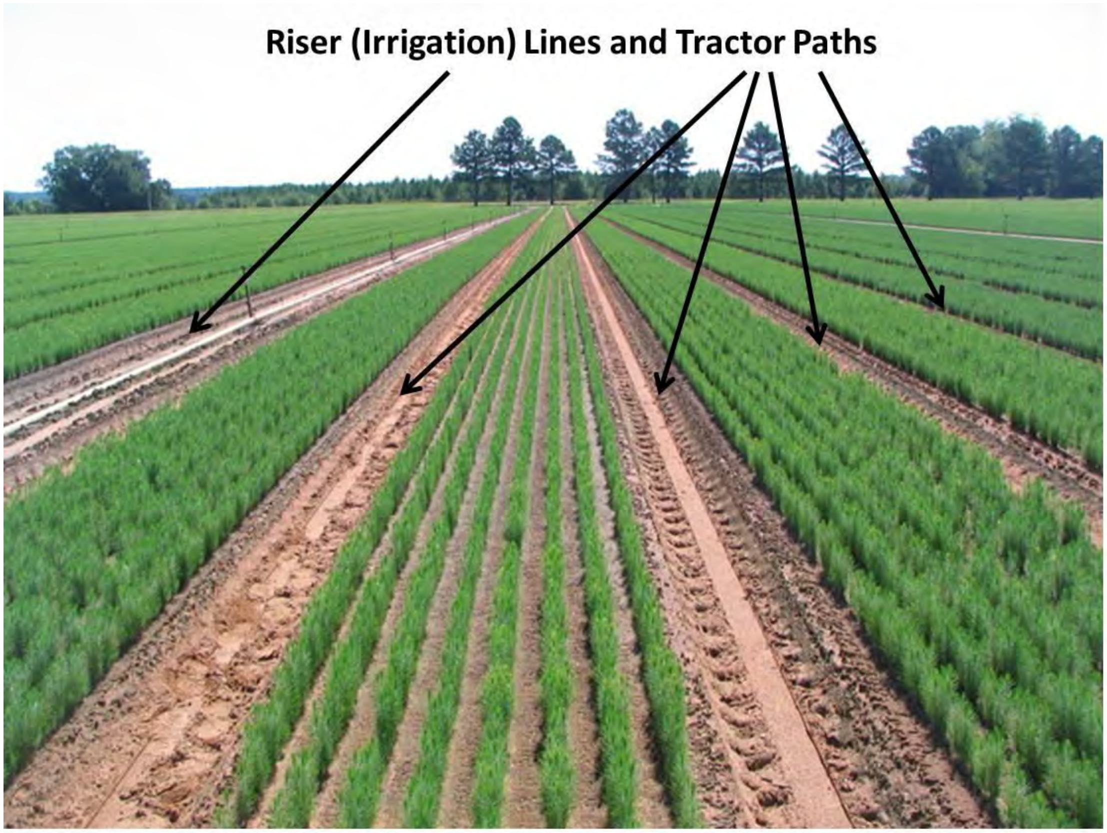
Figure 1. Standard nursery practice is to have nine, 4-ft seedling beds between irrigation risers that are separated by 66 ft.

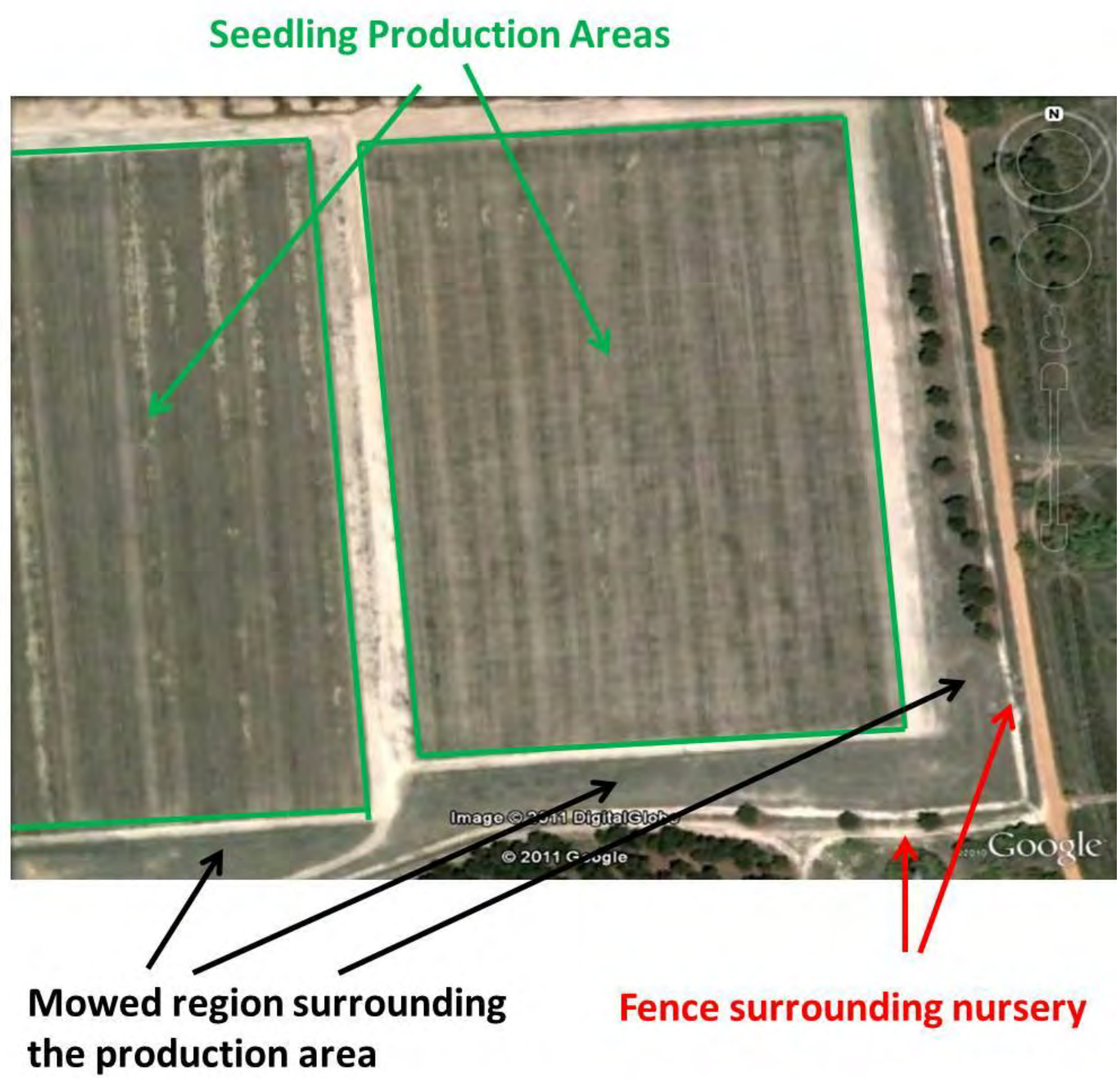


A production acre of nursery is 60% crop, 40% non-crop due to riser lines and tractor paths. Note the lack of vegetation, aquatic/non-aquatic, listed and non-listed within the production areas.

Figure 2. The standard 3-bed boom used in a forest-tree nursery.

A three-bed spray boom common in forest-tree nurseries could be modified/adjusted to a banded sprayer so that only the seeding beds would be treated. The riser lines and tractor paths would not be sprayed with Proline. The crop area within any given acre of land is generally 60%.

Figure 3. Aerial view taken from Google Earth of a nursery production facility.



A close up of one corner of a forest-tree nursery. There is at least 150' between the production field and the property fence where the vegetation is kept mowed. Keeping vegetation down around the production area within the nursery is part of the IPM program as it decreases: 1) Lygus bug feeding on seedlings that use surrounding weeds as egg laying sites, 2) keeps weeds from producing seeds that get blown into production areas, 3) decreases hiding/resting sites of small mammals that use long grass/weeds for foraging, and 4) keeps vegetation from becoming attractive to deer browse.

Figure 4. An image of a forest-tree nursery taken in mid-summer.

A common nursery view; seedlings and bare ground with no listed or non-listed aquatic plants. Fallow area in the fore-ground has been treated with glyphosate to control yellow nutsedge.

Figure 5. An aerial view of a typical forest-tree nursery.

An aerial view of the Georgia Forestry Commission's Flint River Nursery. The 500 acre facility has no ponds, lakes, streams, ditches, that would harbor a listed or non-listed aquatic plant. At any one time, less than 100 acres of this nursery is in production, the rest is either fallow or under a cover crop.

Figure 6. A forest-tree nursery in early fall just prior to lifting and outplanting.

A common nursery view at the end of the growing season. These seedlings are about 12 inches in height and are ready for lifting and outplanting into the field.

Table 1. Seedling production numbers by conifer species, area in acres of each conifer species, estimated amount of disease on each conifer species and estimates on the amount of fungicides used annual for disease control.

2008 Seedling Production	Loblolly	Longleaf	Slash	Others	Total Conifer	Hardwood
Bareroot	801,745,000	8,484,000	127,230,000	12,178,000	949,637,000	38,442,000
Container	21,128,000	42,208,000	2,961,000	3,104,000	69,401,000	791,000
Total Production	822,873,000	50,692,000	130,191,000	15,282,000	1,019,038,000	39,233,000
***Acres Grown = (Production/620,000 per acre)**	1327	82	210	25	1698	65

Diseases Treated by Production Acres	Loblolly	Longleaf	Slash	Others	Total Conifer	Hardwood
Fusiform Rust (100%)	1327	0	210	0	1537	0
Rhizoctonia (40% loblolly and longleaf 0% Slash)	531	33	0	0	564	0
Pitch Canker (20% Loblolly, 100% longleaf, 10% Slash)	265	82	21	0	368	0
					2469	Total Acrage Treated / year

Diseases Treated by Production Acres	No. Acres Treated	No. Applications	Rate (fl oz / acre)	Total Product (fl oz)	Total Product (Gallons)	
Fusiform Rust (100%)	1537	4	5	30,744	240	
Rhizoctonia (40% loblolly and longleaf 0% Slash)	564	4	5	11,272	88	
Pitch Canker (20% Loblolly, 100% longleaf, 10% Slash)	368	4	5	7,364	58	
				49,380	386	Total Product (Proline)
				20,246	158	Total ai (prothioconazole)

Using these rates and acreages and crops one could estimate to use:

0.16	gallons product per acre per year for Fusform Rust
0.16	gallons per acre per year for Rhizoctonia
0.16	gallons per acre per year for Pitch Canker

or 386 gallons Proline (product) per year in the production of forest tree seedlings on 2469 acres of slash, longleaf and loblolly pine to control fusiform rust, pitch canker and rhizoctonia

*620,000 seedlings per acre is an average (range is 600,000 - 640,000/acre).
Using the middle number approxmiates both the number of acres treated and the amount ai used. Actually ai usage and acres treated will be either lower or higher than what is predicted as seedling densities change by nursery.

GEORGIA FORESTRY COMMISSION

P O Box 819
Macon, GA 31202-0819
P. 478-751-3500
F. 478-751-3465

An Equal Opportunity Employer & Service Provider

Mr. Steve Cole
Agriculture Manager ll
Pesticide Section
Georgia Dept. of Agriculture

Dear Mr. Cole,

The Georgia Forestry Commission fully supports Special Local Needs requests for Proline 480 SC.

Forest tree nurseries have faced the loss of a number of fungicides that make growing tree seedlings increasingly difficult. Proline 480 SC is a broad spectrum fungicide that can ameliorate a number of significant nursery diseases including two of the most important – fusiform rust and pitch canker. Fusiform rust is the most important disease in the southern pines and there are no currently registered fungicides for pitch canker control in nurseries. Proline 480 SC would be a valuable tool in a nursery manager's arsenal.

The product has been thoroughly researched by the Auburn University Nursery Management Cooperative and has proven to be effective.

Please consider granting the Special Needs Request submitted by Bayer Cropsciences.

Thank you,

Russell Pohl

Russell Pohl
Chief, Reforestation
Nurseries, Seed Orchards, Tree Improvement

Specimen Label

RESTRICTED USE PESTICIDE
Due to acute toxicity and carcinogenicity.
For retail sale to and use by certified applicators or persons under their direct supervision and only for those uses covered by the certified applicator's certification.

Dow AgroSciences

Telone® C-17

Soil Fungicide and Nematicide

®Trademark of Dow AgroSciences LLC

A multi-purpose liquid fumigant for preplant treatment of soil to control plant parasitic nematodes, symphylans and to help manage certain soil borne diseases in cropland.

Not for use in greenhouses or other enclosed areas and not for use in drip or other chemigation applications.

Active Ingredients:	
1,3-dichloropropene	81.2%
chloropicrin	16.5%
Other Ingredients	2.3%
Total	100.0%

One gallon of Telone C-17 weighs about 10.6 lb at 70°F. Contains 8.6 lb of 1,3-dichloropropene and 1.75 lb of chloropicrin per gallon.

EPA Reg. No. 62719-12

Keep Out of Reach of Children

DANGER PELIGRO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label, find someone to explain it to you in detail.)

Agricultural Use Requirements
Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. Refer to the label booklet under "Agricultural Use Requirements" in the Directions for Use section for information about this standard.

Refer to inside of label booklet for additional precautionary information including Directions for Use.

Notice: Read the entire label. Use only according to label directions. **Before using this product, read Warranty Disclaimer, Inherent Risks of Use, and Limitation of Remedies at end of label booklet. If terms are unacceptable, return at once unopened.**

In case of emergency endangering health or the environment involving this product, call 1-800-992-5994.

Agricultural Chemical: Do not ship or store with food, feeds, drugs or clothing.

Precautionary Statements

Hazards to Humans and Domestic Animals

DANGER

Hazardous Liquid and Vapor

- **Do not swallow any of this product. May be fatal if swallowed.**
- **Corrosive. Do not get in eyes. Causes irreversible eye damage.**
- **Do not get on skin. May be fatal if absorbed through the skin. Causes skin burns. May cause allergic skin reaction.**
- **Do not breathe vapor. May be fatal if inhaled. May cause lung, liver, and kidney damage and respiratory system irritation upon prolonged contact.**
- **The use of this product may be hazardous to your health. This product contains 1,3-dichloropropene, which has been determined to cause tumors in laboratory animals. Risks can be reduced by exactly following directions for use, precautionary statements, and by wearing the personal protective equipment specified in this labeling.**
- **This product also contains chloropicrin, a strong lachrymator (tear-producing eye irritant), which has the capacity to cause marked eye irritation to the upper respiratory tract. Low concentrations are capable of causing painful eye irritation. The effect may be so powerful that a person may become temporarily blinded and panic-stricken. That, in turn, may lead to accidents.**

Personal Protective Equipment (PPE)

Some materials that are chemical-resistant to this product are listed below. For more options, follow the instructions for Category H on the chemical resistance category selection chart. PPE constructed of saranex, neoprene, and chlorinated polyethylene provide short-term contact or splash protection against liquid in this product. Longer-term protection is provided by PPE constructed of viton, Teflon, and EVAL barrier laminates (for example, responder suits manufactured by Life-guard or silvershield gloves manufactured by North). Where chemical-resistant materials are required, leather, canvas, or cotton materials offer no protection from this product and must not be worn as the sole article of protection when contact with this product is possible. Where coveralls are required, they must be loose-fitting and constructed of woven fabrics (e.g., tight knit cotton or cotton/polyester), non-woven fabrics (e.g., tyvek or sontara), or fabrics containing microporous Teflon.

When not performing tasks with liquid contact potential, all handlers (including applicators) must wear:

- Long-sleeved shirt and long pants
- Shoes and socks
- Do not wear jewelry, gloves, goggles, tight clothing, rubber protective clothing, or rubber boots when handling. Chloropicrin is heavier than air and can be trapped inside clothing and cause skin injury.

When performing tasks with liquid contact potential, all handlers (including applicators) must wear:

- Long-sleeved shirt and long pants
- Chemical-resistant gloves
- Chemical-resistant apron
- Protective eyewear (**do not** wear goggles)
- Chemical-resistant footwear and socks

The PPE required when handling liquid must be immediately available and must be worn if the handler is to perform any handling activity with a potential for liquid contact.

1. All handlers (including applicators) must wear a half-face air-purifying respirator (except when handlers are in enclosed cabs or applying the fumigant with equipment that disrupts the chisel trace and seals the soil at the same time, e.g., Yetter applicator) with either an organic-vapor-removing cartridge with a prefilter approved for pesticides (NIOSH approval number prefix TC-23C) or canister approved for pesticides (NIOSH approval number prefix TC-14G). See further respirator requirements in the Directions for Use, Protection for Handlers section on this label.

   If sensory irritation (tearing, burning of the eyes or nose) is experienced and handlers remain in the application block, handlers must wear at a minimum either:
   - a full-face respirator with an organic-vapor-removing cartridge with a prefiler approved for pesticides (NIOSH approval number prefix TC-23C), **or**
   - a full-face respirator with a canister approved for pesticides (NIOSH approval number prefix TC-14G)

   See Directions for Use, Protection for Handlers, Respiratory Protection and Stop Work Triggers, number 1, Handlers Wearing Half-Face Air-Purifying Respirators for when a full-face respirator is required.

   Important: A self-contained breathing apparatus (SCBA) is not permitted for routine handler tasks. Such respirators are only permitted in emergencies such as a spill or leak or when corrective action is needed to reduce air levels to acceptable levels.

2. Handlers using enclosed cabs are not required to wear respiratory protection (**not applicable in California**) provided that the cab has been maintained according to the manufacturer's written operating instructions **and** there is written documentation that the ventilation system has been maintained according to the manufacturer's instructions **and** the enclosed cab is in conformance with the following requirements:
   - the enclosed cab must be positive pressure - 6 mm H_2O gauge
   - the enclosed cab must have a minimum air intake flow of 43 m^3/hour.
   - the enclosed cab must be equipped with activated charcoal filter media containing no less than 1000 grams of activated charcoal.
   - the filter must be changed after no more than 50 hours of application time.

Conformance with these requirements must be documented in the Fumigant Management Plan (FMP).

See Directions for Use, Protection for Handlers, Respiratory Protection and Stop Work Triggers, number 2, Handlers in Enclosed Cabs for stop work procedures

3. Handlers applying the fumigant with equipment that disrupts the chisel trace and seals the soil with one implement, e.g., Yetter applicator (**not applicable in California**) are not required to wear respiratory unless sensory irritation is experienced.

   If sensory irritation (tearing, burning of the eyes or nose) is experienced and handlers remain in the application block, handlers must wear at a minimum either:
   - a full-face respirator with an organic-vapor-removing cartridge with a prefilter approved for pesticides (NIOSH approval number prefix TC-23C), **or**
   - a full-face respirator with a canister approved for pesticides (NIOSH approval number prefix TC-14G)

   See Directions for Use, Protection for Handlers, Respiratory Protection and Stop Work Triggers, number 3, Handlers Applying the Fumigant with Equipment That Disrupts the Chisel Trace and Seals the Soil with One Implement, e.g., a Yetter applicator (**not applicable in California**) for when a full-face respirator is required.

4. Handlers exposed to high airborne concentrations of this product, e.g., emergencies such as a spill or leak or when corrective action is needed to reduce air levels to acceptable levels, and exposure to this product in poorly ventilated areas, must wear at a minimum:
   - Chemical-resistant suit
   - Chemical-resistant gloves such as barrier laminate (EVAL) or viton
   - Chemical-resistant footwear plus socks
   - Chemical-resistant headgear
   - A self-contained breathing apparatus (SCBA) with NIOSH approval number prefix TC-13F. See further respirator requirements in the Protection for Handlers section on this label.

   Note: In-tank cleaning of bulk tanks must be performed only by persons who have been specifically trained for this activity. Refer to OSHA 29 CFR Part 1910.146.

User Safety Requirements

1. **Never fumigate alone:** It is imperative to always have an assistant and proper protective equipment in case of accidents.
2. **Driver's Responsibilities:** Drivers of application equipment must advise other workers of all precautions and procedures. In addition, drivers must instruct their helpers in the mechanical operation of the tractor and how to safely work with the tractor and driver while fumigating.
3. **Dispose of Contaminated Clothing:** Discard clothing and other absorbent materials that have been drenched or heavily contaminated with this product's concentrate. Do not reuse them.
4. **Clean and Maintain PPE:** Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables exist, use detergent and hot water. Keep and wash PPE separately from other laundry.
5. **Contact With Mouth:** Never siphon this product by mouth or use mouth to blow out clogged lines, nozzles, etc.
6. **Heat Illness Avoidance:** Use measures to avoid or minimize heat illness while using this product. These measures include gradual adjustment to heat and respirator stress, fans for cooling, cooling vests, frequent breaks to cool down, frequent intake of drinking water, and maintaining weight from day to day.

User Safety Recommendations

Users should:
- Wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

First Aid

If inhaled: Move person to fresh air. If person is not breathing, call 911 or an ambulance, and then give artificial respiration, preferably mouth-to-mouth, if possible. Call a poison control center or doctor for further treatment advice.
If on skin or clothing: Immediately flush skin with plenty of water for at least 15-20 minutes while removing contaminated clothing and shoes. If water is not immediately available, remove excess chemical from skin with sorbent material such as towel or dry soil, then proceed at once to

First Aid (Cont.)

location where water is available and thoroughly wash contaminated skin with plenty of water. Call a poison control center or doctor for treatment advice.
If in eyes: Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after 5 minutes, then continue rinsing eye. Call a poison control center or doctor for treatment advice.
If swallowed: Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by the poison control center or doctor. Do not give anything by mouth to an unconscious person.

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may also contact 1-800-992-5994 for emergency medical treatment information.

Note to physician: Because rapid absorption may occur through lungs if product is aspirated and cause systemic effects, the decision to induce vomiting or not should be made by a physician. If lavage is performed, endotracheal and/or esophageal control is suggested. Danger from lung aspiration must be weighed against toxicity when considering emptying the stomach.

Environmental Hazards

This pesticide is toxic to mammals and birds. Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwaters or rinsate.
- Chloropicrin has certain properties and characteristics in common with chemicals that have been detected in groundwater (chloropicrin is highly soluble in water and has low adsorption to soil).
- For untarped applications of chloropicrin, leaching and runoff may occur if there is heavy rainfall after soil fumigation.

Groundwater advisory: 1,3-dichloropropene is known to move through soil and under certain conditions has the potential to reach groundwater as a result of agricultural use. Application in areas where soils are permeable and groundwater is near the surface could result in groundwater contamination.

Physical or Chemical Hazards

Combustible. Do not use or store near heat or open flame.

Directions for Use

Restricted Use Pesticide

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.
Read all Directions for Use carefully before applying.

Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your state or tribe, consult the agency responsible for pesticide regulation.

Agricultural Use Requirements

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements in this labeling about personal protective equipment (PPE), restricted entry intervals, and notification to workers. The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard (WPS). No instructions elsewhere on the labeing relieve users from complying with the requirements of WPS. For the entry restricted period and notification requirements, see the Entry Restricted Period and Notification section of this label.

PPE for Entry During the Entry Restricted Period: PPE for entry that is permitted by this labeling is listed in the Hazards to Humans and Domestic Animals section of this labeling.

Storage and Disposal

Do not contaminate water, food or feed by storage and disposal.
Pesticide Storage: Store in tightly-closed original container away from dwellings. Prolonged exposure of container to direct sunlight must be avoided. Do not allow contamination of seeds, plants, fertilizers, or other pesticide chemicals.
Pesticide Disposal: Pesticide wastes are toxic. Improper disposal of excess pesticide and rinsates is a violation of Federal law. If these wastes cannot be disposed of by use according to label instructions, contact your

Storage and Disposal (Cont.)

state pesticide or environmental control agency, or the hazardous waste representative at the nearest EPA regional office for guidance.

Because Telone C-17 is corrosive under certain conditions, flush all application equipment with fuel oil, kerosene or a similar type of petroleum solvent immediately after use. Fill pumps and meters with new motor oil or a 50% motor oil/fuel oil mixture before storing. **Do not use water.** Dispose of rinsate by applicable Federal, state and local regulations. Never introduce rinsate or unused Telone C-17 into surface or underground water supplies.

Refillable containers 5 gallons or larger:
Container Handling: Refillable container. Refill this container with pesticide only. Do not reuse this container for any other purpose. Cleaning the container before final disposal is the responsibility of the person disposing of the container. Cleaning before refilling is the responsibility of the refiller. To clean the container before final disposal, empty the remaining contents from this container into application equipment or a mix tank. Fill the container about 10% full with water and, if possible, spray all sides while adding water. If practical, agitate vigorously or recirculate water with the pump for two minutes. Pour or pump rinsate into application equipment or rinsate collection system. Repeat this rinsing procedure two more times. Then offer for recycling if available, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures allowed by state and local authorities.

Nonrefillable containers 5 gallons or larger:
Container Handling: Nonrefillable container. Do not reuse or refill this container.
Triple rinse or pressure rinse container (or equivalent) promptly after emptying. **Triple rinse** as follows: Empty the remaining contents into application equipment or a mix tank. Fill the container 1/4 full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Turn the container over onto its other end and tip it back and forth several times. Empty the rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Repeat this procedure two more times. **Pressure rinse** as follows: Empty the remaining contents into application equipment or a mix tank and continue to drain for 10 seconds after the flow begins to drip. Hold container upside down over application equipment or mix tank or collect rinsate for later use or disposal. Insert pressure rinsing nozzle in the side of the container, and rinse at about 40 psi for at least 30 seconds. Drain for 10 seconds after the flow begins to drip. Then offer for recycling if available, or puncture and dispose of in a sanitary landfill, or by incineration, or by other procedures allowed by state and local authorities.

General Information

Before using this product, carefully read and follow all label precautions and directions.

Telone C-17 is a multi-purpose liquid fumigant for preplant treatment of cropland soil that can be used as part of a nematode and disease management program involving crop rotation, planting resistant varieties, sanitation, and other cultural practices designed to reduce nematode and disease pressure.

Telone C-17 may be applied as a preplant soil treatment as part of a management program to aid in reducing the damaging effects of certain soil borne diseases [soil rot (soil pox) of sweet potatoes; granville (bacterial) wilt, black root rot, black shank diseases of tobacco; verticillium wilt of strawberries, cole crops and mint, pink root of onions, and fusarium crown and root rot of tomatoes]. This is not a complete list of crops and soil borne diseases. Consult your crop advisor for recommendations on specific soil borne diseases.

Telone C-17 must not be used to control diseases in the plastic culture vegetable and fruit market.

Telone C-17 may be applied as a preplant soil treatment as part of a management program to control and aid in reducing the damaging effects of certain soil pests; plant parasitic nematodes (root-knot, root lesion, citrus, cyst formers, golden, sugarbeet, soybean, burrowing, lance, reniform, ring, spiral, sting, pin, stubby root, dagger, and certain others), symphylans (garden centipedes) and wireworms.

Before fumigation, soil sampling for the type and number of pests present is recommended. In fields where pre-treatment soil samples indicate the presence of high population levels of nematodes, a successful fumigation cannot be expected to eradicate entire populations. Therefore, post-treatment (mid-season and/or preharvest) sampling is recommended to determine the need for additional pest management practices.

Consult State Agricultural Experiment Station or Extension Service specialists for information on other practices such as post-harvest destruction of crop residues, weed control or other cultural practices, and use of nematode resistant crop varieties that may aid in reducing crop losses from soil borne pests.

General Use Precautions

Soil fumigation using Telone C-17 must be conducted only according to directions and conditions of use.

Chemigation
Do not apply Telone C-17 through any type of irrigation system.

Do not formulate and/or tank mix this product into other end-use agricultural products.

Use Restrictions
Do not apply within 100 feet of any well used for potable water. Do not apply this product within 100 feet from the edge of karst topographical features. Karst topography is identified from landscape features that result from the dissolving activity of water in carbonate rock formations (limestone, dolomite and marble). Surface features that are associated with karst topography include sinkholes, caverns, springs, and sinking or disappearing streams. In North Dakota, South Dakota, Wisconsin, Minnesota, New York, Maine, New Hampshire, Vermont, Massachusetts, Utah, and Montana: Where groundwater aquifers exist at a depth of 50 feet or less from the surface, do not apply this product where soils are Hydrologic Group A.

Use Restrictions for Certain Florida Counties
For application of this product in Brevard, Charlotte, Citrus, Collier, DeSoto, Glades, Hardee, Hendry, Hernando, Highlands, Hillsborough, Indian River, Lake, Lee, Manatee, Martin, Monroe, Okeechobee, Orange, Osceola, Palm Beach, Pasco, Pinellas, Polk, Sarasota, Seminole, St. Lucie, Sumter, and Volusia counties, applicators must have labeling for FIFRA Section 24(c) Special Local Need (SLN) FL-990004 in their possession and comply with stated requirements. Use of Telone C-17 is prohibited in Broward and Dade counties.

Use Restrictions for Certain New York Counties
This product is prohibited from sale, use or distribution in Nassau and Suffolk counties.

Fumigation Handlers
The following activities are prohibited from being performed in the application block (i.e., the field or portion of a field treated with a fumigant in any 24-hour period) by anyone other than persons who have been appropriately trained and equipped as handlers in accordance with the requirements in the Worker Protection Standard (40 CFR Part 170), from the start of the application until the entry restricted period ends. **(Note:** Persons installing, perforating, removing, repairing, and monitoring tarps are considered handlers for the durations listed below.) Those activities include those persons:

- Participating in the application as supervisors, loaders, drivers, tractor co-pilots, shovelers, cross ditchers, or as other direct application participants (the application starts when the fumigant is first introduced into the soil and ends after the fumigant has stopped being delivered/dispensed to the soil).
- Using devices to take air samples to monitor fumigant air concentrations.
- Cleaning up fumigant spills (this does not include emergency personnel not associated with the fumigation application).
- Handling or disposing of fumigant containers.
- Cleaning, handling, adjusting, or repairing the parts of fumigation equipment that may contain fumigant residues.
- Installing, repairing, operating or removing irrigation equipment in the fumigant application block.
- Entering the application site to perform scouting, crop advising, or monitoring tasks.
- Installing, perforating (cutting, punching, slicing, poking), removing, repairing or monitoring tarps:
  - o until 14 days after application is complete if tarps are not perforated and removed during those 14 days or
  - o until tarp removal is complete if tarps are both perforated and removed less than 14 days after application or
  - o until 48 hours after tarp perforation is complete if they will not be removed within 14 days after application. **Note:** See Tarp Perforation and/or Removal section on this labeling for requirements about when tarps are allowed to be perforated.
- Performing any handling tasks as defined by the WPS.

Recontamination Prevention
Telone C-17 will help manage certain soil borne pests that are present in the soil treatment zone at time of fumigation. It will not control pests

that are introduced into soil after fumigation. To avoid reinfestation of treated soil do not use irrigation water, transplants, seed pieces, or equipment that could carry soil borne pests from infested land. Avoid contamination from moving infested soil onto treated beds through cultivation, movement of soil from below the treated zone, dumping contaminated soil in treated fields and soil contamination from equipment or crop remains. Clean equipment carefully before entering treated fields. Cultural practices, which provide post-harvest destruction of crop residues and weeds prior to fumigation and practices which prevent weed infestation following fumigation and prior to planting, will help prevent recontamination.

Equipment Clean-Up
Because Telone C-17 is corrosive under certain conditions, flush all application equipment with fuel oil, kerosene or a similar type of petroleum solvent immediately after use. Fill pumps and meters with new motor oil or a 50% motor oil/fuel oil mixture before storing. **Do not use water.** Dispose of rinsate by incorporation into field just treated or by other approved means. Never introduce rinsate or unused Telone C-17 into surface or underground water supplies.

Fertility Interactions
Fumigation may temporarily raise the level of ammonia nitrogen and soluble salts in the soil. This is most likely to occur when high rates of fertilizer and fumigant are applied to soils that are either cold, wet, acidic, or high in organic matter. To avoid injury to certain crops including red beets, carrots, corn, radishes, cole crops, legumes (beans), lettuce, onions, and sugarbeets, fertilize when possible as indicated by soil tests made after fumigation. To avoid ammonia injury or nitrate starvation (or both) to crops grown on high organic soils, do not use fertilizers containing ammonium salts.

When using high rates of Telone C-17 as required by certain state nursery regulations, liming of highly acid soils before fumigation may stimulate nitrification and reduce the possibility of ammonia toxicity. Certain nursery crops such as citrus seedlings, *Cornus* sp., *Crataegus* sp., spruce, and vegetable crops such as cauliflower have shown evidence of phosphorus deficiency following fumigation. To avoid this possible effect, additional phosphate fertilizer (foliar applied) is recommended where experience indicates a deficiency may occur.

Protection for Handlers

Respiratory Protection and Stop Work Triggers

1. **Handlers Wearing Half-Face Air-Purifying Respirators**
   The following procedures must be followed to determine whether a full-face air-purifying respirator is required or if operations must cease for handlers wearing a half-face air-purifying respirator:
   - If at any time any handler experiences sensory irritation (tearing, burning of the eyes or nose) while wearing a half-face respirator:
     - o a full-face air-purifying respirator must be worn by all handlers who remain in the application block **or**
     - o operations must cease and handlers not wearing full-face air-purifying respirators must leave the application block.
   - When full-face air-purifying respirators are worn, then air monitoring samples for chloropicrin must be collected at least every two hours in the breathing zone of a handler performing a representative handling task.
   - When using monitoring devices to monitor air concentration levels, a direct reading detection device, such as a Matheson-Kitagawa, Dräger, or Sensidyne device must be used. The devices must have a sensitivity of at least 0.15 ppm for chloropicrin.
   - When breathing zone samples are required, they must be taken outside respiratory protection equipment and within a 10-inch radius of the handler's nose and mouth.
   - If at any time (1) a handler experiences any sensory irritation when wearing a full-face air-purifying respirator; or (2) an air sample is greater than or equal to 1.5 ppm, then all handler activities must cease and handlers must be removed from the application block. If operations cease, the emergency plan detailed in the FMP must be implemented.
   - Handlers can remove full-face air-purifying respirators or resume work if all of the following conditions exist provided that a half-face air-purifying respirator is worn:
     - o two consecutive breathing zone samples for chloropicrin taken at the handling site at least 15 minutes apart must be less than 0.15 ppm
     - o handlers do not experience sensory irritation, and
     - o air-purifying respirator cartridges have been changed
   - During the collection of air samples a full-face air-purifying respirator must be worn by the handler taking the air samples. Samples must be taken where the sensory irritation is first experienced

2. **Handlers in Enclosed Cabs (Not Applicable in California)**
   - If at any time a handler experiences any sensory irritation (tearing, burning of the eyes or nose) while in the enclosed cab, operations must cease and handlers must leave the application block.
   - Operations may resume in the enclosed cab provided that:
     - o two consecutive breathing zone samples for chloropicrin taken at the handling site at least 15 minutes apart must be less than 1.5 ppm,
     - o handlers do not experience sensory irritation, and
     - o the filter has been changed.
   - During the collection of air samples, a full-face air-purifying respirator must be worn by the handler taking the air samples. Samples must be taken where the sensory irritation is first experienced.

3. **Handlers Applying the Fumigant with Equipment That Disrupts the Chisel Trace and Seals the Soil with One Implement, e.g., a Yetter Applicator (Not Applicable in California)**
   The following procedures must be followed to determine whether a full-face air-purifying respirator is required or if operations must cease for handlers applying the fumigant with equipment that disrupts the chisel trace and seals the soil with one implement, e.g., a Yetter applicator.
   - If at any time any handler experiences sensory irritation (tearing, burning of the eyes or nose) then either:
     - o a full-face air-purifying respirator must be worn by all handlers who remain in the application block **or**
     - o operations must cease and handlers not wearing resiratory protection must leave the application block
   - Handlers can remove full-face air-purifying respirators or resume operations if two consecutive breathing zone samples taken at the handling site at least 15 minutes apart show that levels of chloropicrin have decreased to less than 0.15 ppm provided that handlers do not experience sensory irritation. During the collection of air samples, a full-face air-purifying respirator must be worn by the handler taking the air samples. Samples must be taken where the sensory irritation is first experienced.
   - When using monitoring devices to monitor air concentration levels, a direct reading detection device, such as a Matheson-Kitagawa, Dräger, or Sensidyne device, must be used. The devices must have a sensitivity of at least 0.15 ppm for chloropicrin.
   - When breathing zone samples are required, they must be taken outside of the respiratory protection equipment and within a 10-inch radius of the handler's nose and mouth.
   - When full-face air-purifying respirators are worn, then air monitoring samples must be collected at least every two hours in the breathing zone of a handler performing a representative handling risk.
   - If at any time: (1) a handler experiences any sensory irritation when wearing a full-face air-purifying respirator, or (2) an air sample is greater than or equal to 1.5 ppm, then all handler activities must cease and handlers must be removed from the application block. If operations cease, the emergency plan detailed in the FMP must be implemented.
   - Handlers can resume work activities without full-face air-purifying respirators if two consecutive breathing zone samples taken at the handling site at least 15 minutes apart show levels of chloropicrin have decreased to less than 0.15 ppm, provided that handlers do not experience sensory irritation. During the collection of air samples a full-face air purifying respirator must be worn by the handler taking the air samples. Samples must be taken where the sensory irritation is first experienced.
   - Handlers can resume work activities if all of the following conditions exist provided that a full-face air-purifying respirator is worn:
     - o two consecutive breathing zone samples for chloropicrin taken at the handling site at least 15 minutes apart must be less than 1.5 ppm but are greater than 0.15 ppm
     - o handlers do not experience sensory irritation while wearing the air-purifying respirator, and
     - o air-purifying respirator cartridges have been changed
   - During the collection of air samples, a full-face air-purifying respirator must be worn by the handler taking the air samples. Samples must be taken where the sensory irritation is first experienced.

Supervision of Handlers
For all applications from the start of the application until the fumigant has stopped being delivered/dispensed into the soil, i.e., after the soil is

sealed, the certified applicator must be at the fumigation site in the line of site of the application and must directly supervise all persons performing handling activities.

For handling activities that take place after the fumigant has been delivered/dispensed into the soil until the entry restricted period expires, the certified applicator does not have to be on site but must have communicated in a manner than can be understood to the site owner/ operator and handlers responsible for carrying out those activities the information necessary to comply with the label and procedures described in the FMP (e.g., emergency response plans and procedures). Communication activities must be captured in the FMP.

Important: This requirement does not override the requirements in the Worker Protection Standard for Agricultural Pesticides for information exchange between owners/operators of agricultural establishments and commercial pesticide applicators.

The certified applicator must provide **Fumigant Safe Handling** information to each handler involved in the application or confirm that each handler participating in the application has received **Fumigant Safe Handling** information in a manner they can understand within the past 12 months. **Fumigant Safe Handling** information will be provided where this product is purchased or at http://www.epa.gov/fumiganttraining.

For all handling tasks, at least two handlers trained under the provisions of the WPS 40 CFR 170.230 must be present.

Exclusion of Non-Handlers From Application Block
The certified applicator supervising the application and the owner/ operator of the establishment where the fumigation is taking place must make sure that all persons who are not trained and PPE equipped and who are not performing one of the handling tasks as stated in this label are excluded from the application block during the entry-restricted period.

Providing, Cleaning, and Maintaining PPE
The employer of any handler (as stated in this label) must make sure that all handlers are provided and correctly wear the required PPE. The PPE must be cleaned and maintained as required by the Worker Protection Standard for Agricultural Pesticides.

Air-Purifying Respirator Availability
The employer of any handler must confirm that an air-purifying respirator and appropriate cartridges of the type specified in the PPE section of this label are immediately available for each handler who will wear one. These handlers must be fit-tested, trained, and medically examined. This must be documented in the FMP. Cartridges or canisters must be replaced when odor or irritation from this product becomes apparent, if the measured concentration of chloropicrin is greater than 1.5 ppm, or after 8 hours of use, whichever occurs first.

Availability of Respirators for Emergencies
The employer of any handler must confirm that at least one self-contained breathing apparatus (SCBA) is on site and is ready for use in case of an emergency. This must be documented in the FMP.

Respirator Fit Testing, Medical Qualification and Training
Employers must verify that any handler who uses a respirator is:

- Fit tested and fit checked using a program that conforms to OSHA's requirements (see 29 CFR Part 1910.134).
- Trained using a program that conforms to OSHA's requirements (see 29 CFR Part 1910.134).
- Examined by a qualified medical practitioner to ensure physical ability to safely wear the style of respirator to be worn. A qualified medical practitioner is a physician or other licensed health care professional who will evaluate the ability of a worker to wear a respirator. The initial evaluation consists of a questionnaire that asks about medical conditions (such as a heart condition) that would be problematic for respirator use. If concerns are identified, then additional evaluations, such as a physical exam, might be necessary. The initial evaluation must be done before respirator use begins. Handlers must be reexamined by a qualified medical practitioner if their health status, respirator style or use conditions change. Upon request by local/state/federal/tribal enforcement personnel, employers must provide documentation demonstrating how they have complied with these requirements.

Application Requirements

Tarp Perforation and/or Removal
Important: Persons perforating, repairing, removing, and/or monitoring tarps are defined, within certain time limitations, as handlers (see handlers as stated in this label) and must be provided the PPE and other protections for handlers as required on this labeling and in the Worker Protection Standard for Agricultural Pesticides.

Tarps must not be perforated until a minimum of five days (120 hours) have elapsed after the fumigant injection into the soil is complete (e.g., after injection of the fumigant product and tarps have been laid) unless a weather condition exists which necessitates the need for early perforation or removal. See Early Tarp Removal for Broadcast Applications Only and Early Tarp Perforation for Flood Prevention Activities sections.

If tarps will be removed before planting, tarp removal must not begin until at least two hours after tarp perforation is complete. If tarps will not be removed before planting, planting or transplanting must not begin until at least 48 hours after the tarp perforation is complete. If tarps are left intact for a minimum of 14 days after fumigant injection into the soil is complete, planting or transplanting may take place while the tarps are being perforated. Each tarp panel used for broadcast fumigation must be perforated.

Tarps used for fumigations may be perforated manually **only** for the following situations:

- At the beginning of each row when a coulter blade (or other device which performs similarly) is used on a motorized vehicle such as an ATV.
- In fields that are 1 acre or less.
- During flood prevention activities.

In all other instances, tarps must be perforated (cut, punched, poked, or sliced) only by mechanical methods. Tarp perforation for broadcast fumigations must be completed before noon. For broadcast fumigations, tarps must not be perforated if rainfall is expected within 12 hours.

Early Tarp Removal for Broadcast Applications Only
Tarps may be removed before the required five days (120 hours) if adverse weather conditions have compromised the integrity of the tarp, provided that the compromised tarp poses a safety hazard. Adverse weather includes high wind, hail, or storms that blow tarps off of the field and create a hazard, e.g., tarps blowing into power lines and onto roads. A compromised tarp is a tarp that, due to an adverse weather condition, is no longer performing its intended function and is creating a hazard.

If tarps are removed before the required five days have elapsed due to adverse weather, the events must be documented in the post-application summary.

Early Tarp Perforation for Flood Prevention Activities
Early tarp perforation is allowed before the five days (120 hours) have elapsed for flood prevention. Tarps must be immediately retucked and packed after soil removal.

Mandatory Good Agricultural Practices (GAPs)

The following GAPs must be followed during all fumigant applications. All measurements and other documentation planned to ensure that the mandatory GAPs are achieved must be recorded in the FMP and/or the post-application summary.

Application Timing
Apply Telone C-17 at any time of the year when soil conditions permit. Conditions that allow rapid diffusion of the fumigant as a gas through the soil normally give the best results. Because Telone C-17 does not provide residual control of soil pests, use it as a preplant application before planting each crop.

Tarps
When tarps are used in applications of Telone C-17, a written tarp plan must be developed and included in the FMP. The plan must include:

- Schedule and procedures for checking tarps for damage, tears, and other problems.
- Plans for determining when and how repairs to tarps will be made, and by whom.
- Minimum time following injection that tarp will be repaired.
- Minimum size of tarp damage that will be repaired.
- Other factors used to determine how and when tarp repair will be conducted.
- Schedule, equipment and methods used to perforate tarps.
- Aeration plans and procedures following perforation of tarp, but prior to tarp removal or planting/transplanting.
- Schedule, equipment, and procedures for tarp removal.

Weather Conditions
Prior to fumigation, the weather forecast for the day of the application and the 48-hour period following the fumigation must be checked to determine if unfavorable weather conditions exist (see Identifying Unfavorable Weather Conditions section) or are predicted and whether fumigation should begin.

Wind speed at the application site must be a minimum of 2 mph at the start of the application or forecasted to reach at least 5 mph during the application.

Do not apply if a shallow, compressed (low-level) temperature inversion is forecast to persist for more than 18 consecutive hours for the 48-hour period after the start of application, or if there is an air stagnation advisory issued by the National Weather Service in effect for the area in which the fumigation is planned. Detailed local forecasts for weather conditions, wind speed, and air stagnation advisories may be obtained on-line at http://www.nws.noaa.gov, or by contacting your local National Weather Service Forecasting Office.

Identifying Unfavorable Weather Conditions: Unfavorable weather conditions block upward movement of air, which results in trapping fumigant vapors near the ground. The resulting air mass can move off site in unpredictable directions. These conditions typically exist prior to sunset, continue past sunrise and persist as late as noontime. Unfavorable conditions are common on nights with limited cloud cover and light to no wind, and their presence can be indicated by ground fog or smog and can also be identified by smoke from a ground source that flattens out below a ceiling layer and moves laterally in a concentrated cloud.

Soil Preparation

Soil must be in good tilth and free of large clods. Large clods can prevent effective soil sealing and reduce effectiveness of the application. If subsurface soil compaction layers (hardpans) are present within the intended fumigation treatment zone, a deep tillage to fracture these layers must occur prior to or during the soil fumigant application.

Plant residue that is present must not interfere with the application or the soil seal. Undecomposed plant material may harbor pests that will not be controlled by fumigation. Crop residue that is present must lie flat to permit the soil to be sealed effectively and limit the natural "chimneys" that may occur in the soil when plant residue is present. These "chimneys" allow the soil fumigants to move through the soil quickly and escape into the atmosphere. This may create potentially harmful conditions for workers and bystanders and limits the efficacy of the fumigant. Plant residue on the field serves to prevent soil erosion from both wind and water.

Soil Sealing

Broadcast Untarped Applications: Use a disc or similar equipment to uniformly mix the soil to at least a depth of 4 to 6 inches to eliminate the chisel or plow traces. Following elimination of the chisel trace, the soil surface must be compacted with a cultipacker, ring roller, and roller in combination with tillage equipment. When using equipment similar to the Yetter applicator (chisel trace disruption and soil sealing are done with one implement), additional tillage and compaction are not required.

Bedded Applications: Preformed beds must be sealed by disruption of the chisel trace using press sealers, bed shapers, cultipackers, or by reshaping (e.g., relisting, lifting and replacing) the beds immediately following injection. Beds formed at the time of application must be sealed by disrupting the chisel trace using press sealers or bed shapers. When bedding, prebedders such as ripper hippers, hillers, or other prebedders may be used to disrupt the chisel trace and seal the soil. When using equipment similar to the Yetter applicator (chisel trace disruption and soil sealing are done with one implement), additional tillage and compaction are not required. Beds may be formed following the Yetter-type applicator in a normal interval consistent to area production practices.

Tarped Applications: The use of a tarp does not eliminate the need to minimize chisel traces prior to application of the tarp, such as by using a Nobel plow or other injection shank that disrupts the chisel traces. When bedding, prebedders such as ripper hippers, hillers, or other prebedders may be used to disrupt the chisel trace and seal the soil. When using equipment similar to the Yetter applicator (chisel trace disruption and soil sealing are done with one implement), additional tillage and compaction are not required. Beds may be formed following the Yetter-type applicator in a normal interval consistent to area production practices.

Telone C-17 Bedded and Broadcast Shank Applications – Additional GAPs

In addition to the GAPs required for all soil fumigation applications with Telone C-17, the following GAPs apply for injection applications.

Tarps: When tarps are used in applications of Telone C-17, they must be installed immediately after the fumigant is applied to the soil.

Soil Preparation: Trash pulled by the shanks to the ends of the field must be covered with tarp or soil depending upon the application method before making the turn for the next pass.

Soil Temperature: The minimum soil temperature at the depth of injection is 40°F. The maximum soil temperature at the depth of injection must not exceed 90°F at the beginning of the application. If air temperatures have been above 100°F in any of the three days prior to application, then soil temperature must be measured and recorded in the FMP.

Soil Moisture: The soil must be moist 9 inches below the surface. The amount of moisture needed will vary according to the soil type. Surface soil generally dries rapidly and must not be considered in this determination. Soil moisture must be determined by one of the following methods: (1) The USDA Feel and Appearance Method for testing; or (2) an instrument, such as a tensiometer. If there is insufficient moisture 9 inches below the surface, the soil moisture must be adjusted. If irrigation is not available and there is adequate soil moisture below 9 inches, soil moisture can be adjusted by discing or plowing before fumigant injection. To conserve existing soil moisture, pretreatment irrigation or pretreatment tillage should be done as close to the time of application as possible. Measure soil moisture at a depth of 9 inches at either end of the field no more than 48 hours prior to application.

Soil Moisture Determination Using the USDA Feel and Appearance Method:

- For **coarse** textured soils (fine sand and loamy fine sand), there must be enough moisture (50 to 75% available soil water moisture) so that the soil is moist, forms a weak ball with loose and clustered sand grains on fingers, darkened color, moderate water staining on fingers and will not ribbon.
- For **moderately coarse** textured soils (sandy loam and fine sandy loam), there must be enough moisture (50 to 75% available soil water moisture) so that the soil is moist, forms a ball with defined finger marks, very light soil/water staining on fingers, and darkened color will not stick.
- For **medium** textured soils (sandy clay loam, loam, and silt loam), there must be enough moisture (50 to 75% available soil water moisture) so that the soil is moist, forms a ball, very light staining on fingers, darkened color, pliable, and forms a weak ribbon between the thumb and forefinger.
- For **fine** textured soils (clay, clay loam, and silty clay loam), there must be enough moisture (50 to 75% available soil water moisture) so that the soil is moist, forms a smooth ball with defined finger marks, light soil/water staining on fingers, and ribbons between thumb and forefinger.
- For **fields with more than one soil texture**, soil moisture content in the lightest textured (most sandy) areas must comply with this soil moisture requirement. Whenever possible, the field should be divided into areas of similar soil texture and the soil moisture of each area should be adjusted as needed. Coarser textured soils can be fumigated under conditions of higher soil moisture than finer textured soils; however, if the soil moisture is too high, fumigant movement will be retarded and effectiveness of the treatment will be reduced. Previous and/or local experience with the soil to be treated or the crop to be planted can often serve as a guide to conditions that will be acceptable. If there is uncertainty in determining the soil moisture content of the area to be treated, a local extension service agent or soil conservation service specialist or pest control advisor (agriculture consultant) should be consulted for assistance.

Application Depth

Tarped Broadcast Applications: The injection point must be a minimum of 8 inches from the nearest final soil/air interface.

Tarped and Untarped Bedded Applications: The injection point must be a minimum of 12 inches from the nearest final soil/air interface.

Untarped Broadcast Applications: The injection point must be a minimum of 12 inches from the nearest final soil/air interface. When using the Nobel plow for untarped broadcast applications, the injection point must be a minimum of 15 inches from the nearest final soil/air interface.

Untarped Broadcast Deep Applications: The injection point must be a minimum of 18 inches from the nearest final soil/air interface.

Application Methods and Equipment

Broadcast Applications: Use chisel (shank) or coulter (e.g., Yetter 30-inch Avenger), offset wing shank, Nobel (sweep) plow, or plow-sole application equipment. For best results when using chisel equipment, use ripper-type, forward-swept shanks. Nobel plow equipment is particularly useful for fall fumigation when the soil still contains some standing undecomposed plant material. Subsoiling may be necessary before application. Choose application equipment that allows the deepest application and best soil seal under existing conditions.

The fumigant outlet spacing varies with the type of application equipment used.

With chisel and coulter equipment, a fumigant shank spacing of 12 to 24 inches is recommended. Do not exceed the maximum shank and outlet spacing of 24 inches. The outlet spacing for this equipment may be up to 1 1/2 times the application depth but generally should be equal to the application depth and should not exceed the soil-shattering capability of the chisels.

With plow-sole equipment, a 12-inch outlet spacing is recommended. Do not exceed an outlet spacing of 18 inches.

With Nobel (sweep) plow equipment, use an outlet spacing of 9 to 12 inches along the sweeps.

Broadcast application can be made in the same direction or at an angle to the direction of row planting.

Refer to Table 1 for broadcast treatment rates for various crops.

Bedded Applications (for Row Spacing Greater Than 24 Inches): Use chisel equipment to treat a band of soil where the crop is to be planted, i.e., the plant row. When multiple chisels per plant row are used, space the chisels (fumigant outlets) no more than 12 inches apart.

With certain deeper rooted crops such as potatoes and sugarbeets, higher flow rates may be necessary to ensure adequate treatment of the zone of soil where primary root growth occurs.

To prevent seed germination problems caused by improper seed-to-soil contact or improper planting depth, do not place the seed directly over the furrow left by the applicator chisel(s). When one chisel is used per plant row, place the seed about 4 inches to one side of the chisel furrow. When two chisels are used per plant row, plant the seed offset from the chisel trace.

Prevention of End Row Spillage
Do not apply or allow fumigant to spill onto the soil surface. For each injection line either have a check valve located as close as possible to the final injection point, or drain/purge the line of any remaining fumigant prior to lifting injection shanks from the ground.

Do not lift injection shanks from the soil until the shut-off valve has been closed and the fumigant has been depressurized (passively drained) or purged (actively forced out via air compressor) from the system.

The dispensing system must shut off the feed stream when chisels are raised out of the ground. Do not stop or park near any area where dribble from chisel tips has fallen.

- A flow shutoff device must be placed as close as is technically feasible to the fluid discharge point. This can be a ball, poppet, or diaphragm check valve, or full flow shutoff device such as an electric or pneumatically actuated valve.
- Service any system immediately if continuous drip occurs.
- If mechanical check valves and orifices are used, place the check valve above the orifice. Also, isolate the check valve from upstream pressure by installing a main line shut off or bypass valve prior to the manifold.
- Pipe diameter from check valve to injection point must not exceed 1/4 inches ID National Pipe Standard (NPS). Preferably, use the smallest diameter pipe or tubing possible which achieves the required flow rate.
- Alternative end-row spillage devices or methods, such as, but not limited to, micro-bore restricted flow tubing or line purge systems may be used if they provide equal or superior control versus check valves.

Calibration, Set Up, Repair and Maintenance for Application Rigs
Compatible Materials:
- Copper, stainless steel, stainless steel braided hose, steel, brass, Kynar, Kalrez, Chemraz, Santoprene, Hasteloy, Monel, polypropylene, polyethylene, nylon, Teflon, rigid PVC and viton (F/G best).
- Do not expose rigid PVC to undiluted Telone C-17 or more than 1500 ppm of Telone C-17 in the diluted form.

The following materials must **not** be used with Telone C-17:

- Do not use containers, pumps, or other transfer equipment made of aluminum, magnesium, zinc (including galvanized), cadmium, tin and alloys, or vinyl as under certain conditions Telone C-17 may be severely corrosive to such materials. Unless referring to plasticized vinyl, vinyl and PVC are the same. PVC is listed above under Compatible Materials.
- Buna-N, neoprene and fiberglass have the potential to disintegrate and must not be used with Telone C-17.

All rigs must include a filter to remove any particulates from the fumigant and for pressurized systems a check valve to prevent backflow of the fumigant into the pressurizing cylinder or the compressed air system.

Rigs must include a flowmeter or a constant pressure system with orifice plates to insure the proper amount of fumigant is applied.

To prevent the backflow of fumigant into the compressed gas cylinder (e.g., nitrogen, other inert gas or compressed air), if used, applicators must:

- Ensure that positive pressure is maintained in the cylinder at not less than 200 psi during the entire time it is connected to the application rig if a compressed gas cylinder is used. (This is not required for a compressed air system that is part of the application rig because if the compressor system fails, the application rig will not be operable.)
- Ensure that application rigs are equipped with properly functioning check valves between the compressed gas cylinder or compressed air system and the fumigant cylinder. The check valve is best placed on the outlet side of the pressure regulator and is oriented to only allow compressed gas to flow out of the cylinder or compressed air out of the compressed air system.
- Always pressurize the system with compressed gas or by use of a compressed air system before opening the fumigant cylinder valve.

Before using a fumigation rig for the first time, or when preparing it for use after storage, the operator must check the following items carefully:

- Check the filter and clean or replace the filter element as required.
- Check all tubes and chisels to make sure they are free of debris and obstructions.
- Check and clean the orifice plates and screen checks if installed.
- Pressurize the system with compressed gas or compressed air, and check all fittings, valves, and connections for leaks using soap solution.

Install the fumigant cylinder and connect and secure all tubing. Slowly open the compressed gas or compressed air valve and increase the pressure to the desired level. Slowly open the fumigant cylinder valve, always watching for leaks.

When the application is complete, close the fumigant cylinder valve and blow residual fumigant out of the fumigant lines into the soil using compressed gas or compressed air. At the end of the application, disconnect all fumigant cylinders from the application rig. At the end of the season, seal all tubing openings with tape to prevent entry of insects and dirt.

Application equipment must be calibrated and all control systems must be working properly. Proper calibration is essential for application equipment to deliver the correct amount of fumigant uniformly to the soil. Refer to the manufacturer's instructions on how to calibrate your equipment. Usually the equipment manufacturer, fumigant dealer, or cooperative extension service can provide assistance.

Planting Interval
Leave the soil undisturbed and unplanted for at least 7 days after applying Telone C-17. A longer undisturbed interval is required if the soil becomes cold or wet, and for deep-rooted tree, shrub and vine planting sites.

After fumigation to prevent phytotoxicity, allow the fumigant to dissipate completely before planting the crop. Dissipation is usually complete when Telone C-17 can no longer be detected at the application depth. Under optimum soil conditions for dissipation, a period of 1 week for each 10 gallons per treated acre is generally required for complete dissipation. If virtually impermeable films (VIF) are used, a longer dissipation period may be needed. Rapidly germinating seed (i.e., lettuce or radish) and/or seed or transplants to be grown may be used as a bioassay to determine if Telone C-17 is present in the soil at concentrations sufficient to cause plant injury.

To hasten dissipation especially if heavy rains or low temperatures occur during the treatment period, till the soil to the depth of fumigant application. Use a knife-like chisel without turning the soil to reduce the possibility of recontaminating the treated soil. Dissipation is usually complete when Telone C-17 is no longer evident at the application depth. Seed may be used as a bioassay to determine if Telone C-17 is present in the soil at concentrations sufficient to cause plant injury. Do not plant if Telone C-17 is detected.

Bulk and Non-Bulk Containers
Telone C-17 must be transferred through connecting hoses, pipes, and/or couplings sufficiently tight to prevent workers or other persons from coming in contact with liquid Telone C-17.

- All hoses, piping, and tanks used in connection with Telone C-17 shall be of the type appropriate for use under the pressure and vacuum conditions to be encountered.
- External sight gauges shall be equipped with valves so that pipes to sight gauge can be shut off in case of breakage or leakage.
- The mechanical transfer system must be adequate to make necessary measurements of the pesticide being used.
- Shut-off devices must be installed on the exit end of all hoses and at all disconnect points to prevent leakage of Telone C-17 when the transfer is stopped and hose is removed or disconnected. A dry coupler that will minimize pesticide leakage must be installed at the disconnect point.
- The pressure in hoses used to move Telone C-17 beyond a pump must not exceed the manufacturer's maximum pressure specification.

Telone C-17 Tree Replant Applications Using Handheld Equipment – Additional GAPs
This application method is used when Telone C-17 is applied to individual tree sites in an existing orchard where shank applications are not possible. In addition to the GAPs required for all soil fumigation applications with Telone C-17, the following GAPs apply for tree replant applications with Telone C-17.

Site Preparation: Remove the tree stump and primary root system in each individual tree site with a backhoe or other similar equipment, for example, an auger. The backhoe site must be dug in the approximate dimensions of 10 x 10 x 10 feet.

Application Depth: The fumigant must be injected at least 18 inches into the soil. For sites where no restrictive soil layers are present, Telone C-17 can be applied to a depth of 5 feet using an injection auger. For tree replant sites in the wetern U.S., apply Telone C-17 at a single point in the center of each planting site at a depth of 5 feet below the original soil surface, or into at least three points per planting site, at a depth of 3 feet below the original soil surface.

System Flush: Before removing the application wand from the soil the wand must be cleared using nitrogen or compressed air.

Soil Sealing: After the wand is cleared and removed from the soil, the injection hole must be either covered with soil and tamped or the soil must be compacted over the injection hole.

Planting Interval: To prevent phototoxicity, assure that the chemical has dissipated completely before planting. Dissipation is slower in cold, wet soils. Prepare and treat planting sites in the fall and plant in the spring. Do not place in groundwater.

Site Specific FMP

Prior to the start of fumigation, the certified applicator supervising the application must verify that a site specific FMP exists for each application block (i.e., field or portion of a field treated with a fumigant in any 24-hour period). In addition, an agricultural operation fumigating multiple application blocks may format the FMP in a manner whereby all of the information that is common to all of the application blocks is captured once and any information unique to a particular application block or blocks is captured in subsequent sections. The FMP must be prepared by the certified applicator, the site owner/operator, registrant, or other party. The certified applicator must verify in writing (sign and date) that the site specific FMP reflects current site conditions before the start of fumigation.

Each site specific FMP must contain the following elements:

- **Applicator Information**
  - Name
  - Phone number
  - Pesticide applicator license and/or certificate number
  - Employer name and address
- **General Site Information**
  - Application block location (e.g., county, township-range-section quadrant), address or global positioning system (GPS) coordinates
  - Name, address, and phone number of owner/operator of the application block
- **General Application Information**
  - Target application date/window
  - Brand name of fumigant
  - EPA registration number
- **Tarp Information and Procedures for Repair, Perforation and Removal (if tarp is used)**
  - Brand name, lot number, thickness
  - Name and phone number of person responsible for repairing tarps
  - Schedule for checking tarps for damage, tears, and other problems
  - Maximum time following notification of damage that the person(s) responsible for tarp repair will respond
  - Minimum time following application that tarp will be repaired
  - Minimum size of damage that will be repaired
  - Other factors used to determine when tarp repair will be conducted
  - Name and phone number of person responsible for perforating and/or removing tarps
  - Equipment/methods used to perforate tarps
  - Schedule and target dates for perforating tarps
  - Schedule and target dates for removing tarps
- **Soil Conditions**
  - Description of soil texture in application block
  - Method used to determine soil moisture
- **Weather Conditions**
  - Summary of forecasted conditions for the day of application
  - Summary of conditions in the 48-hour period following the fumigant application
    - Wind speed
    - Inversion conditions [e.g., shallow, compressed (low-level) temperature inversion]
    - Air stagnation advisory
- Air-purifying respirators, SCBAs, and other personal protective equipment (PPE) for handlers (handler task, protective clothing, respirator make, model, type, style, and size, respirator cartridge type, respirator cartridge replacement schedule, eye protection, gloves, other PPE)
- If using an enclosed cab in lieu of wearing an air-purifying respirator, verify that the cab:
  - Has positive pressure (6 mm H_2O Gauge)
  - Has a minimum air intake flow of 43 m^3/hour
  - Is equipped with activated charcoal filter-media containing no less than 1000 grams of activated charcoal.
  - Document the application hours of the filter to confirm that the filter has been used for no more than 50 hours of application time.
  - In addition document that the ventilation system has been maintained according to manufacturer's instructions.
- **Emergency Procedures**
  - Evacuation routes
  - Locations of telephones
  - Contact information for first responders
  - Local/state/federal/tribal contacts
  - Key personnel and emergency procedures/responsibilities in case of an incident
  - Equipment/tarp/seal failure or complaints
  - Other emergencies
- **Fumigant Treated Area Posting Procedures**
  - Person(s) who will post Fumigant Treated Area signs
  - Location of Fumigant Treated Area signs
  - Procedures for Fumigant Treated Area sign removal
- Plan describing how communication will take place between applicator, land owner/operator, and other on-site handlers (e.g., tarp perforators/removers, irrigators) for complying with label requirements (e.g., timing of tarp perforation and removal, PPE)
  - Name and phone number of persons contacted
  - Date contacted
- **Authorized On Site Personnel**
  - Names, addresses and phone numbers of handlers
  - Names, addresses and phone numbers for employers of handlers
  - Tasks that each handler is authorized and trained to perform
  - For handlers designated to wear respirators (air-purifying respirator or SCBA):
    - Date of medical qualification for respirator(s) that each handler is designated to wear
    - Date of training for respirator(s) that each handler is designated to wear and
    - Date of fit testing for respirator(s) that each handler is designated to wear
- **Air Monitoring Plan**
  - If sensory irritation is experienced, indicate whether operations will be ceased or operations will continue with an air-purifying respirator.
  - If the intention is to cease operations when sensory irritation is experienced, provide the name, address, and phone number of the handler that will perform monitoring activities prior to operations resuming.
  - When air-purifying respirators are worn:
    - ◊ Representative handler tasks to be monitored
    - ◊ Monitoring equipment to be used and timing of monitoring
- **Good Agricultural Practices (GAPs)**
  - Description of applicable mandatory GAPs
  - Measurements and documentation to ensure GAPs are achieved (e.g., measurement of soil and other site conditions)
- **Description of Hazard Communication**
  - The application block has been posted in accordance with the label.
  - Pesticide product labels and material safety data sheets are on site and readily available for employees to review.
- **Recordkeeping Procedures**
  The owner/operator of the application block as well as the certified applicator must keep a signed copy of the site specific FMP for two years from the date of the application.

For situations where an initial FMP is developed and certain elements do not change for multiple fumigation sites (e.g., applicator information, authorized on site personnel, recordkeeping procedures, emergency procedures), only elements that have changed need to be updated in the site specific FMP provided the following:

- The certified applicator supervising the application has verified that those elements are current and applicable to the application block before it is fumigated.
- Recordkeeping requirements are followed for the entire FMP (including elements that do not change).

Once the application begins, the certified applicator must make a copy of the FMP available for viewing by handlers involved in the fumigation. The certified applicator or the owner/operator of the application block must provide a copy of the FMP to any local/state/federal/tribal enforcement personnel who requests the FMP. In the case of an emergency, the FMP must be made immediately available when requested by local/state/federal/tribal emergency response and enforcement personnel.

Within 30 days of completing the application portion of the fumigation process, the certified applicator supervising the application must complete a post-application summary that describes any deviations from the FMP that have occurred, measurements taken to comply with GAPs, monitoring results, as well as any complaints and/or incidents that have been reported to him/her.

The post-application summary must contain the following elements:

- **Application Information**
  - o Actual application date
  - o Actual application rate
  - o Size of application block fumigated
- **Weather Conditions**
  - o Summary of weather conditions on day of application
  - o Summary of weather conditions during 48-hour period following fumigant application
- **Soil Temperature Measurement**
  If air temperatures were above 100°F in any of the three days prior to the application
- **Tarp Damage and Repair Information (if Applicable)**
  - o Location and size of tarp damage
  - o Description of tarp/tarp seal/tarp equipment failure
  - o Date and time of tarp repair
- **Tarp Perforation/Removal Details (if Applicable)**
  - o Description of tarp removal (if different than in the FMP)
  - o Date tarps were perforated
  - o Date tarps were removed
- **Complaint Details (if Applicable)**
  - o Person filing complaint (e.g., on site handler, person off site)
  - o If off site person filing complaint
    - Name
    - Address
    - Phone number
  - o Description of control measures or emergency procedures followed after complaint
- Description of incidents, equipment failure, or other emergency and emergency procedures followed (if applicable)
- **Details of Elevated Air Concentrations Monitored On Site (if Applicable)**
  - o Location of elevated air concentration levels
  - o Description of control measures or emergency procedures followed
  - o Air monitoring results
    - When sensory irritation experienced:
      - Date and time of sensory irritation
      - Handler task/activity
      - Handler location where sensory irritation was observed
      - Resulting action (e.g., cease operations, continue operations with air-purifying respirators)
    - When using a direct read instrument:
      - Sample date and time
      - Handler task/activity
      - Handler location
      - Air concentration
      - Sampling method
- **Date of Fumigant Treated Area Sign Removal**
- **Any Deviations From the FMP**
- **Recordkeeping Procedures**
  The owner/operator of the application block as well as the certified applicator must keep a signed copy of the post-application summary for two years from the date of application.

Entry Restricted Period and Notification Requirements

Entry Restricted Period

Entry (including early entry that would otherwise be permitted under the WPS) by any person – other than a correctly trained and PPE-equipped handler who is performing a handling task listed on this label – is **prohibited** from the start of the application until:

- 5 days (120 hours) after the application is complete for untarped applications or
- 5 days (120 hours) after the application is complete if tarps are not perforated and removed for at least 14 days following application. **Note:** Persons installing, repairing, or monitoring tarps are handlers until 14 days after the application is complete if tarps are not perforated and removed during those 14 days, or
- 48 hours after tarp perforation is complete if tarps will not be removed for at least 14 days following application or
- tarp removal is completed if tarps are both perforated and removed less than 14 days after application

Note: See Tarp Perforation and/or Removal section fon this labeling about when tarps are allowed to be perforated.

Notification Requirements

Notify workers of the application by warning them orally and by posting Fumigant Treated Area signs. The Fumigant Treated Area signs must bear the skull and crossbones symbol and state:

- "DANGER/PELIGRO"
- "Area under fumigation, DO NOT ENTER/NO ENTRE"
- "1,3-dichloropropene and chloropicrin fumigants in use"
- The date and time of fumigation
- The date and time entry prohibition period is over
- Telone C-17
- Name, address, and telephone number of the certified applicator in charge of the fumigation.

Post the Fumigant Treated Area sign instead of the WPS sign for this application, but follow all WPS requirements pertaining to location, legibility, size, and timing of posting and removal. Post the Fumigant Treated Area sign at all entrances to the application block (i.e., field or portion of a field treated with a fumigant in any 24-hour period).

Application Directions

Buffer Zone

An application of Telone C-17 shall not be made within 100 feet of an occupied structure, such as a school, hospital, business or residence. No person shall be present at this structure at any time during the seven consecutive day period following application. **This buffer zone does not apply to use on soils that will not experience an additional 1,3-D treatment for at least three years, for example, on soils to be planted with fruit trees, nut and nursery crops, perennial vines, hops, mint or pineapple. Note:** Telone C-17 shall not be applied to soils more frequently than once each year.

Uses

Control of Nematodes

Use Telone C-17 for control of nematodes and symphylans, management of soil diseases, and suppression of wireworms in soils to be planted to vegetable crops, field crops, fruit and nut crops, nursery crops and mint.

Table 1. Broadcast Application Rates for Nematodes, Symphylans, Wireworms, and Certain Soil Borne Diseases

		Broadcast Application Rates[1] (Gallons/Acre)	
Crops	**Soil Type**	**Untarped Shank Injection**	**Tarped Shank or Untarped Deep (18" Minimum) Shank Injection**
vegetable crops	mineral muck or peat	10.8 to 17.1[3] 27.4[4] to 30	
potato[2, 3] and onion[2]	mineral muck or peat	18 to 27.5[2] 30	
field crops[5]	mineral muck or peat	10.8 to 17.1[3] 21.6	
fruit and nut crops[6,7] including strawberries	mineral, muck, or peat	32.4 to 37	32.4 to 42
nursery crops	mineral, muck, or peat	---	50.4 to 66
mint	mineral, muck, or peat	27.5	

Note: For control of symphylans (garden centipedes) or suppression of wireworms, consult the Soil Insects section below for more specific directions and application rates.

[1] Rates given may be concentrated in the row, but in no case shall the amount applied per acre exceed the maximum broadcast application rates [gallons per acre (gpa)] given in Table 1.

[2] Potatoes and onions: To control root knot nematode and suppress wireworms in mineral soils, apply Telone C-17 at the rate of 24 gpa. To control northern root knot nematode in mineral soils, apply Telone C-17 at the rate of 18 to 21 gpa. To control stubby root nematode in mineral soils, apply Telone C-17 at the rate of 27.5 gpa. For best results, apply the fumigant consistently at least 18 inches below the final soil/air interface.

Preharvest soil sampling and preharvest tuber sampling is recommended to detect developing nematode populations or early tuber infection.

There are a range of soil conditions under which Telone C-17 can be applied. Within that range, product performance will improve as the soil condition moves toward optimum. Using Telone C-17 under soil conditions outside the range will yield less than satisfactory performance.

[3] Potatoes: Before fumigation, soil sampling for the type and number of pests present is recommended and can help to determine the need for additional treatment with a contact nematicide. Preharvest tuber

sampling for nematodes also is recommended. For best timing and sampling methods, consult a local extension service agent, pest control advisor, or Dow AgroSciences representative for assistance. If the nematode population is high enough to damage the crop, the potatoes can be havested early. Fumigation cannot be expected to eradicate the entire pest population. Therefore, post-treatment and preplant soil sampling is recommended to determine the need for additional pest population control or other management practices. Do not store potatoes with a detectable nematode infestation. Row treatment is not recommended for potatoes in irrigated areas of western and northwestern states. Do not use plow-sole application.

Using Telone C-17 does not guarantee pest-free potatoes at harvest. Using Telone C-17 according to use directions will control only the nematode populations present within the fumigated zone at the time of fumigation. The fumigated zone can vary depending upon a number of factors such as fumigant rate, application methods used, depth of application, soil moisture, soil type, soil temperature and soil tilth (including soil compaction and soil porosity). Telone C-17 will not control or prevent reinfestation subsequent to treatment. Subsequent pest populations may infest the fumigated zone from irrigation water, equipment or other sources of contamination, or may invade the fumigated zone from surrounding untreated soil such as from beneath the fumigated zone or from unfumigated pockets within the fumigated zone.

Do not plow the ground in the spring in such a way that inverts the soil prior to a spring fumigation. Conduct such tillage operations in the fall to allow winter kill of residual nematode populations in the top 1 to 2 inches of the soil profile. A cover crop, such as wheat or grass, can be planted to reduce the potential for soil erosion following a fall soil fumigation and undisturbed soil interval.

[4] When using the coulter system (e.g., Yetter 30-inch Avenger) in moderate to heavy disease pressure, use the maximum rate of Telone C-17 followed by chloropicrin in-bed. Consult your local certified dealer for rate recommendations.

[5] For muck soils containing less than 30% organic matter use 21.6 gpa. **In New York:** for high organic matter soils, use up to 41 gpa.

[6] Citrus Fruits: For burrowing nematode control, inject Telone C-17 on 18-inch centers at least 12 inches deep. For buffers within existing groves or for tree planting sites within existing groves, do not apply within 5 feet of living trees. Keep the field free of plants susceptible to burrowing nematodes for 2 years before replanting to citrus.

[7] Tree Planting Sites in the U.S. use 31 fl oz of Telone C-17.

Control of Soil Insects

Symphylans (Garden Centipedes): Use Telone C-17 for treatment of soil to be planted to crops where these pests have been shown to be a problem. Apply the fumigant only as a broadcast treatment at the rate of 21.6 to 42 gpa. For best results, apply during late summer or early fall when the soil is warm.

Wireworms: Use Telone C-17 for treatment of soil to be planted to crops where these pests have been shown to be a problem. Apply the fumigant as a broadcast treatment at 24 gpa by injection at least 18 inches below the final soil surface.

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Produced for
Dow AgroSciences LLC
9330 Zionsville Road
Indianapolis, IN 46268

Label Code: D02-015-021
Replaces Label: D02-015-020
LOES Number: 010-00016

EPA accepted 05/13/10

Revisions:

1. Added PPE requirements.
2. Added requirements for use in enclosed cabs.
3. Added sections for fumigation handlers; protection for handlers; application requirements; mandatory good agricultural practices; site specific fumigant management plan; entry restricted period and notification requirements; and compatible materials.
4. In rate table added potato, onion, strawberries and mint.

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November 21, 2008

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Ref: 24(c) label for Proline®to control Pitch Canker and Rhizoctonia Foliar Blight in southeastern US forest tree nurseries.

Dear Ms. Aschbrenner,

This letter is divided into the following sections:

1. Background on the requesting organization: Southern Forest Nursery Management Cooperative
2. 24-C request and supporting data for the use of Proline on loblolly, longleaf, slash and shortleaf pine to control Pitch Canker.
3. 24-C request and supporting data for the use of Proline on loblolly and longleaf pine to control Rhizoctonia Foliar Blight.

Our future intent is to seek full registration for the use of Proline to control Pitch Canker, Rhizoctonia Foliar Blight and Fusiform Rust on loblolly, longleaf, slash and shortleaf pine. However, due to the extraordinary lab, greenhouse and field test results with Proline, this 24(c) request will help to control these nursery diseases in the immediate future.

I have indicated Priority 1 and Priority 2 States. Priority 1 States can have significant losses yearly and are our major concern. Priority 2 States had significant losses when environmental factors are optimum for disease development.

1. The Southern Forest Nursery Management Cooperative

The Southern Forest Nursery Management Cooperative, headquartered in School of Forestry & Wildlife Sciences at Auburn University currently has 16 members: 4 forest industries, 8 state forestry organizations, 3 private nurseries, and the U.S. Forest Service. Together, the Cooperative membership produces approximately 82% of the 1 billion tree seedlings grown in the southern United States. The Nursery Cooperative's mission is to develop and disseminate cultural, biological and chemical technologies in an integrated system for the economical production and utilization of forest tree seedlings in the southern United States. The Nursery Cooperative's research is in both pest management and seedling quality issues, with an increased emphasis on the environmental impact of pesticides and fertilizers in nurseries, hardwood culture, and the integration of nursery practices with site preparation and post-outplanting operations. The Nursery Cooperative also represents the forest tree nursery community of the South to the EPA and USDA regarding policy and regulatory decisions that affect the nursery business. This includes the re-registration and labeling of pesticides for Nursery use and the Critical Use Exemption for Methyl Bromide. The Nursery Cooperative represents nurseries in Virginia, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Arkansas and Texas.

2. 24(c) request for the use of Proline®on Loblolly, Longleaf, Slash and Shortleaf pine to control Pitch Canker. For the States:

Priority 1 States: Georgia, Mississippi, South Carolina, North Carolina, Arkansas

Priority 2 States: Virginia, Tennessee, Alabama, Louisiana, Texas

Pitch canker, caused by *Fusarium circinatum* is considered by some to be the most threatening disease in the world (Dwinell et al 1985). Pitch Canker is the limiting disease in South African nurseries (Storer et al 1998, Vilijoen and Wingfield 1994). In California, it has caused significant losses on Monterey Pine (Correll et al 1991). In the southern US, *Fusarium circinatum* attacks Loblolly (*Pinus taeda*), Slash (*P. elliotti*), Longleaf (*P. palustris*) and Shortleaf pine (*P. echinata*) (Carey and Kelley 1994, Dwinell 1978, Barrows-Broaddus and Dwinell 1984, Blakeslee and Rockwood 1984, Lowerts et al. 1985, Kelley and Williams 1982, Dwinell and Barrows-Broaddus 1981). Pitch canker has been reported on 47 pine species worldwide, and thus en ever-increasing economically important disease (Enebak and Carey 2003). **There are no registered fungicides for the control of Pitch Canker on nursery stock.** Although the genera, *Fusarium* is listed on many fungicide labels efficacious control for *Fusarium circinatum* has not been found. The Southern Forest Nursery Management Cooperative research outlined below shows that Proline provides efficacious, fungicidal control of this fungus.

Study 1: Efficacy of Proline® in the Laboratory. Two fungicides, Proline® and Pagaent® (BASF) were evaluated to determine if *Fusarium circinatum* was able to grow on agar media amended with three concentration levels. Labels of both fungicides report activity against *Fusarium* spp. The active ingredient of fungicides and the rates of each fungicide used in the study are shown in Table 1.

Table 1 Fungicides, active ingredients and rates used in study

Fungicide	Active Ingredient	Rate
Proline 480 SC®	Prothioconazole – 41%	1x – 5 fl oz/a based upon 30 g water/a 0.5x – 2.5 fl oz/a 0.25x – 1.25 fl oz/a
Pagaent®	Pyraclostrobin 12.8% Boscalid 25.2%	1x – 14 oz/100 gal 0.5x – 7 oz 0.25 – 3.5 oz

Potato Dextrose Agar (Difco® PDA) was amended with each fungicide rate after autoclaving and just before pouring the plates. There were 20 plates of each fungicide concentration plus 20 non-amended PDA plates as a control. A #4 cork borer (~8mm) plug of *Fusarium circinatum* from a two week old culture was placed at the center of each plate. The radial growth of the fungus was measured in one direction over a period of 10 days. To determine if the treatments were fungicidal (killed the fungus) or fungistatic (stopped fungal growth), 11 days after placing onto the media, the agar plugs within each treatment were removed from the amended agar media onto non-amended media. Fungal growth was recorded for five days.

S**tudy 1 Results and Discussion:** Fungal growth did not occur on any of the Proline ® amended PDA plates for any concentration examined for the 11 day trial (Figure 1). All three rates of Proline ® are indicated as the yellow line at -0 mm. On some Proline ® plates the fungus grew from the original plug for several mm, but never touched the amended PDA. The appearance was that of a mushroom cap suspended over the soil. *Fusarium circinatum* was inhibited and able to grow on all concentrations of Pageant ® tested. The levels of Pageant® are the three lines below the Control line, respectively. There were no significant differences between the concentrations of Pagaent ®. Fungal growth on the control plates was significantly greater than either Pagaent® or Proline®. The radial growth for each of the seven treatments is shown in Figure 2.

Figure 1. Representative plates of fungal growth from Control, Proline and Pageant treatments

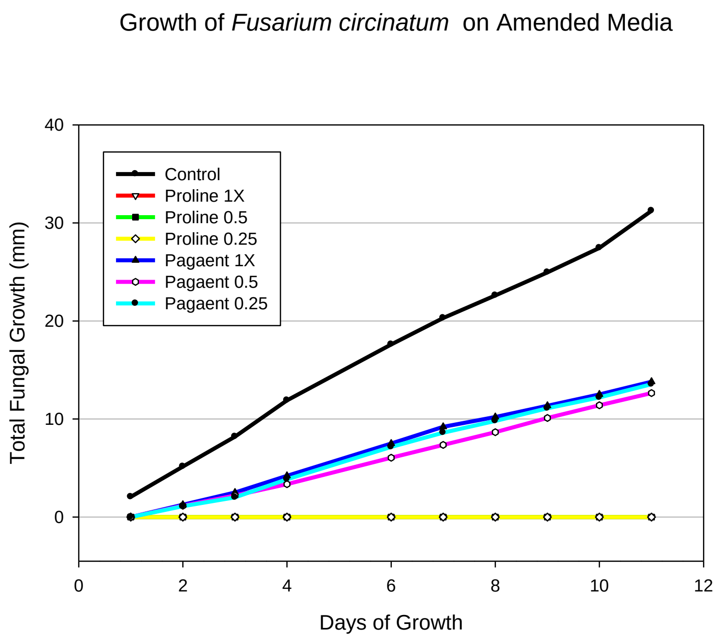
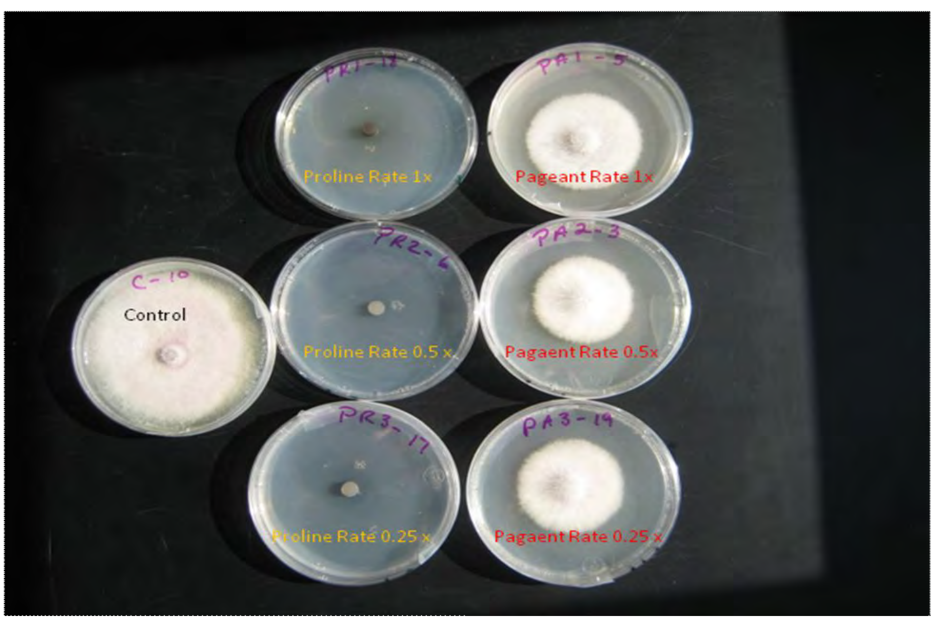
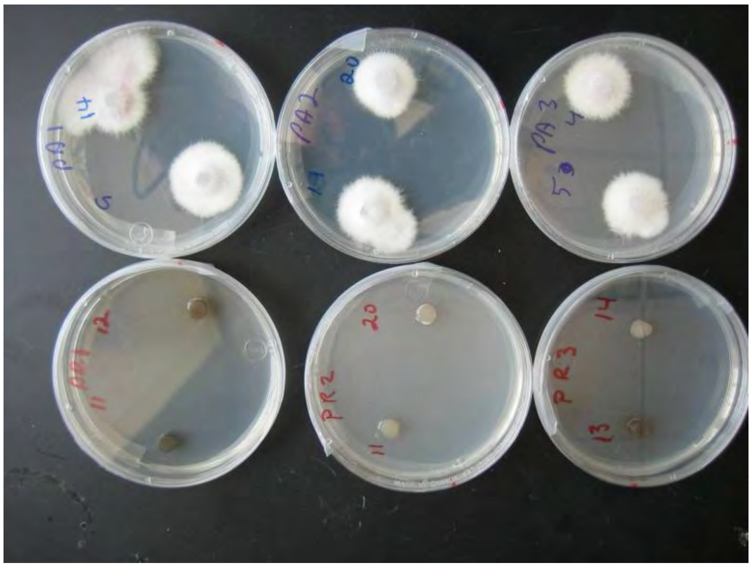


Figure 2. Radial growth of *Fusarium circinatum* on fungicide amended and non-amended agar.



After 11 days, the plugs were removed from the amended media and put onto non-amended agar media. This step was taken to determine if the fungicide was fungicidal (able to kill the fungus) or fungistatic (inhibited the growth). None of the agar plugs from the Proline® amended plates resumed fungal growth when returned to non-amended agar indicating that Proline® was fungicidal. However, agar plugs from the Pagaent® amended media did resume growth on the unamended agar indicating that Pagaent® was fungistatic (Figure 3).

Figure 3: Fungal plug growth on non-amended agar media indicating Proline (bottom three agar plates) to be fungicidal and Pageant (top three agar plates) to be fungistatic .



A supplemental study with Bayleton was conducted to see if it had any effect on the fungus responsible for pitch canker. A small agar-amended study was repeated as described above that used Bayleton® at label rate and one half label rate added to the agar media. In this trial, the pitch canker fungus *Fusarium circinatum* grew on the Bayleton amended plates at a similar rate to the Pagaent®. Therefore Bayleton® was fungistatic to *Fusarium circinatum* and not fungicidal, and would have some, but limited affect against the fungus.

Study 2: Efficacy of Proline® on Longleaf pine in the Greenhouse: Longleaf seed from a family n to have had Pitch Canker in the past was stratified for 10 days and sown in the greenhouse. While we were confident that the longleaf pine seed had *Fusarium circinatum* present on the seed, ensure disease and increase fungal pressure, an 8 mm agar plug from a two week old stock culture of *Fusarium circinatum* was added to ½ of the container cavities at the time of sowing. There were 20 container sets, each with 20 cavities for each treatment. The treatment and spray rate of Proline® are described in Table 2.

Table 2. Greenhouse Pitch Canker Study treatments and Proline®Rate

	Treatment	**Spray Rate**
1	Fungal plug , no Proline®	0
2	Fungal plug , Proline®	5.5 Fl oz/a
3	No fungal plug , no Proline®	0
4	No fungal plug Proline®	5.5 Fl oz/a

Following sowing and the addition of a fungal plug, treatments #2 and #4 were sprayed with Proline®. These treatments were sprayed every two weeks throughout the study. All cavities were covered with a thin layer of course perlite. Seedling counts were measured weekly for four weeks following germination and then one time per month until Oct. 2008. Samples of dead seedlings were taken to the laboratory to confirm the presence of *Fusarium circinatum.* Dead seedlings from treatment #1 and #3 tested positive for the fungus.

Study 2. Results and Discussion: The percent cavity fill by treatment for the longleaf pine is shown in Table 3. The percentage for no fungal plug and no Proline® treatment is what a nursery sowing this seed would expect to obtain. By week 18, the, no fungal plug with Proline® treatment, had 11% better cavity fill. The same relationship held with cavities that had a fungal plug added, for example, cavities with a fungal plug added and no Proline® had 69% fill at week 18 which was significantly less than cavities with no fungal plug and no Proline®. Cavities with a fungal plug and Proline® had 17% greater fill percentage than without Proline®.

It was also visually observed that the Proline® treatments produced larger longleaf seedlings. This was verified in height and top dry weights presented in Table 3. Proline® treatments had statistically larger top growth. It was difficult to evaluate if the root mass was different between Proline® and no Proline® treatments. Since these were container trees, it was very difficult to avoid losing root when trying to separate the root mass from the peat moss plug.

Table 3. Fill percentage and seedling quality data of Proline® study.

				Dry Weight	
	Proportion of Cavities Filled	Height (in)	RCD (mm)	Top (g)	Root (g)
Fungal Plug + Proline®	0.79 A	12.6 A	4.6 A	1.40 A	0.56 B
Fungal Plug No Proline®	0.62 C	11.1 B	4.7 A	1.23 B	0.64 A
No Fungal Plug + Proline®	0.80 A	12.5 A	4.7 A	1.42 A	0.58 AB
No Fungal Plug No Proline®	0.69 B	11.4 B	4.3 B	1.22 B	0.52 B
lsd	*0.07*	*0.5*	*0.2*	*0.11*	*0.07*

Figure 4. Typical early death of longleaf seed germinant from *Fusarium circinatum*. *Fusarium circinatum* was re-isolated from this germinant.

3. 24(c) request and supporting data for the use of Proline®on loblolly and longleaf pine to control Rhizoctonia Foliar Blight. For the States:

Priority 1 States: Mississippi, Georgia, South Carolina, North Carolina, Arkansas

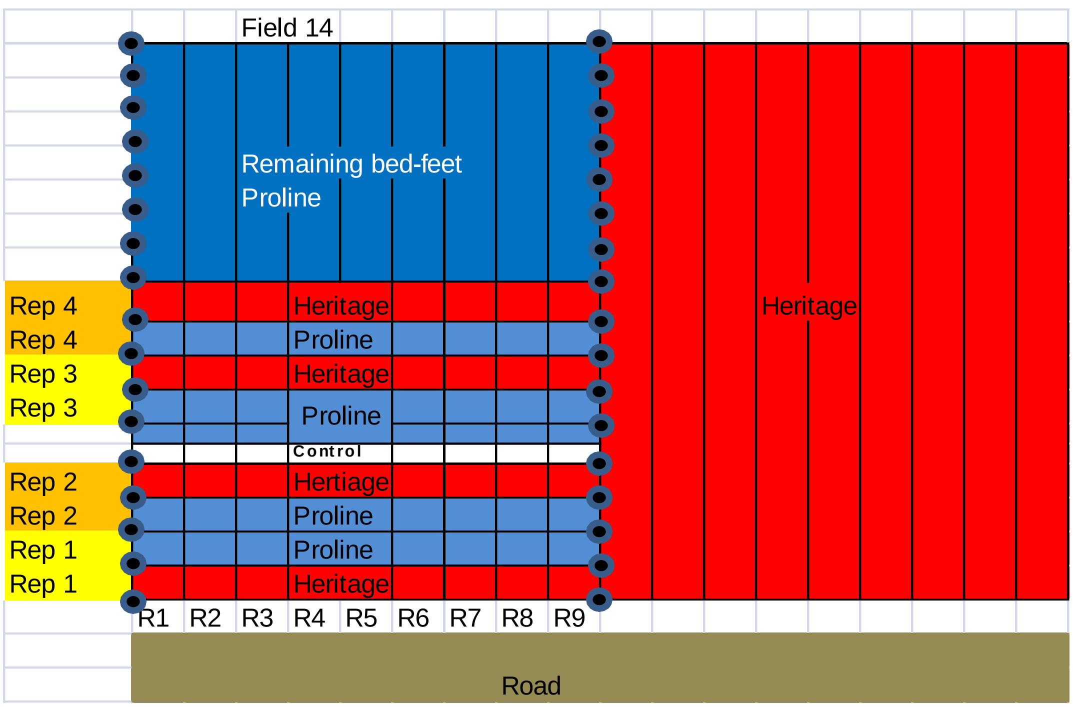
Priority 2 States: Virginia, Tennessee, Alabama, Louisiana, Texas

This request is based upon early field observations from a study which will not be completed until January 2009.

Both longleaf and loblolly pine seedlings are susceptible to foliage blight caused by a Rhizoctonia in the *Ceratobasidium anastomosis* group CAG-3 (English et al. 1986, Runion and Kelley 1993). In several longleaf nurseries prophylactic control measures must be practiced. Throughout the region, the disease occurs sporadically on loblolly pine (Runion and Kelley 1993) so that treatment is generally applied after symptoms are observed. However, when the seedling canopy closes in; there are extended periods of free moisture on the needles and the average daily temperature begins to drop below 90°F disease development can rapidly develop. In these nurseries, prophylactic control measures must be practiced to avoid significant seedling loss. This disease is many time difficult to see since it starts on the lowest needle in the center of the seedling bed and spreads up and outward. Usually it is first noticed when top clipping exposes disease foci.

Three fungicides (Iprodione, fludioxonil and azoxystrobin)have been found to be efficacious in controlling this disease (Cary and McQuage 2003). Of the three, azoxystrobin has shown the best results. However, when disease pressure is high and favorable environmental conditions exist, aroxystrobin is not effective (see photos below). **<u>The currently available fungicide do not provide efficacious control of Rhizoctonia Foliar Blight.</u>**

In 2008 at study was put in at the Plum Creek Nursery in Hazlehurst, MS. The following chemical treatments were used: **Proline**® - 41% prothioconazole – Bayer Cropscience @ 5.5 fl oz/ac – 2 wk intervals beginning July 15 and **Heritage**® - 50% azoxystrobin – Sygenta @ 24 oz/ac – 2 wk intervals beginning July 15. The study was designed as randomized block design with 4 replications (Figure 5). One 20' section in the center of the study was a non-sprayed control. Each chemical was applied to a 40'x58' plot using a Hardee 550 gallon sprayer with a 9 bed (58' long) spray boom with nozzles on 20" centers.



In late September visual evaluations of the study plots was made and are represented in the following photos:

Rhizoctonia Foliar Blight in a nursery bed sprayed with Heritage

Rhizoctonia Foliar Blight in Control plot

Rhizoctonia Foliar Blight in Heritage sprayed plot

Rhizoctonia Foliar Blight in Heritage sprayed plot

Proline® Sprayed Plot. **NOTE: Green needles to the ground which is rare to find this late in the season.**

Proline® provided efficacious control of Rhizoctonia Foliar Blight under heavy disease pressure and favorable environment. This same level of control was not achieved by the currently best registered fungicide.

Supplemental Information of Proline:

We have been testing prothioconazole for 2 years (Provost 2007, Proline® 2008) for the control of fusiform rust caused by *Cronartium quercum f.sp. fusiforme.* Pine seedlings cannot be grown without fungicides to control this disease. Currently Bayleton is used by 99.9% of forest tree nurseries. Our research to date has shown that Proline® provides efficacious control of fusiform rust. We are currently collecting lab and field data in view of a possible full registration for this disease.

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Resistance to QoI Fungicides in *Ascochyta rabiei* from Chickpea in the Northern Great Plains

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ABSTRACT

Wise, K. A., Bradley, C. A., Pasche, J. S., and Gudmestad, N. C. 2009. Resistance to QoI fungicides in *Ascochyta rabiei* from chickpea in the Northern Great Plains. Plant Dis. 93:528-536.

Ascochyta blight, caused by *Ascochyta rabiei* (teleomorph: *Didymella rabiei*), is an important fungal disease of chickpea (*Cicer arietinum*). A monitoring program was established in 2005 to determine the sensitivity of *A. rabiei* isolates to the QoI (strobilurin) fungicides azoxystrobin and pyraclostrobin. A total of 403 isolates of *A. rabiei* from the Northern Great Plains and the Pacific Northwest were tested. Ninety-eight isolates collected between 2005 and 2007 were tested using an in vitro spore germination assay to determine the effective fungicide concentration at which 50% of conidial germination was inhibited (EC_{50}) for each isolate–fungicide combination. A discriminatory dose of 1 µg/ml azoxystrobin was established and used to test 305 isolates from 2006 and 2007 for in vitro QoI fungicide sensitivity. Sixty-five percent of isolates collected from North Dakota in 2005, 2006, and 2007 and from Montana in 2007 were found to exhibit a mean 100-fold decrease in sensitivity to both azoxystrobin and pyraclostrobin when compared to sensitive isolates, and were considered to be resistant to azoxystrobin and pyraclostrobin. Under greenhouse conditions, QoI-resistant isolates of *A. rabiei* caused significantly higher amounts of disease than sensitive isolates on azoxystrobin- or pyraclostrobin-amended plants. These results suggest that disease control may be inadequate at locations where resistant isolates are present.

Ascochyta blight, caused by the fungus *Ascochyta rabiei* (Pass.) Labr. (teleomorph: *Didymella rabiei* (Kovacheski) v. Arx.), is an important disease of chickpea (*Cicer arietinum* L.) throughout the world (22). *A. rabiei* can infect chickpea at all stages of plant phenology and can cause over 50% yield reduction under conditions favorable for disease development (13,17). Within the United States and Canada, Ascochyta blight epidemics are common, making it the most important disease of chickpea in these regions (8,13).

Management of Ascochyta blight requires an integrated approach that includes crop rotation and burial of debris from the previous crop to reduce overwintering inoculum. Chickpea cultivars with moderate levels of resistance are available for use, but none have complete resistance to the dominant pathotype of *A. rabiei* in the United States (8,10,32). Current resistance levels are often insufficient to prevent disease development and economic loss in the Northern Great Plains (15). Fungicide seed treatments are used to control seed-borne *A. rabiei* (29), and several applications of foliar fungicides often are required in the Northern Great Plains of the United States and in the Canadian prairies to manage Ascochyta blight (7).

Chlorothalonil and maneb are fungicides with multi-site mode of action and broad-spectrum protectant activity, and are typically applied prior to flowering to delay the onset of Ascochyta blight. However, once blight symptoms are present, applications of chlorothalonil or maneb alone do not control disease, forcing producers to employ fungicides with both pre- and post-infection modes of action (11,13). Prior to 2007, only two classes of fungicide chemistry with post-infection activity were registered for control of Ascochyta blight on chickpea in the United States: the quinone outside inhibitor (QoI) class (azoxystrobin and pyraclostrobin) and the carboximide class (boscalid). In 2002, the United States Environmental Protection Agency (EPA) granted a section 18 emergency exemption for use of azoxystrobin on chickpea to control Ascochyta blight in North Dakota. In 2003, azoxystrobin, boscalid, and pyraclostrobin were granted full section 3 registrations on chickpea in the United States. In 2007, prothioconazole, a sterol-demethylation inhibitor (DMI) fungicide, was registered for the control of Ascochyta blight. All of these fungicides have a single-site mode of action and are at risk for fungicide resistance development.

Currently, of these fungicides, QoI fungicides play an important role in management of Ascochyta blight. These fungicides inhibit mitochondrial respiration by binding to the center of the Qo site of the cytochrome bc_1 complex (complex III) on the positive side of the inner mitochondrial membrane (4,5). While this class of fungicides is extremely effective at managing a broad range of diseases on many crops, the site-specific mode of action may increase the potential for selection of resistant mutants of fungal pathogens (3). QoI fungicide resistance was first reported in *Erysiphe graminis* on wheat just 2 years after the class was registered for use in Europe (4).

Since 1998, field resistance to QoI compounds has been documented for important pathogens of horticulture and field crops (1–4,14–16,19,22,25,30,31,35). Until recently, the mechanism of resistance has been attributed to single-point mutation resulting in amino acid substitution at one of two positions in the cytochrome b gene. In the majority of pathogens, glycine is replaced by alanine at codon 143 (G143A), resulting in expression of resistant phenotypes (3,5,12,14,16,18,19,34), while a second mutation results in a phenylalanine to leucine change on amino acid 129 (F129L), and is found in *Pyricularia grisea* (19), *Pyrenophora tritici-repentis* and *Pyrenophora teres* (27), and *Alternaria solani* (23). In 2007, a third cytochrome b mutation resulting in a glycine to arginine change at amino acid position 137 was reported. This G137R mutation has recently been observed in two isolates of *Pyrenophora tritici-repentis* (27). The type of mutation present in a fungal population greatly influences the level of disease control obtained with QoI fungicide applications (14,23,27). Fungal isolates with the G143A mutation typically have complete resistance, meaning that applications of all QoI fungicides are ineffective at controlling disease (14). The presence of the F129L or G137R mutation results in reduced sensitivity and levels of disease control obtained by QoI fungicide applications (19,23,24,27).

Since the registration of QoI fungicides for use on chickpea in 2003, fungicide applications in North Dakota for Ascochyta blight control have relied almost

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exclusively on fungicides within the QoI class. Applications of fungicides with post-infection activity typically begin when disease is first observed in a field, and continue on a 10- to 14-day schedule until conditions are no longer favorable for disease development. In the Northern Great Plains, favorable environmental conditions can often persist throughout the growing season, and in some instances up to six sequential applications of QoI fungicides have been made to a chickpea field in a single growing season. Ascochyta blight is a polycyclic disease (29), and the continuous use of QoI fungicides in this region increases the frequency of selection and pathogen population exposed to this fungicide class during a growing season, potentially contributing to the development of fungicide resistance. QoI-resistant isolates of *A. rabiei* have been identified through in vitro testing in Canada since 2004 (7,15), and the risk of fungicide resistance development in the Northern Great Plains populations is high. In 2006, anecdotal reports from chickpea producers in western North Dakota indicated that applications of QoI fungicides were not providing adequate control of Ascochyta blight.

Because of the nearly exclusive use of this chemistry, the limited number of fungicide chemistries with different modes of action, the identification of resistance in Canada, and anecdotal reports of reduced fungicide efficacy in North Dakota, QoI resistance development for *A. rabiei* has been identified as a major concern in the Northern Great Plains region. Baseline sensitivity of *A. rabiei* to azoxystrobin and pyraclostrobin was determined in a previous study (33), facilitating the development of a regional fungicide sensitivity monitoring program. The overall objectives of this study were to (i) determine if a shift in sensitivity to QoI fungicides has occurred in the North Dakota *A. rabiei* population, (ii) establish an in vitro single discriminatory dose testing method using azoxystrobin, and (iii) determine if isolates exhibiting in vitro QoI fungicide resistance were controlled less by QoI fungicides in vivo using greenhouse experiments.

MATERIALS AND METHODS

Collection of *A. rabiei* isolates. Isolates of *A. rabiei* were obtained from chickpea production fields in North Dakota receiving QoI fungicide applications during 2005, 2006, or 2007. Chickpea plants with symptoms of Ascochyta blight were sampled on a cross-diagonal transect pattern (‘X’), with samples taken at set intervals of approximately 15 m. Isolates also were obtained from diseased chickpea in research plots located at North Dakota State University Research Extension Centers in Hettinger, Minot, and Williston, ND. Disease samples were bulked by field or research plot and returned to the laboratory for isolation. Additional isolates were recovered from infected plant material from South Dakota and Nebraska from Martin Draper (South Dakota State University, Brookings) and Robert Harveson (University of Nebraska, Scottsbluff) in 2005 and Mary Burrows in Montana (Montana State University, Bozeman) in 2006 and 2007. Isolates were obtained from Idaho and Washington in 2005 from the *A. rabiei* culture collection of Weidong Chen at the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) in Pullman, WA.

Isolates of *A. rabiei* tested for in vitro fungicide sensitivity screening were obtained by cutting symptomatic chickpea stems into 2- to 3-cm sections. Stem sections were placed in a 95% ethanol solution for 1 min, followed by a rinse in sterile distilled water (SDW) for 1 min followed by 0.5% NaOCl solution for 1 min, and rinsed again for 1 min in SDW. Sterilized stem sections were air-dried in a laminar flow hood for 30 s on autoclaved paper towels and placed on potato dextrose agar (PDA) (Difco Laboratories, Detroit, MI) amended with 10 mg/liter streptomycin sulfate (Sigma-Aldrich, St. Louis, MO) in petri plates. Conidial and mycelial growth was observed from plated stem sections after 3 to 6 days of incubation at 20°C under a diurnal cycle of cool white fluorescent light (12 h light followed by 12 h dark). The presence of *A. rabiei* was confirmed by microscopic observation of conidia at ×100 magnification. An individual conidium from each sterilized stem section was considered a distinct isolate, and was incubated on fresh PDA under the conditions previously described. Single-spore isolates were stored for short-term use (up to 6 months) by removing three to four 0.25-cm-diameter plugs of agar covered with sporulating growth from each 14-day-old culture and placing plugs in a 1.5-ml centrifuge tube with 1 ml of SDW. Tubes were sealed with Parafilm and stored at 4°C. Isolates were preserved for long-term storage as conidia and mycelia on sterile filter paper at –20°C (33).

In vitro fungicide sensitivity assay. Fungicide sensitivity to azoxystrobin and pyraclostrobin was determined in vitro for 98 isolates of *A. rabiei* collected from 2005 to 2007 using previously published methods (33) (Table 1). Stock solutions of technical grade formulations of azoxystrobin (97.6% active; Syngenta Crop Protection, Greensboro, NC) and pyraclostrobin (99% active; BASF Corporation, Research Triangle Park, NC) were prepared at concentrations of 100 mg/ml and diluted serially in acetone. Fungicide sen-

Table 1. Collection information and results of in vitro *Ascochyta rabiei* isolate sensitivity assays to azoxystrobin and pyraclostrobin in 2005, 2006, and 2007

Collection location by county	Number of isolates	EC_{50} (μg/ml)[a] Azoxystrobin Range	Pyraclostrobin Range
2005			
North Dakota			
Cass	2	0.033-0.034	0.0032-0.0039
Foster	5	0.030-0.039	0.0019-0.0101
Ward	7	0.026-19.0	0.0035-0.5473
Total	14	0.026-19.0	0.0019-0.5473
South Dakota	1	0.032	0.0037
Nebraska	1	0.033	0.0043
Idaho	1	0.033	0.0044
Washington	2	0.031-0.032	0.0077-0.0182
Overall total	19	0.026-19.0	0.0019-0.5473
2006			
North Dakota			
Cass	4	3.81-5.82	0.2100-2.730
Foster	3	0.030-16.2	0.0027-2.400
McClean	5	5.87-29.0	2.380-3.233
Mountrail	8	3.22-25.7	0.3470-3.090
Renville	10	5.68-16.5	0.3710-3.145
Ward	17	0.032-32.4	0.0029-2.970
Williams	1	5.94	0.5900
Total	48	0.030-37.7	0.0027-3.233
Montana	1	0.032	0.0032
Overall total	49	0.030-37.7	0.0027-3.233
2007			
North Dakota			
Adams	1	3.40	2.927
Hettinger	1	0.032	0.0030
McClean	6	3.30-31.9	2.740-3.549
Mountrail	5	0.029-28.4	0.0034-3.613
Williams	17	0.032-32.4	0.0030-3.780
Total	30	0.029-32.4	0.0030-3.780

[a] Fungicide sensitivity was determined by calculating the mean effective fungicide concentration inhibiting spore germination by 50% of the nontreated control (EC_{50} value; μg/ml).

sitivity was determined for 2005 and 2006 isolates by evaluating *A. rabiei* conidial germination on PDA amended with 0, 0.001, 0.01, 0.1, 1, 10, and 100 µg/ml of each fungicide. Sensitivity of isolates collected in 2007 was determined on azoxystrobin-amended PDA at concentrations of 0, 0.01, 0.1, 1, 10, and 100 µg/ml and pyraclostrobin-amended PDA at 0, 0.001, 0.1, 1, and 10 µg/ml. Salicylhydroxamic acid (SHAM; Sigma-Aldrich) was dissolved in methanol and added to all fungicide-amended media at a concentration 100 µg/ml to minimize the effects of the alternative oxidative pathways that some fungi use to overcome QoI fungicide toxicity in fungicide sensitivity assays in vitro (4,9,33). *A. rabiei* is able to use this alternative pathway in the presence of QoI fungicides, and SHAM has been determined to have no effect on conidial germination (33). In all experiments, the 0 µg/ml treatment served as a control and was amended with 100 µg/ml SHAM, 1 ml of acetone, and 1 ml of methanol per liter.

A. rabiei isolates in all experiments were prepared using previously reported methods (33). Briefly, a conidial suspension was obtained by adding sterile 0.05% Tween 20 (Sigma-Aldrich) solution in water and dislodging conidia of a 7-day-old culture of *A. rabiei* with a sterile glass rod. The concentration of the conidial suspension for each isolate was determined with the aid of a hemacytometer, adjusted to 2×10^5 conidia/ml, and 100 µl of the suspension was pipetted onto each of two replicate petri plates (60 × 15 mm). Plates were incubated at 20°C for 18 h in the dark, and subsequently examined at ×100 magnification under a compound microscope. Percent germination was recorded for at least 100 conidia per isolate. A conidium was considered germinated if the germ tube was at least as long as the conidium (33). Percent conidial germination was converted into percent inhibition calculated as 100 – [(% germination of fungicide-amended media/mean % germination of nonamended control) × 100]. From this, EC_{50} values (the fungicide concentration that inhibits conidial germination by 50% of the nonamended control) for each isolate were calculated using a linear interpolation method (23,24,33). The resistance factor of individual isolates relative to sensitive isolates was calculated by dividing the EC_{50} value of individual isolates by the mean EC_{50} values of the baseline population to azoxystrobin (0.0272 µg/ml) and pyraclostrobin (0.0023 µg/ml) (33).

A. rabiei isolates were tested in groups with 5 to 12 isolates per group. In each group, at least one internal control isolate was included to ensure assay reproducibility (23,24,33,34,36). In the in vitro fungicide sensitivity trials conducted on 2005 *A. rabiei* isolates, a known QoI-sensitive isolate (AR666) was selected from the previously established baseline (33) to serve as an internal control; for those collected in 2006 and 2007, a QoI-resistant internal control isolate (06BWEF2-46) was also included. The internal controls were tested in five separate trials as described above, and the mean, standard error, and 95% confidence intervals were calculated based on the resulting EC_{50} values (33,34,36). If the internal control isolate EC_{50} values were within the previously determined 95% confidence intervals, trials were combined for statistical analysis. Only trials that satisfied the assay reproducibility requirements were included in analysis. Isolates were combined into a single experiment by year of isolate collection. Isolate EC_{50} values were analyzed using the general linear models (PROC GLM) in SAS (version 9.1, SAS institute, Inc., Cary, NC), following a completely randomized design. The experiment was repeated, and *F* tests were conducted to determine if variances were homogeneous ($P \leq 0.05$) between experiments. Correlation analysis was performed on EC_{50} values for azoxystrobin and pyraclostrobin using Pearson's correlation coefficient (PROC CORR). Mean EC_{50} values were compared using Fisher's protected least significant difference (LSD) test ($\alpha = 0.05$).

Establishment of a discriminatory dose system. Preliminary experiments to determine a discriminatory dose for screening *A. rabiei* fungicide sensitivity using azoxystrobin-amended media prepared at concentrations of 0, 0.1, and 1 µg/ml with 100 µg/ml SHAM were established as described above. *A. rabiei* isolates were prepared for testing and evaluated for percent germination as described above. Results of these experiments demonstrated that spore germination of sensitive isolates is completely inhibited at fungicide concentrations of 1 µg/ml, but resistant isolates had greater than 50% germination at the same fungicide concentration (*data not shown*). Based on these results, a discriminatory dose of 1 µg/ml of azoxystrobin was selected for testing an additional 22 isolates from 2006, and 283 isolates from 2007 for in vitro QoI fungicide sensitivity. Isolates were tested as described above in nine groups with 35 to 50 isolates per group. The internal control isolates previously tested were included in each group. Isolates were considered resistant to azoxystrobin if germination was greater than 50% at the discriminatory dose. Thirty arbitrarily selected isolates from 2007 were tested for azoxystrobin sensitivity using both the discriminatory dose method, and by calculating EC_{50} values using the procedures described above. This was done to validate discriminatory dose results by determining if isolates with high EC_{50} values had high germination rates on the discriminatory dose. The experiment was repeated, and percent germination values for each isolate were examined for statistical measures of dispersion and normality using PROC UNIVARIATE of SAS. Due to skewed, non-normal distributions of values, data were arcsine transformed and re-examined for normality. Because of the nature of the fungicide sensitivity response, transformation of percent values did not reduce skew, and distributions of discriminatory dose data were compared using the Kolmogorov-Smirnov two-sample test in SAS.

Effect of *A. rabiei* fungicide sensitivity on disease control on chickpea. Greenhouse trials were performed to determine the level of in vivo disease control attainable with QoI fungicides against isolates with differing QoI-sensitivities based on in vitro tests. Two QoI-sensitive *A. rabiei* isolates (JB9-5 and SHRF12) and three QoI-resistant isolates (BMXQ65, DF8, and H201-6) were included in the trial. QoI sensitivity of these five isolates was determined using the discriminatory dose of 1 µg/ml azoxystrobin described above. Conidia of each of the three QoI-resistant isolates had over 95% germination on the discriminatory dose of 1 µg/ml, while conidia germination of the two sensitive isolates was completely inhibited at the same dose (*data not shown*).

Methods established by Pasche et al. (23,24) were used as a basis for performing greenhouse experiments. Briefly, chickpea seeds (cv. Burpee) were sown in 473-ml plastic cups filled with Sunshine Mix 1 (Sun Gro Horticulture Inc., Bellevue, WA) and grown under 400 watt high-pressure sodium lamps set for an 18-h photoperiod, at 22 ± 2°C. Ten to 14 days after planting, chickpea plants were treated with commercial formulations of azoxystrobin (Quadris 2.08 SC; Syngenta Crop Protection) or pyraclostrobin (Headline, 2.09 EC; BASF Corporation) at concentrations of 0, 0.1, 1.0, 10, and 100 µg a.i./ml of water. Fungicides were applied to runoff using a CO_2-powered hand-held sprayer. Approximately 24 h after fungicides were applied, plants were inoculated with *A. rabiei* conidial suspensions prepared from 14-day-old cultures of selected sensitive and resistant isolates. Suspensions were adjusted to a concentration of 3×10^5 conidia/ml and applied to chickpea plants within an hour after preparation. Inoculum from each isolate was applied to plants using a hand-held airbrush paint sprayer connected to a vacuum pump (Welch Dry-Fast Vacuum Pump, Gardner Denver Inc., Niles, IL). Chickpea plants were placed in separate mist chambers by isolate and held at >95% relative humidity for 36 h at a 16-h photoperiod under artificial lighting before being placed in enclosed chambers on greenhouse benches. Chambers were constructed with 1-m-high polyethylene plastic barriers between plants inoculated with different isolates to reduce the potential for cross-contamination. After 10 days, disease severity for plants was visually assessed as the percent area infected of whole plant. The experiment was designed as a randomized complete block (RCB) with a split-plot arrangement. Isolate was considered as the whole plot factor and a factorial arrangement of fungicides and fungicide concentrations as the subplot. All main effects were considered fixed for the purpose of testing significance. Three replicates were included in each experiment, and the average disease severity was calculated for two plants from each experimental unit. Percent disease control was calculated by: [1 – (% diseased tissue/% disease on 0 μg/ml control)] × 100. The experiment was repeated, and *F* tests were conducted to determine if variances were homogeneous between the two greenhouse experiments. Data were converted to percent disease control to facilitate direct comparisons between sensitive and resistant isolates, and analyzed using PROC GLM in SAS. Mean percent disease severity and control were compared using Fisher's protected LSD test ($\alpha = 0.05$).

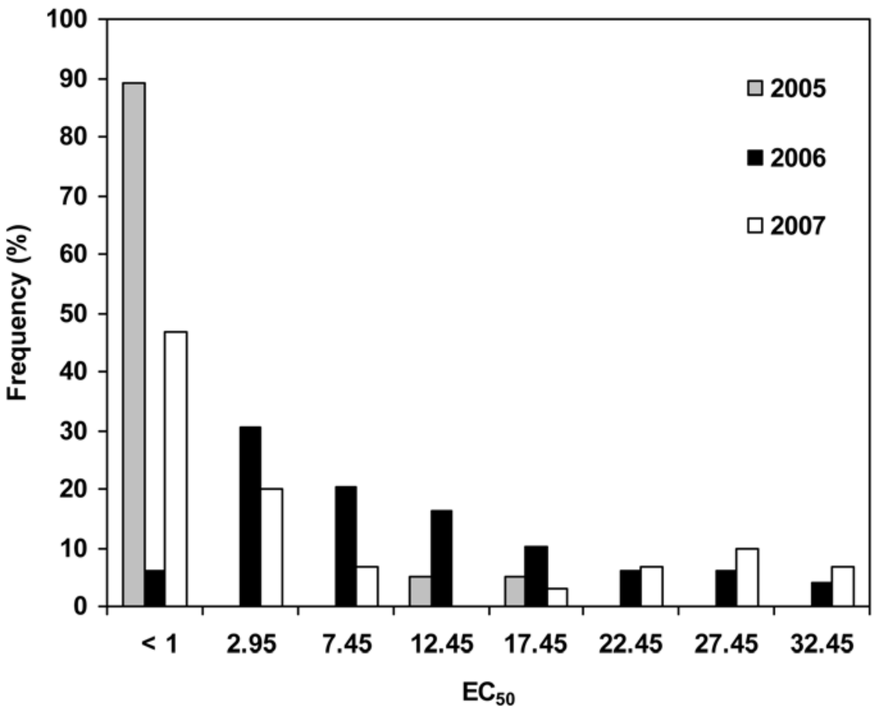

Fig. 1. Frequency distributions of effective fungicide concentrations that inhibited spore germination by 50% (EC_{50} value; μg/ml) for *Ascochyta rabiei* isolates to azoxystrobin in 2005 (n = 19), 2006 (n = 49), and 2007 (n = 30). Individual isolates are grouped in class intervals of 4.9 μg/ml; values on the x-axis indicate the midpoint of the interval.

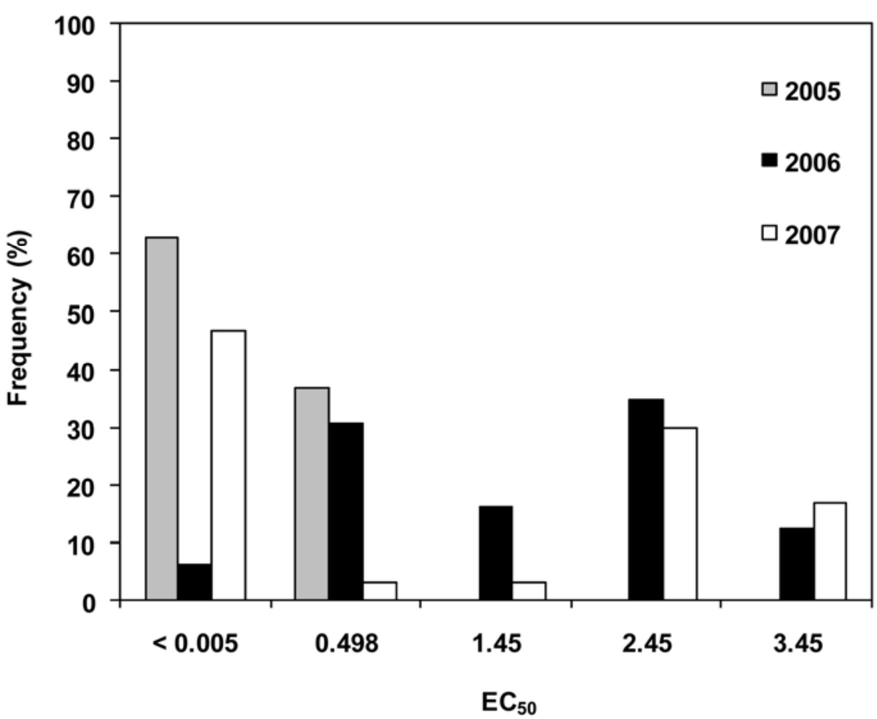

Fig. 2. Frequency distributions of effective fungicide concentrations that inhibited spore germination by 50% (EC_{50} value; μg/ml) for *Ascochyta rabiei* isolates to pyraclostrobin in 2005 (n = 19), 2006 (n = 49), and 2007 (n = 30). Individual isolates are grouped in class intervals of 0.9 μg/ml; values on the x-axis indicate the midpoint of the interval.

RESULTS

In vitro fungicide sensitivity assay. Independent analyses of variance of in vitro fungicide sensitivity experiments for pyraclostrobin and azoxystrobin EC_{50} values determined that error variances were homogenous (P = 0.05); thus, experiments were combined for further analysis. Frequency distributions of 19 *A. rabiei* isolates collected in 2005 demonstrated that 89 and 63% of isolates had EC_{50} values of less than 1 μg/ml and 0.005 μg/ml for azoxystrobin and pyraclostrobin, respectively (Figs. 1 and 2). These isolates were considered to be sensitive to the fungicides tested, and EC_{50} values of these isolates were comparable to previously established baseline values of 0.0272 μg/ml for azoxystrobin and 0.0023 μg/ml for pyraclostrobin (33). EC_{50} values for two 2005 isolates were well outside the range established by the baseline; they exhibited a 539-fold decrease in sensitivity to azoxystrobin and a 704-fold decrease in sensitivity to pyraclostrobin when compared to the mean sensitivity of baseline isolates. Conversely, in 2006 and 2007, 93.7 and 53.1% of *A. rabiei* isolates were determined to have EC_{50} values greater than 1 μg/ml and 0.005 μg/ml for azoxystrobin and pyraclostrobin, respectively (Figs. 1 and 2). Correlation analysis revealed a positive association between azoxystrobin and pyraclostrobin EC_{50} values (r = 0.66, P < 0.001, n = 98) (Fig. 3).

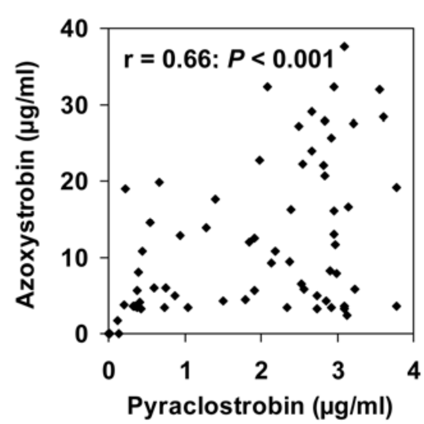

Fig. 3. Relationship between in vitro mean effective fungicide concentration that inhibited spore germination by 50% (EC_{50} value; μg/ml) for azoxystrobin and pyraclostrobin sensitivity of 98 *Ascochyta rabiei* isolates from 2005 to 2007.

Establishment of a discriminatory dose. Comparison of distributions of percent germination on the discriminatory dose of 1 μg/ml by the Kolmogorov-Smirnov two-sample test showed no significant differences between experiments (*KSa* = 1.143, *P* = 0.1466). The selected discriminatory dose of 1.0 μg/ml azoxystrobin was effective in determining the in vitro fungicide sensitivity of 30 isolates of *A. rabiei* from 2007 when compared to EC_{50} values generated for the same isolates, and a clear differential response in conidial germination was observed between QoI-resistant and -sensitive isolates (Fig. 4). Sixteen isolates with resistance factors of approximately 100-fold had a mean germination of 94.0% in the presence of 1 μg/ml azoxystrobin (Fig. 4). QoI-sensitive control isolates had less than 3% conidial germination on the discriminatory dose, with a mean of 0.3% conidial germination (Fig. 4). Discriminatory dose data from the 305 isolates collected in 2006 and 2007 determined that the frequency of azoxystrobin resistance in *A. rabiei* was over 60% in each year. These results are similar to the frequencies determined by EC_{50} values generated for isolates collected in those same years (Fig. 5).

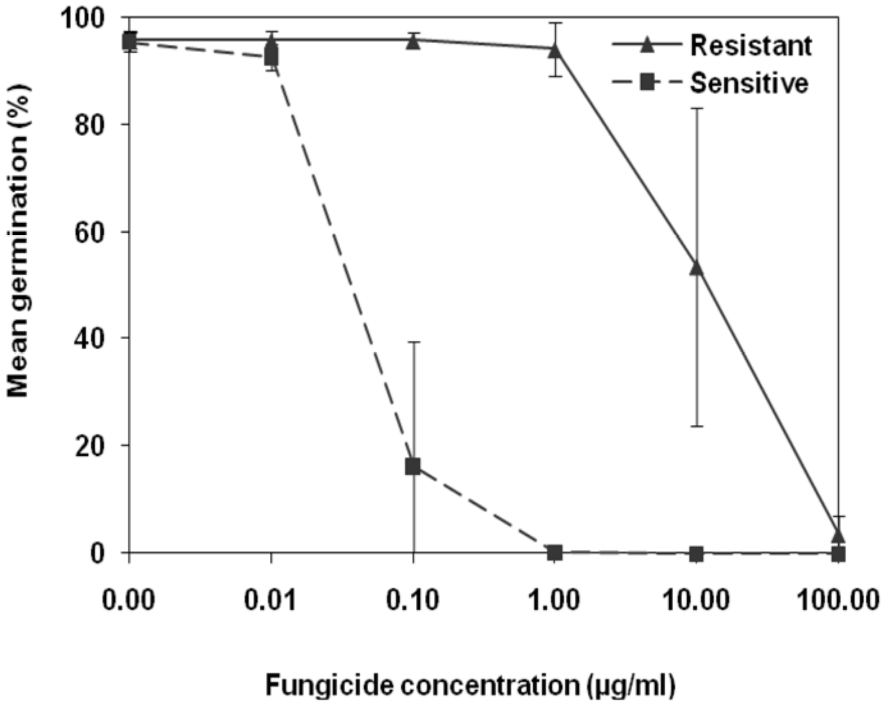

Fig. 4. Mean in vitro sensitivity of 16 QoI-resistant (—) and 14 QoI-sensitive (- - -) *Ascochyta rabiei* isolates from 2007 measured as mean percent germination on azoxystrobin-amended media at different fungicide concentrations (μg/ml) for determination of a discriminatory dose. Values include standard errors of percent germination.

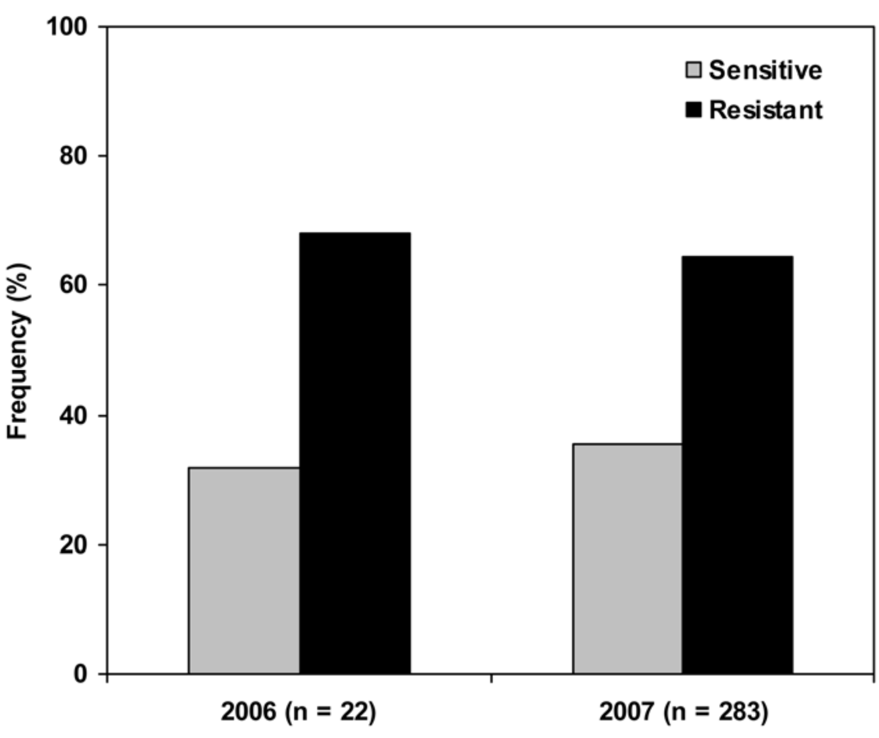

Fig. 5. Frequency of QoI-sensitive and resistant *Ascochyta rabiei* isolates in the Northern Great Plains as determined by a discriminatory dose of 1 μg/ml of azoxystrobin-amended media for isolates collected in 2006 (*n* = 22) and 2007 (*n* = 283).

QoI-resistant isolates (determined by EC_{50} values or discriminatory dose measurements) were present in only one of three counties sampled in North Dakota in 2005, in all seven counties sampled in 2006, and in seven of eight counties sampled in 2007. QoI-resistant isolates were detected in four of five counties sampled in Montana in 2007 (Tables 1 and 2).

Effect of *A. rabiei* fungicide sensitivity on disease control on chickpea. Independent analysis of disease control experiments determined that variances were homogenous, and experiments were combined for further analysis. Significant interactions were observed between the whole plot (isolate) and subplot factors (fungicide and fungicide concentration) ($P < 0.001$), as well as between the subplot factors of fungicide and fungicide concentration ($P < 0.001$) for percent disease severity and percent disease control of fungicides on Ascochyta blight–infected chickpea. Significant effects ($P < 0.001$) were also observed for isolate, fungicide, and level of fungicide concentration for both percent disease severity and percent disease control.

Disease severity was significantly greater on plants inoculated with QoI-resistant isolates at all concentrations of azoxystrobin and pyraclostrobin, including the nontreated control (0 μg/ml). QoI-sensitive isolates were completely controlled at concentrations of 10 and 100 μg/ml azoxystrobin and pyraclostrobin (Figs. 6 and 7). Disease control of QoI-resistant isolates was significantly reduced for azoxystrobin and pyraclostrobin when compared to QoI-sensitive isolates at all fungicide concentrations (Fig. 7). Pyraclostrobin provided significantly greater disease control of QoI-resistant isolates at concentrations of 100 μg/ml when compared to azoxystrobin. However, pyraclostrobin provided less than 65% disease control of QoI-resistant isolates, while 100% disease control of sensitive isolates was achieved at the same concentration (Fig. 7).

DISCUSSION

Resistance to QoI fungicides was observed in isolates of *A. rabiei* in North

Dakota in all years of collection and in Montana in 2007. In this study, only two *A. rabiei* isolates from one county were considered to be QoI-resistant in 2005, while in 2006 and 2007, QoI-resistant isolates were present at a higher frequency than sensitive isolates, and resistance was widespread across the sampling locations in North Dakota. With the continued application of QoI fungicides, it would not be expected for the frequency of resistant isolates to decrease slightly from 2006 to 2007, but differences among years can most likely be explained by the increase in the numbers of samples and sampling locations from 2006 to 2007.

When the monitoring program was established in 2005, isolates were available from a limited number of locations. Fungicide sensitivity monitoring was expanded in 2006 and 2007 to include a greater number of isolates from grower locations, which provided a more complete sensitivity distribution of the *A. rabiei* population in these areas. If the frequency of resistant isolates in a population is low at a given time and location, it is likely that a large number of isolates will need to be tested to detect fungicide resistance, especially if a loss in disease control has not been observed with a fungicide (26). Subsequently, it is difficult to determine if a pathogen population is truly sensitive to fungicides based on the EC_{50} values of one or a few isolates from a location, and we cannot accurately state that fungicide resistance did not exist in some locations sampled in the Northern Great Plains and the Pacific Northwest, since only a few samples were available for testing. This reinforces the need for adequate sample numbers in fungicide sensitivity monitoring programs, so that determination of isolate sensitivity, and consequently disease management recommendations, are based on adequate and representative data.

QoI sensitivity evaluations via the generation of EC_{50} values from percent conidial germination is considered to be a reliable and established method for determining fungicide sensitivity (24,35) and was utilized to develop the previously described baseline for *A. rabiei* to QoI fungicides (33). However, these methods are very time-consuming, especially considering the large number of samples that must typically be examined to detect the true level of resistance in a pathogen population (26). Fungicide sensitivity assays using a single discriminatory dose often are utilized where fungicide resistance has been identified in a pathogen population (21,25,34). An effective discriminatory dose is typically a fungicide concentration at which growth of sensitive isolates is mostly or completely inhibited and resistant isolates have greater than 50% growth. This screening method allows a large number of isolates to be rapidly and accurately assessed for fungicide resistance,

Table 2. Collection information and location of 2006 and 2007 *Ascochyta rabiei* isolates tested for in vitro QoI fungicide sensitivity using a discriminatory dose of 1 μg/ml azoxystrobin

Collection location by county	Number of locations sampled	Total number of isolates	Isolates with QoI resistance[a]
2006			
North Dakota			
McClean	1	4	0
Renville	2	11	11
Ward	1	5	3
Williams	1	2	0
Total	5	22	14
2007			
North Dakota			
Adams	1	12	12
Burke	2	22	22
Divide	3	17	17
Hettinger	1	4	0
McClean	3	27	27
Mountrail	2	25	8
Ward	1	16	16
Williams	11	144	66
Total	24	267	168
Montana			
Gallatin	1	2	2
Richland	1	2	2
Sheridan	2	9	8
Valley	1	2	0
Yellowstone	1	1	1
Total	6	16	13

[a] An isolate was considered resistant if mean conidia germination was >50% on the discriminatory dose.

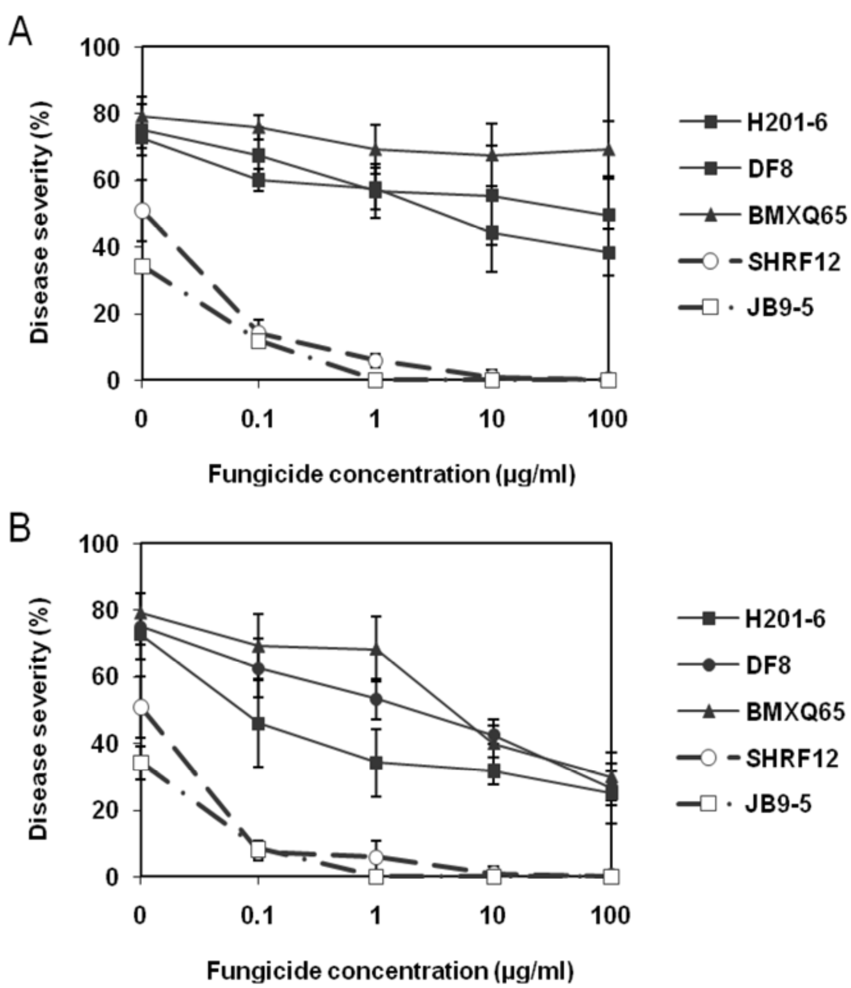

Fig. 6. Mean in vivo percent disease severity for two QoI-sensitive (- - -) and three QoI-resistant (—) *Ascochyta rabiei* isolates to **A,** azoxystrobin and **B,** pyraclostrobin at each fungicide concentration (μg/ml). Values include standard errors of disease control measurements obtained from two plants across three replications.

and has been used in several pathogen systems (21,25,34). The discriminatory dose of 1 µg/ml was very effective in identifying *A. rabiei* isolates resistant to azoxystrobin. The development and use of a discriminatory dose fungicide sensitivity assay for azoxystrobin and pyraclostrobin resistance monitoring facilitated the screening of a much larger sample size of the *A. rabiei* population.

Differences in disease control were observed when azoxystrobin and pyraclostrobin were applied to chickpea plants infected with QoI-resistant and QoI-sensitive isolates. Applications of azoxystrobin at a concentration of 100 µg/ml provided less than 50% control of disease on plants infected with QoI-resistant isolates. This level of control is commercially unacceptable, and indicates that in vitro fungicide assays are capable of predicting *A. rabiei* isolate sensitivity in vivo. Clear differences in disease severity were observed between both QoI-sensitive isolates causing significantly less disease on non-fungicide-treated plants as compared to the three QoI-resistant isolates used in the study. This suggests that QoI-resistant *A. rabiei* isolates may have increased aggressiveness compared to QoI-sensitive isolates, possibly providing a competitive advantage in nature. These conclusions are based on a limited number of isolates, however, and additional pathogenicity studies should be conducted on a larger number of QoI-sensitive and -resistant isolates to determine if true differences in aggressiveness exist.

Since no *A. rabiei* isolates were collected from North Dakota prior to 2005, it cannot be determined if detectable QoI fungicide resistance was present before this time. Despite this, QoI fungicide resistance was detected in under 3 years of registration and use for azoxystrobin and within 2 years for pyraclostrobin. This rapid shift in sensitivity has been observed in several other plant pathogens, including *Erysiphe graminis* (4), *Podosphaera xanthii* (16), *Pyricularia grisea* (31), *Colletotrichum cereale* (34), and *Didymella bryoniae* (28). In each case, resistance to QoI fungicides occurred in two or less years. However, the speed at which resistance to QoI fungicides was expressed in *A. rabiei* is not necessarily surprising, since curative applications of a single chemical class were applied repeatedly to a pathogen with the potential for high inoculum production and genetic diversity.

QoI resistance in *A. rabiei* was first reported in Canada in 2004, and in vitro baseline sensitivity of Canadian populations of *A. rabiei* to pyraclostrobin was reported as 0.25 ppm (7). This value is substantially higher than the sensitivity of *A. rabiei* baseline populations in the Northern Great Plains (0.0023 µg/ml) (33), and due to methodological differences and different baseline populations it is difficult to compare the results of the Canadian work with those of the current research (7,15). Although it is difficult to ascertain the effect of methodological differences on the detection of QoI-resistant phenotypes of *A. rabiei*, it is clear that standardized testing methods using baseline populations, spore germination assays (4), and SHAM (33) are necessary to provide accurate assessments of QoI sensitivity in different chickpea production areas.

Large shifts in magnitude of fungicide sensitivity (>100×) and a complete loss of disease control with QoI fungicides are typical of isolates that have developed the G143A mutation conferring QoI fungicide resistance, and is documented in many pathogens (3,5,6,12,14,16,18,19,34). While the specific mutation conferring QoI resistance in *A. rabiei* has not been determined, greater than 100× sensitivity shifts were observed in vitro and in our greenhouse fungicide efficacy study. Both azoxystrobin and pyraclostrobin applied at the highest rate (100 µg a.i./ml) did not provide adequate disease control of suspected QoI-resistant isolates. This leads to speculation that the G143A mutation is present in *A. rabiei*, and indicates that applications of either QoI fungicide to a resistant *A. rabiei* population may not provide the disease control necessary for a profitable crop. The lack of disease control and magnitude of resistance factors observed with both azoxystrobin and pyraclostrobin with QoI-resistant isolates indicates that cross-resistance to QoI fungicides is observed in *A. rabiei* on chickpea, and confirms a previous report of in vitro cross-sensitivity (33).

Once the mutation conferring resistance is determined for *A. rabiei*, allele-specific primers can be designed to distinguish QoI-sensitive isolates from QoI-resistant isolates, and a real-time or quantitative PCR (Q-PCR) assay can be implemented for fungicide resistance monitoring. This method is preferable to screening isolates

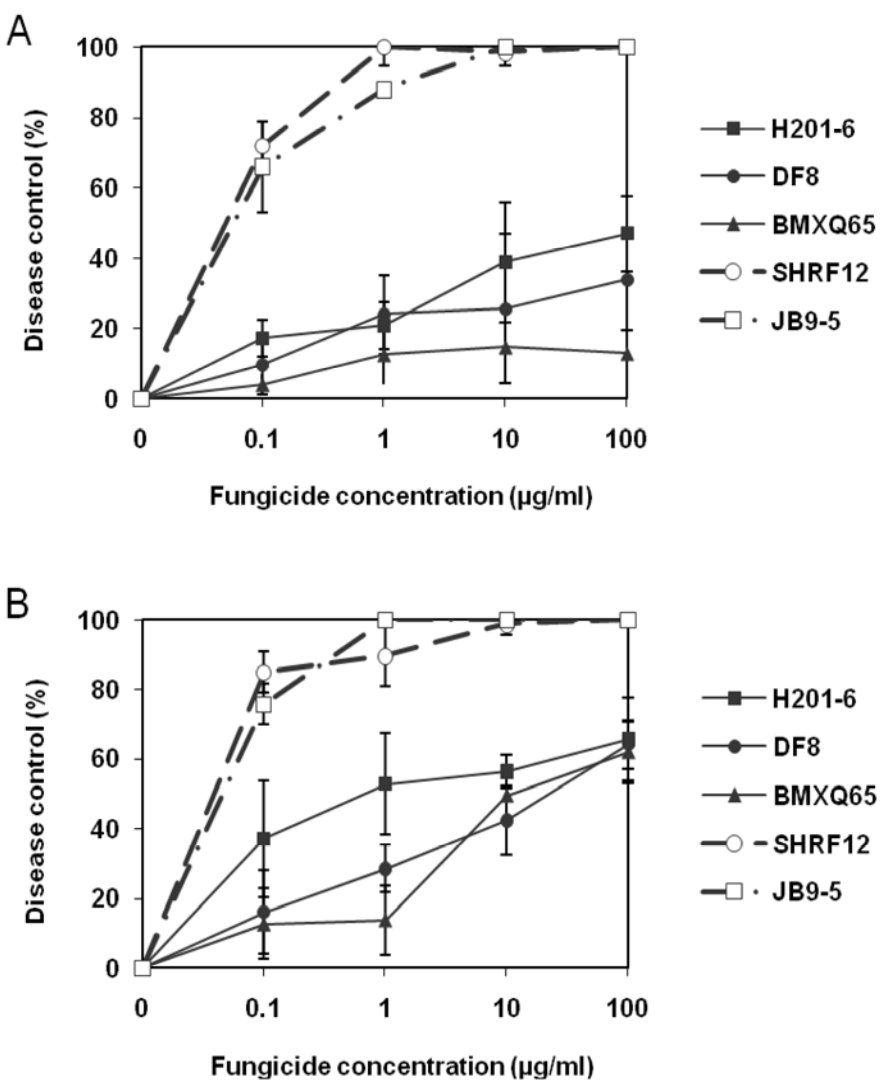

Fig. 7. Mean in vivo percent disease control for two QoI-sensitive (- - -) and three QoI-resistant (—) *Ascochyta rabiei* isolates to **A,** azoxystrobin and **B,** pyraclostrobin at each fungicide concentration (µg/ml). Values include standard errors of disease control measurements obtained from two plants across three replications.

using in vitro spore germination techniques, because it is rapid and accurate, and fungicide sensitivity can be determined for a large number of isolates in a short amount of time. This method would also aid in determining if other resistance genotypes such as the F129L or G137R exist in populations of *A. rabiei*, since these mutations may not be easily observed with a discriminatory dose assay. Q-PCR has been used in fungicide resistance studies in several pathogens (12,18,23,27) and would be a desirable alternative for screening for QoI fungicide sensitivity in *A. rabiei* isolates in the Northern Great Plains.

In response to the results presented here, North Dakota State University recommended that no applications of QoI fungicides be applied to chickpea in North Dakota in 2007. Instead, it was recommended that preventative applications of chlorothalonil or maneb be applied prior to flowering, followed by a rotation of the fungicides boscalid and prothioconazole at flowering, or if conditions were favorable for disease development. Although the DMI and carboximide fungicides are considered to be at a medium risk for developing resistance, fungicide resistance has developed within each of these classes in other pathogens (1,6). Thus, extreme care should be taken to use these fungicides in a manner that prevents further development of *A. rabiei* fungicide resistance in other fungicide classes. Cross-resistance within fungicide classes limits the potential of new fungicides from the same chemical class for use in chickpea if resistance to one member of that class is already present. Furthermore, recent work in another system has resulted in further complication of resistance development: DMI-resistant isolates of *Monilinia fructicola* were reported to develop resistance to the QoI fungicide azoxystrobin more quickly than DMI-sensitive isolates (20). This information reinforces the need for fungicide sensitivity monitoring in pathogens such as *A. rabiei* that are predisposed to fungicide resistance due to their biological nature, and are intensively managed with fungicide applications.

Until chickpea cultivars with durable levels of Ascochyta blight resistance are available, fungicide applications for disease management will be essential in the Northern Great Plains. Additional research is needed on the efficacy of new fungicidal compounds and/or different chemical classes on Ascochyta blight to increase the management options available for growers and minimize the selection pressure on the pathogen due to repeated applications of one fungicide class.

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Baseline Sensitivity of *Ascochyta rabiei* to Azoxystrobin, Pyraclostrobin, and Boscalid

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ABSTRACT

Wise, K. A., Bradley, C. A., Pasche, J. S., Gudmestad, N. C., Dugan, F. M., and Chen, W. 2008. Baseline sensitivity of *Ascochyta rabiei* to azoxystrobin, pyraclostrobin, and boscalid. Plant Dis. 92:295-300.

Ascochyta rabiei, causal agent of Ascochyta blight on chickpea (*Cicer arietinum*), can cause severe yield loss in the United States. Growers rely on applications of fungicides with site-specific modes of action such as the quinone outside inhibiting (QoI) fungicides azoxystrobin and pyraclostrobin, and the carboximide fungicide boscalid, to manage disease. In all, 51 isolates collected prior to QoI fungicide registration and 71 isolates collected prior to boscalid registration in the United States were tested in an in vitro assay to determine the effective fungicide concentration at which 50% of conidial germination was inhibited (EC_{50}) for each isolate–fungicide combination. The effect of salicylhydroxamic acid (SHAM) on conidia of *A. rabiei* in the presence and absence of azoxystrobin also was assessed to determine whether the fungus is capable of using alternative respiration. Five of nine *A. rabiei* isolates tested had significantly higher ($P \leq 0.05$) EC_{50} values when SHAM was not included in media amended with azoxystrobin, indicating that *A. rabiei* has the potential to use alternative respiration to overcome fungicide toxicity in vitro. EC_{50} values of azoxystrobin and pyraclostrobin ranged from 0.0182 to 0.0338 µg/ml and from 0.0012 to 0.0033 µg/ml, with mean values of 0.0272 and 0.0023 µg/ml, respectively. EC_{50} values of boscalid ranged from 0.0177 to 0.4960 µg/ml, with a mean of 0.1903 µg/ml. Establishment of these baselines is the first step in developing a monitoring program to determine whether shifts in sensitivity to these fungicides are occurring in the *A. rabiei* pathogen population.

Additional keywords: *Didymella rabiei*, fungicide resistance

Ascochyta blight, caused by the fungal pathogen *Ascochyta rabiei* (Pass.) Labr. (teleomorph, *Didymella rabiei* (Kovatsch.) Arx.), is a limiting disease of chickpea (*Cicer arietinum* L.) production throughout the world (18,27). In the United States and Canada, chickpea production has decreased in the last decade due to the devastating effects of Ascochyta blight, which is considered to be the most important disease affecting chickpea production in these regions (5,7,30). *A. rabiei* can spread quickly throughout chickpea fields, causing significant yield losses (5,30). Development of chickpea cultivars with durable resistance has been complicated by the presence of different pathotypes of *A. rabiei* (5,7). Therefore, growers rely on fungicide applications to manage the disease (27).

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Two of the most widely used fungicide active ingredients for control of Ascochyta blight in the United States are azoxystrobin (Amistar or Quadris; Syngenta Crop Protection, Greensboro, NC) and pyraclostrobin (Headline; BASF Corporation, Research Triangle Park, NC). Azoxystrobin became available for use on chickpea in the 2002 growing season in areas of the United States where section 18 emergency exemptions were approved for control of Ascochyta blight on chickpea. In 2003, both azoxystrobin and pyraclostrobin received United States Environmental Protection Agency section 3 registrations prior to the growing season. These fungicides are classified as quinone outside inhibitors (QoI) and block electron transport at the quinol-oxidizing site of the cytochrome bc_1 complex (complex III) in the mitochondrial respiration chain (2,10). The site-specific mode of action of this chemistry increases the potential for fungicide resistance to develop in the target fungal populations. Several fungal pathogens are reported to have reduced levels of sensitivity to QoI fungicides due to single amino acid substitutions in the cytochrome b site (6,10,15,16,23).

The fungicide boscalid (Endura; BASF Corporation) was registered in 2003 on chickpea for control of Ascochyta blight in the United States, but was not available for use by growers until the 2004 growing season. Boscalid is a novel chemistry in the carboximide group that acts at succinate-ubiquinone reductase (complex II) in the mitochondrial respiration pathway (3). Due to price constraints, this fungicide currently has limited use in chickpea production in the United States; however, the site-specific mode of action increases the likelihood that shifts in fungicide sensitivity will occur in the pathogen population if boscalid use on chickpea becomes more widespread in the future. The first report of fungal resistance to boscalid was published recently by Avenot and Michailides (1), in which *Alternaria alternata* isolates from pistachio (*Pistacia vera*) in California were found to be resistant.

Because growers rely heavily on fungicide applications to manage Ascochyta blight, it is important to determine whether the fungal population is changing in response to selection pressure. Isolates of *D. bryoniae*, a pathogen of cucurbits in the same genus as the teleomorph of *Ascochyta rabiei* (*D. rabiei*), have been reported to be resistant to the QoI fungicide azoxystrobin (20,29). Because of these reports and the history of QoI resistance in other pathogens, a baseline sensitivity level should be established to facilitate a monitoring program to detect shifts in sensitivity. According to Brent and Holloman (4), there are three reasons to conduct baseline fungicide sensitivity studies: (i) to develop and test an accurate, rapid, reproducible method for determining the degree of sensitivity of large numbers of field samples of major target fungi, so that such a method is readily available for any future monitoring that may be required; (ii) to obtain initial data regarding the range of sensitivity that exists in major target pathogens and major areas of use, to serve as a baseline against which any future measurements of sensitivity can be compared in order to reveal any possible shifts in sensitivity; and (iii) to detect any differences in sensitivity between samples that might, through the buildup of the less-sensitive components, lead to future resistance problems. Jutsum et al. (12) and Russell (26) stressed the importance of determining the range of sensitivities present in target pathogen populations prior to commercialization of the product. Establishing a baseline for the carboximide fungicide, boscalid, is a proactive approach to fungicide resistance management and will allow pathogen sensitivity to be monitored if the chemistry use becomes more widespread on chickpea in the United States.

Previous research involving in vitro testing of fungi in the presence of respiration-inhibiting fungicides has indicated that some fungi are able to use an alternative respiration pathway to bypass complex III and IV in the mitochondrial respiration chain, allowing fungal spores to germinate even in the presence of high doses of certain fungicides (22,31,35). This phenomenon is observed only in vitro, and it is hypothesized that plant-produced flavones prevent the induction of alternative oxidase in nature, thus inhibiting alternative respiration (22,31). However, alternative respiration is still important because it may strongly impact results of in vitro assays, leading to inaccurate assessments of fungicide sensitivity in vitro. The chemical salicylhydroxamic acid (SHAM) is used in QoI in vitro fungicide testing to prevent fungal pathogens from using an alternative respiration mechanism (22). The ability of *A. rabiei* to use alternative respiration has not been reported.

The objectives of this research were to (i) determine whether *A. rabiei* isolates are capable of using alternative respiration during in vitro fungicide sensitivity assays and (ii) establish the baseline sensitivities of *A. rabiei* isolates to azoxystrobin, pyraclostrobin, and boscalid using isolates collected prior to exposure to QoI and boscalid fungicides.

MATERIALS AND METHODS

Collection of isolates of *A. rabiei*. Fifty-one *A. rabiei* isolates were obtained from the Ascochyta collection in the United States Department of Agriculture–Agricultural Research Service collection in Pullman, WA (Table 1). These *A. rabiei* isolates were collected prior to the registrations of QoI fungicides and boscalid in the United States, and represent a true baseline group with no possible exposure to any QoI chemistry or boscalid. An additional 20 isolates of *A. rabiei* were used to establish the baseline for boscalid (Table 1); these isolates were collected prior to the use of boscalid in U.S. chickpea fields. Each isolate was preserved for long-term storage by plating 2 µl of conidial suspension onto individual plates of potato dextrose agar (PDA) (Difco Laboratories, Detroit) with Whatman no. 1 filter paper cut into small strips, sterilized, and placed on the agar surface. Each isolate was grown in a growth chamber for 14 to 21 days under a diurnal cycle (12 h of light and 12 h of dark) at 20 ± 2°C, at which time the filter paper was covered with mycelia. Filter papers were removed from the agar surface using sterile forceps and dried for approximately 18 h in a laminar flow hood. Filter papers were placed in sterile 15-ml centrifuge tubes; tubes were sealed with Parafilm and stored at –20°C.

Preparation of *A. rabiei* isolates for conidia germination assays. All *A. rabiei* isolates in all experiments were prepared using the following methods adapted from Pasche et al. (24). Sterile 0.05% Tween 20 (Sigma-Aldrich, St. Louis) was added to 7-day-old cultures of *A. rabiei* and the conidia were dislodged from the agar using a sterile glass rod. The resulting conidial suspension was adjusted to 2×10^5 conidia/ml using a hemacytometer. A conidial suspension (100 µl) of each isolate was pipetted onto each of two replicate petri plates (60 by 15 mm). Plates were held at 19°C for 18 h in the dark. Following incubation, 100 conidia per plate were visually assessed microscopically (×100 magnification) and evaluated for germination. A conidium was considered to be germinated if the germ tube was at least as long as the length of the conidium.

Effect of SHAM on conidia germination. The effect of SHAM (Sigma-Aldrich) at a concentration of 100 µg/ml on *A. rabiei* conidial germination was examined in a preliminary experiment. Ten isolates (AR401, AR402, AR418, AR430, AR477, AR604, AR660, AR666, AR668, and AR721) were selected randomly to test on PDA amended with SHAM at 100 µg/ml and nonamended PDA. Random selection of the isolates was done using the RAND function in Microsoft Excel 2003 software (Microsoft Corp., Redmond, WA). For this experiment, a stock solution of SHAM was prepared by adding 100 mg of SHAM for each 1 ml of methanol. The final concentration of both acetone and methanol in media amended with fungicide and nonamended media was 0.1% by volume. All amendments were filter sterilized and added to the autoclaved media after it had cooled to 55°C. The experiment was arranged as a completely randomized design (CRD) with two replicate plates of each isolate. The experiment was repeated once in an additional run, and data were analyzed using the general linear model procedure (PROC GLM) in SAS (version 8.2; SAS Institute, Inc., Cary, NC). Data from each run were analyzed separately first to compute variances, and a two-tailed F test for equality of variances was conducted to determine whether trials could be combined. In the combined analysis, the lack of significant ($P \leq 0.05$) run and run–isolate interactions were used additionally to determine whether runs could be combined. If run or run–isolate interactions were not significant, then run was dropped from the model and an analysis of variance was calculated.

Effect of SHAM and azoxystrobin on conidia germination. Nine isolates (AR401, AR402, AR418, AR477, AR604, AR660, AR666, AR668, and AR721) were randomly selected and tested to compare the effect of azoxystrobin on in vitro conidial germination with and without the addition of SHAM to the media. This experiment was conducted to determine whether alternative respiration is induced in *A. rabiei* by the presence of a respiration-inhibiting fungicide such as azoxystrobin. Isolates were prepared for plating using the methods described previously, with the addition of technical-grade azoxystrobin (97.6% a.i.; Syngenta Crop Protection) to the media. A stock solution of azoxystrobin was prepared at a concentration of 100 mg/ml in acetone. Serial dilutions of the stock solution were prepared in acetone and conidia germination was as-

Table 1. Collection information for baseline isolates of *Ascochyta rabiei* from chickpea

Year[a]	Location	Isolates[b]
1983	Pullman, WA	AR465, AR468, AR471, AR477
1984	Genesee, ID	AR714, AR721
1984	Pullman, WA	AR439, AR441, AR444, AR445, AR456
1987	Genesee, ID	AR401, AR402, AR403, AR404, AR405, AR406, AR407, AR408, AR453
1987	Kendrick, ID	AR430, AR437
1987	Lapwai, ID	AR414, AR415, AR416, AR417, AR418, AR419, AR420
1987	Nez Pierce County, ID	AR409, AR410, AR411, AR413
1994	Genesee, ID	AR423, AR424, AR425, AR427, AR428
1995	Albion, WA	AR590
1995	Genesee, ID	AR588, AR598, AR601, AR604
1995	LaGrande, OR	AR625
1995	Steptoe, WA	AR666, AR668
1995	Waitsburg, WA	AR616, AR617
1995	Walla Walla WA	AR618, AR660, AR661
2002	Fresno, CA	C2-1, C2-2, C2-4
2002	Genesee, ID	B3-15, B3-25, B3-45
2002	Pullman, WA	A2-25, A3-15, A4-15, CAB01-4
2003	Culdesac, ID	03-C1-3
2003	Genesee, ID	03-A1, 03-A2, 03-A3, 03-B1, 03-B2, 03-B3, 03-E3, 03-F1, 03-F4

[a] Year collected. All isolates were used as boscalid fungicide baseline isolates, but only isolates collected prior to 2002 were used as azoxystrobin and pyraclostrobin fungicide baseline isolates.
[b] Isolates with an “AR” designation were obtained from Dr. Frank Dugan, United States Department of Agriculture–Agricultural Research Service (USDA-ARS), Pullman, WA. All other isolates were obtained from Dr. Weidong Chen, USDA-ARS, Pullman, WA.

sessed on PDA amended with azoxystrobin at 0, 0.001, 0.01, 0.1, 1, and 10 µg/ml. Conidial germination also was assessed on PDA amended with the six concentrations of azoxystrobin and SHAM at 100 µg/ml dissolved in methanol. All amendments were filter sterilized and added to the autoclaved media after it had cooled to 55°C. Conidia were incubated and percent conidial germination was assessed as described previously. Conidial germination for each of the replicate plates was converted to percent inhibition compared with the untreated control by: 100 – ([percent germination of fungicide-amended]/[mean percent germination of non-amended]). The fungicide concentration that effectively inhibited conidial germination by 50% of the untreated control (EC_{50}) was determined for each isolate by linear interpolation using the two concentrations that bracketed 50%. This experiment was arranged as a CRD with two replicate plates per isolate, and the experiment was repeated once in an additional run. Data were analyzed using PROC GLM in SAS (version 8.2) as described in the previous section. Least square means *t* tests (PDIFF option in SAS) were used to compare EC_{50} values of individual *A. rabiei* conidia on SHAM-amended PDA versus nonamended PDA.

Determination of baseline EC_{50} values. Stock solutions of technical-grade formulations of azoxystrobin (97.6% a.i.; Syngenta Crop Protection), pyraclostrobin (99% a.i.; BASF Corporation), and boscalid (95% a.i.; BASF Corporation) were prepared at concentrations of 100 mg/ml in acetone. Serial dilutions in acetone were prepared for each fungicide. Fungicide sensitivity was determined by evaluating *A. rabiei* conidial germination on PDA amended with each fungicide at 0, 0.001, 0.01, 0.1, 1, and 10 µg/ml and SHAM at 100 µg/ml dissolved in methanol. The final concentration of both acetone and methanol in media amended with fungicide and nonamended media was 0.1% by volume. All amendments were filter sterilized and added to the autoclaved media after it had cooled to 55°C.

A. rabiei cultures were prepared for fungicide sensitivity testing using the methods described in the previous sections. Conidial germination and conversion of germination to percent inhibition was assessed and determined as described previously. EC_{50} values were determined for each isolate and fungicide.

Baseline isolates were tested across seven trials due to time and space constraints. In all, 6 to 12 isolates were tested in each trial along with an internal control isolate (AR666) that was used to determine reproducibility of the trials. An assay reproducibility test described by Wong and Wilcox (32) was used to validate the reproducibility of each of the seven trials conducted. For this reproducibility test, the internal control isolate (AR666) was tested in another experiment that was repeated 10 times in different runs, and the assay reproducibility calculations used by Wong and Wilcox (32) were applied to the resulting EC_{50} values, in which the mean, standard error, and 95% confidence intervals were calculated for the internal control isolate. For each of the seven trials conducted to determine baseline EC_{50} values, if the EC_{50} value of the internal control isolate did not fall within the 95% confidence interval, then that specific trial was repeated until the internal control fell within the 95% confidence interval. Isolates were arranged in a CRD with two replicate plates per isolate. Each of the seven trials was repeated once over time in an additional run. A two-tailed *F* test was conducted as previously described to determine whether variances of the two runs were equal. In the combined analysis of the two runs, the lack of significant ($P \leq 0.05$) run and run–isolate interactions was used additionally to determine whether runs could be combined. If run or run–isolate interactions were not significant, then run was dropped from the model and an analysis of variance was calculated. The baseline sensitivity distributions of each fungicide were tested for normality using the Shapiro-Wilk test (PROC UNIVARIATE NORMAL) in SAS (version 8.2). Associations among baseline sensitivities of each fungicide were evaluated using Pearson correlation analysis (PROC CORR) in SAS (version 8.2).

RESULTS

Effect of SHAM on conidial germination. Analysis of the effects of SHAM on conidial germination indicated no significant isolate–SHAM interaction ($P = 0.3251$) and no effect of SHAM on *A. rabiei* conidial germination ($P = 0.4495$). Mean percent germination for conidia on PDA amended with 100 µg/ml of SHAM was 98.3%, compared with 98.5% for conidia on nonamended PDA. Because SHAM alone was determined not to influence conidial germination, it was used in subsequent trials.

Effect of SHAM and azoxystrobin on conidial germination. Separate analysis of experiments conducted to determine the impact of SHAM on conidial germination in the presence and absence of azoxystrobin produced equal variances according to an *F* test; therefore, experiments were combined for analysis. Analysis of EC_{50} values of the nine isolates exposed to azoxystrobin with and without SHAM at 100 µg/ml indicated that the main effects of isolate and SHAM were significant (P = 0.0003 and 0.0001, respectively) and the interaction of isolate–SHAM was significant ($P = 0.0004$). In five of the nine isolates tested (AR401, AR402, AR418, AR668, and AR721), EC_{50} values were significantly ($P \leq 0.05$) greater when SHAM was not included in the fungicide-amended media (Table 2). No other significant differences were found.

Determination of baseline EC_{50} values. Analyses of in vitro fungicide sensitivity trials were conducted and the *F* test for homogeneity of variance indicated that variances were equal, and no significant ($P \leq 0.05$) interactions were observed between run and other factors. Therefore, data from runs were combined to determine the mean EC_{50} values for each isolate–fungicide combination. The range of EC_{50} values for isolates exposed to azoxystrobin was 0.0182 to 0.0338 µg/ml, and the mean value was 0.0272 µg/ml (Fig. 1). The azoxystrobin, EC_{50} values were normally distributed ($P = 0.0922$). For pyraclostrobin, the range of EC_{50} values of the isolates was 0.0012 to 0.0033 µg/ml, and the mean value was 0.0023 µg/ml (Fig. 2). The pyraclostrobin EC_{50} values were normally distributed ($P = 0.2787$). The range of EC_{50} values for isolates exposed to boscalid was 0.0177 to 0.4960 µg/ml, and the mean value was 0.1903 µg/ml (Fig. 3). The boscalid EC_{50} values did not have a normal distribution ($P = 0.0226$). Pearson correlation analysis indicated that there was a significant ($P = 0.0001$) relationship between azoxystrobin and pyraclostrobin baseline sensitivities ($r = 0.53$), and no other relationships were significant.

Table 2. Comparison of azoxystrobin effective concentration at which 50% of conidial germination was inhibited (EC_{50}) values (µg/ml) of nine *Ascochyta rabiei* baseline isolates in salicylhydroxamic acid (SHAM)-amended potato dextrose agar and nonamended potato dextrose agar

Isolate	SHAM-amended	Nonamended	*P* value[a]
AR401	0.0277	0.0509	0.0024
AR402	0.0287	0.0435	0.0237
AR418	0.0338	0.0566	0.0026
AR477	0.0251	0.0306	0.3307
AR604	0.0264	0.0314	0.3763
AR660	0.0335	0.0414	0.1728
AR666	0.0238	0.0340	0.0911
AR668	0.0209	0.0675	0.0001
AR721	0.0232	0.0399	0.0136
Mean	0.0269	0.0439	0.0003

[a] *P* value for individual isolates were determined using least-square means *t* tests; *P* value for comparison of overall isolate means of SHAM-amended and nonamended was determined from an *F* test.

DISCUSSION

The chemical SHAM is used in QoI in vitro fungicide testing to prevent fungal pathogens from using an alternative respiration mechanism to bypass complex III in the mitochondrial pathway (the QoI fungicide binding site), which may allow the fungus to germinate in the presence of high levels of QoI fungicides (22,35). The effects of SHAM and azoxystrobin were tested with the pathogen *Alternaria alternata* (17). In that study, no significant differences were observed between EC_{50} values when SHAM was included with the fungicide and when it was omitted, although the mean EC_{50} value was 2× higher when SHAM was omitted than when SHAM was included in the fungicide-amended media (0.12 versus 0.06 µg/ml). In contrast, conidial germination of baseline isolates of *Pyricularia grisea* were inhibited by azoxystrobin and trifloxystrobin at fungicide concentrations of 0.1 µg/ml when SHAM was added to conidial suspensions at a rate of 100 µg/ml (31); however, when SHAM was not included in conidial suspensions, EC_{50} values of baseline isolates did not differ significantly from the EC_{50} values of resistant isolates (31). In vitro QoI fungicide resistance due to alternative respiration also has been demonstrated in *Venturia inaequalis* and *Septoria tritici* (22,35). The current study indicates that there are isolates in the *Ascochyta rabiei* population that may be able to use alternative respiration to bypass the QoI fungicide binding site, leading to higher in vitro EC_{50} values. These skewed EC_{50} values can, in turn, lead to inaccurate assessments of fungicide sensitivity in the pathogen population. Ziogas et al. (35), showed that alternative respiration occurs in both the wild-type and mutant strain of *S. tritici*. This information, along with our results, indicates that isolates need not be previously exposed to QoI fungicides to utilize alternative respiration. Therefore, SHAM at 100 µg/ml should be included in all in vitro QoI fungicide testing conducted with *A. rabiei*.

A. rabiei isolates exhibited a narrow range of EC_{50} values for azoxystrobin similar to other fungal pathogens with baselines previously established (Fig. 1). Baseline EC_{50} values of conidial isolates of *P. grisea* for azoxystrobin ranged from 0.015 to 0.064 µg/ml, with a mean of 0.0290 µg/ml (31). Similarly, in *Alternaria solani*, EC_{50} values for baseline isolates for azoxystrobin ranged from 0.011 to 0.090 µg/ml, with a mean of 0.038 µg/ml (24). Isolates of *Erysiphe graminis* f. sp. *tritici* also had similar values for azoxystrobin, ranging from 0.022 to 0.235 µg/ml (6).

Few examples exist in the literature reporting baseline sensitivity of fungal pathogens to pyraclostrobin. EC_{50} values for *A. solani* baseline isolates indicate that the fungus is 10 times more sensitive to pyraclostrobin than azoxystrobin (24), which is similar to the *Ascochyta rabiei* isolates tested in our research trials. Similarly, EC_{50} values for *Uncinula necator* sensitivity to pyraclostrobin ranged from 0.0016 to 0.010 µg/ml, with a mean of 0.0044 µg/ml (33), which is comparable with the EC_{50} values shown for *A. rabiei* in our study. In a study on fungicide sensitivi-

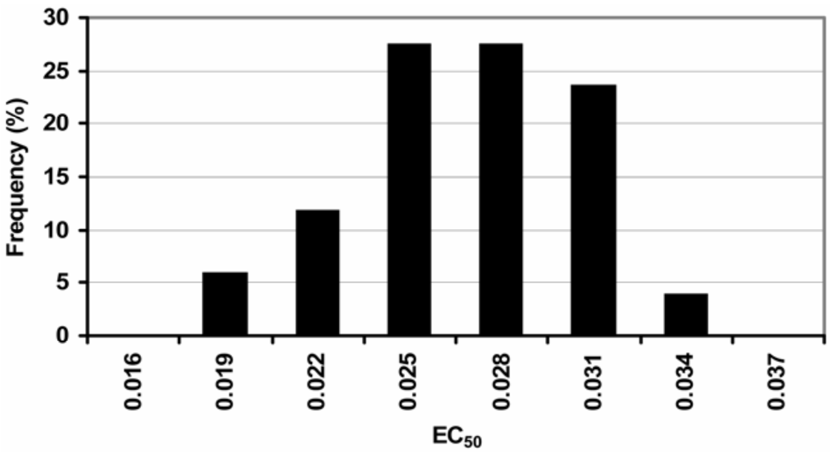

Fig. 1. Frequency distribution of effective fungicide concentration at which 50% of conidial germination was inhibited (EC_{50}) values (µg/ml) for 51 baseline isolates of *Ascochyta rabiei* to azoxystrobin. Individual isolates are grouped in class intervals of 0.003 µg/ml; values on the X-axis indicate the midpoint of the interval.

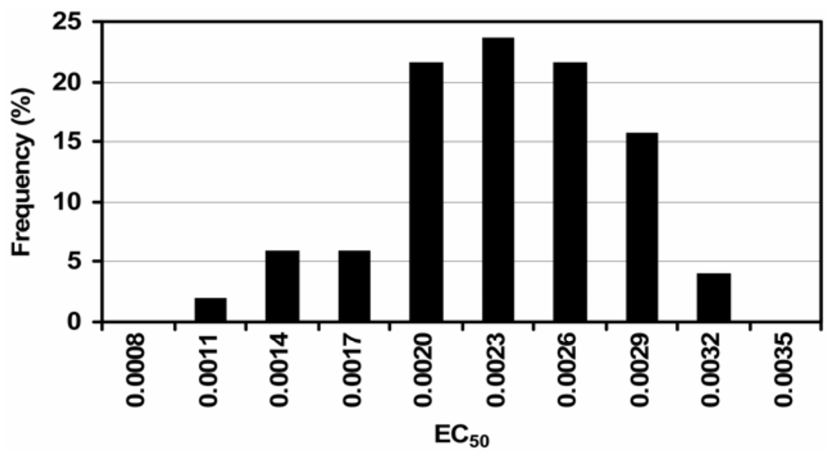

Fig. 2. Frequency distribution of effective fungicide concentration at which 50% of conidial germination was inhibited (EC_{50}) values (µg/ml) for 51 baseline isolates of *Ascochyta rabiei* to pyraclostrobin. Individual isolates are grouped in class intervals of 0.0003 µg/ml; values on the X-axis indicate the midpoint of the interval.

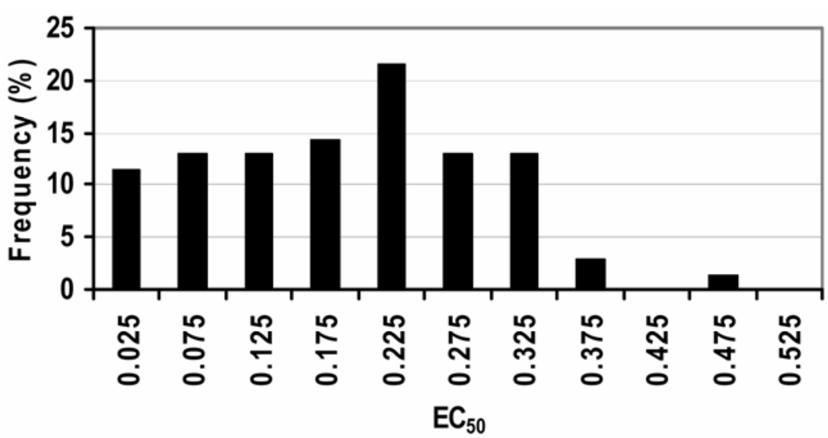

Fig. 3. Frequency distribution of effective fungicide concentration at which 50% of conidial germination was inhibited (EC_{50}) values (µg/ml) for 71 baseline isolates of *Ascochyta rabiei* to boscalid. Individual isolates are grouped in class intervals of 0.05 µg/ml; values on the X-axis indicate the midpoint of the interval.

ties of citrus pathogens, Mondal et al. (17) reported baseline sensitivities of five fungal pathogens (*Colletotrichum acutatum*, *Alternaria alternata*, *Elsinoe fawcettii*, *Diaporthe citri*, and *Mycosphaerella citri*) to pyraclostrobin, and mean EC_{50} values for isolate sensitivity to pyraclostrobin was over 8× higher for each of the five citrus pathogens than for *Ascochyta rabiei*. This could be attributed to the fact that Mondal et al. (17) used inhibition of mycelial growth to determine EC_{50} values, rather than conidial germination inhibition. Because QoI fungicides are powerful inhibitors of spore germination (2), an assay based on spore germination is likely a better method for determining sensitivity of fungi to this chemistry. The difference in methodology could partially explain why baseline isolates of *A. rabiei* are more sensitive to pyraclostrobin than the citrus pathogens reported. A preliminary finding of resistance to azoxystrobin and pyraclostrobin in *Didymella rabiei* was reported in Canada (8). This report of QoI resistance in *D. rabiei* was based on mycelial growth inhibition without the addition of SHAM (8). A more definitive conclusion of the sensitivity of the Canadian isolates to QoI fungicides would be obtained if these isolates were additionally tested using conidial germination with the addition of SHAM and compared with the azoxystrobin baseline sensitivity developed. As discussed previously, our research indicates the importance of using SHAM when measuring *A. rabiei* sensitivity to QoI fungicides in vitro.

A few reports of in vitro fungal pathogen sensitivities to boscalid are available. In *Spilocaea oleagina*, EC_{50} values for conidial germination of isolates exposed to boscalid ranged from 0.005 to 0.5 µg/ml, with a mean of 0.031 µg/ml (19). In *Alternaria solani*, EC_{50} values of boscalid ranged from 0.275 to 2.70 µg/ml, with a mean of 0.6878 µg/ml (23). In *A. alternata*, EC_{50} values of boscalid in isolates never before exposed to boscalid ranged from 0.089 to 3.435 µg/ml, with a mean of 1.515 µg/ml (1). Based on conidial germination of *Botrytis cinerea*, Stammler and Speakman (28) reported that EC_{50} values of boscalid ranged from 0.01 to 0.21 µg/ml, with a mean of 0.06 µg/ml, while Zhang et al. (34) reported EC_{50} values of 0.02 to 1.68 µg/ml, with a mean of 0.42 µg/ml. Zhang et al. (34) also reported EC_{50} values of boscalid based on mycelial growth of *B. cinerea* ranging from 0.09 to 3.69 µg/ml, with a mean of 1.07 µg/ml. The comparison of conidial germination and mycelial growth of *B. cinerea* in the Zhang et al. study (34) indicated that conidial germination was more sensitive to boscalid than mycelial growth. Although these pathogens do not have similar mean EC_{50} values compared with *Ascochyta rabiei* (0.1903 µg/ml), they do exhibit the same broad range in boscalid EC_{50} values displayed by individual *A. rabiei* isolates (0.0177 to 0.4960 µg/ml).

The EC_{50} values for *A. rabiei* baseline isolates to azoxystrobin and pyraclostrobin were similar in that both had relatively narrow ranges in values, which were represented by two- and threefold differences in sensitivity to these fungicides for the majority of isolates, respectively (Figs. 1 and 2). Additionally, azoxystrobin and pyraclostrobin baseline sensitivities both were distributed normally, and there was a significant, positive relationship between azoxystrobin and pyraclostrobin sensitivity values. The narrow distribution of pyraclostrobin EC_{50} values and 12-fold difference in mean EC_{50} values when compared with azoxystrobin indicate that pyraclostrobin has higher intrinsic activity against *A. rabiei* than either azoxystrobin or boscalid (Figs. 1 to 3). This same phenomenon also has been found previously in both *Alternaria solani* and *U. necator*. In each case, isolates were 10 times more sensitive to pyraclostrobin than azoxystrobin as indicated by EC_{50} values (24,33). The distribution of *Ascochyta rabiei* EC_{50} values to boscalid had a broad range, which was represented by a 28-fold difference in sensitivity to this fungicide. This broad range of EC_{50} values is a warning that the potential of *A. rabiei* developing resistance to boscalid is present (12).

Although information on fungicide sensitivity of ascospores of the teleomorph *D. rabiei* would be valuable for comparison purposes, *A. rabiei* conidia are the primary target of QoI fungicide applications to prevent repeated cycles of conidial infection. Conidia of *A. rabiei* often are considered to be secondary inoculum; however, conidia also can serve as primary inoculum by overwintering on infected debris and as inoculum on infected seed (9,13). The conidial stage of other ascomycetes has been used previously to assess QoI fungicide sensitivity in spore germination assays (6,21,29,31,33). Sensitivity tests of *Venturia inaequalis* isolates to flusilazole indicated that ascospores were more sensitive than conidia, but both were suitable for fungicide resistance monitoring (25). Fungicide sensitivities of *A. rabiei* conidia and ascospores were not compared in our research; however, using conidia of *A. rabiei* to establish baseline fungicide sensitivity levels and in future fungicide resistance monitoring should provide an accurate assessment.

Fungal plant pathogens that are able to generate variation through sexual recombination and that have a polycyclic disease cycle have an increased risk of developing resistance to fungicides (4,11,12,14). Sexual recombination occurs in *A. rabiei* (*D. rabiei*) and it has a polycyclic disease cycle. Due to these risk factors present in *A. rabiei*, and the high risk of resistance development in QoI and carboximide fungicides, baseline sensitivity developed in this research will be important in monitoring *A. rabiei* populations to help ensure efficacy of current fungicide spray programs. A fungicide resistance *A. rabiei* monitoring program recently established at North Dakota State University, Fargo, is using these fungicide sensitivity baselines to measure for shifts in sensitivity of *A. rabiei* isolates exposed to these fungicides.

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Ascochyta Blight of Chickpea

Figure 1. Ascochyta lesions on chickpea pods, leaves and stems. (Photo by Kiersten Wise)

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Ascochyta blight is the most problematic disease of chickpea in North Dakota and a severe disease in most chickpea growing regions of the world. Complete yield loss to Ascochyta has been recorded, and the disease can reduce seed quality significantly. In 2005, the Ascochyta pathogen developed resistance to FRAC group 11 fungicides (Headline and Quadris), rendering the most frequently applied fungicides ineffective in North Dakota.

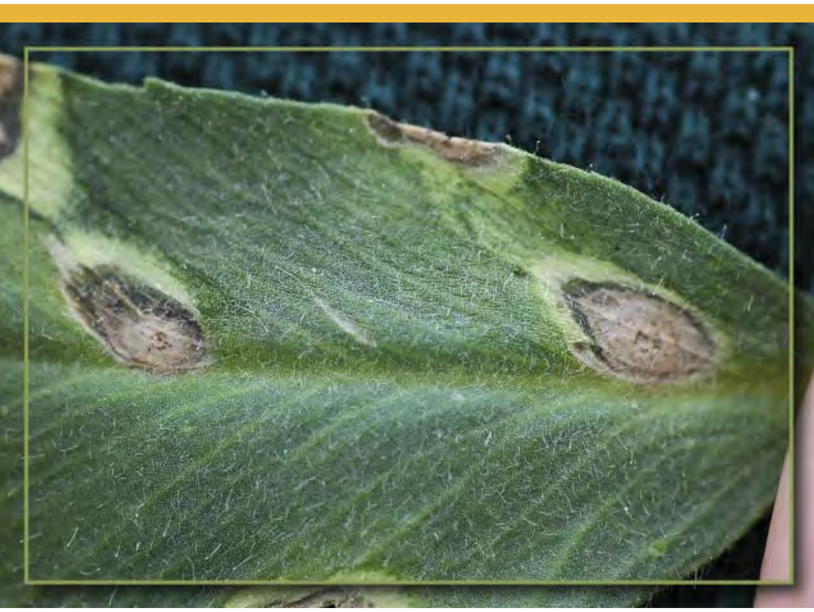

Figure 2. Early Ascochyta blight symptoms on chickpea leaf. Note gray center with black margin. (Photo by Sam Markell)

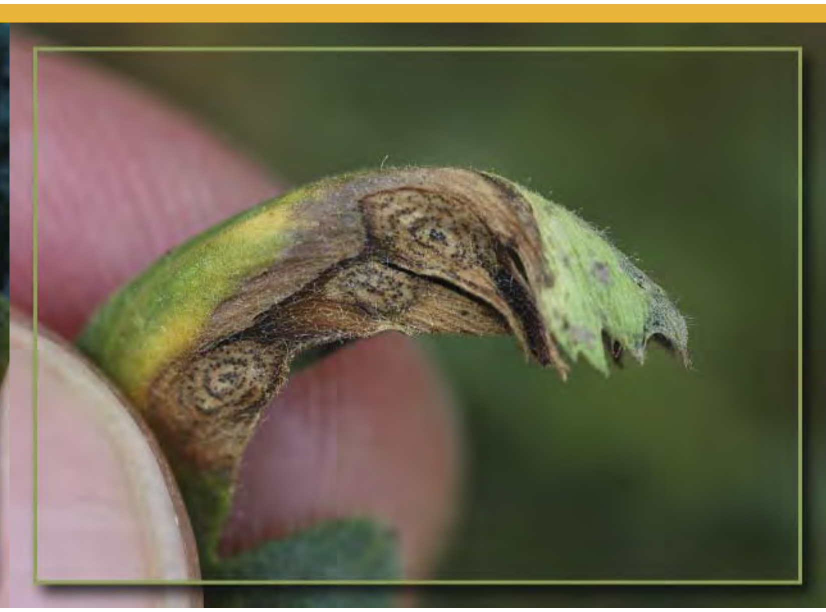

Figure 3. Ascochyta blight lesions on chickpea leaf. Note raised black dots (pycnidia) arranged in concentric rings. (Photo by Sam Markell)

Cause

The fungus *Ascochyta rabiei* (also called *Didymella rabiei*) causes Ascochyta blight of chickpea. Ascochyta blight of pea *(Ascochyta pisi)* and lentil *(Ascochyta lentis)* are caused by different species, and do not cause Ascochyta blight on chickpea.

Symptoms and Signs

Ascochyta blight can infect all above-ground plant parts (Figure 1), and can be found anytime after crop emergence. Ascochyta blight first appears as gray areas on the leaves, stems or pods that quickly turn into brown lesions with dark borders (Figure 2). As the disease progresses, small, circular, brown-black dots (pycnidia) develop in the center of the lesions, and are frequently arranged in concentric circles and resemble a bull's-eye (Figures 3-5). The concentric circles of pycnidia are large and relatively easy to identify on unifoliate or large kabuli varieties, while lesions on varieties with a desi-type leaf or fern leaf are smaller and may require a small magnifying glass. Concentric rings of pycnidia are the most diagnostic characteristic of the disease. Infected seed may be discolored, shrunken or shriveled and, when severe, lesions with dark pycnidia may be present on the seed.

Disease cycle

Ascochyta blight develops rapidly in cool (59 to 77 F), wet conditions. High humidity and periods of morning dew also favor disease development and spread. Hot, dry conditions can halt the development of disease, but spread can continue once conditions become favorable again.

Ascochyta rabiei can overwinter in field stubble for several years, and the pathogen is also seed-borne. In spring, sexual spores (ascospores) are produced on field stubble or seed and dispersed by wind. Ascospore dispersal can continue for several weeks and usually occurs before or at flowering. Spores can travel up to five miles, which allows disease to spread to new areas rapidly. Ascospores that land on chickpea leaves and stems need at least two hours of surface moisture (dew) to germinate, but the likelihood of infection increases if leaves and stems are wet for more than six hours. After infection, symptoms of disease may not appear for several days. Once pycnidia are formed in lesions, they can produce asexual spores (conidia). Conidia are dispersed by rain or other moisture on to surrounding plants, where they cause new infections. Repeated infection cycles can occur if conditions are favorable, allowing the disease to spread quickly through a field.

Figure 4. **Ascochyta blight lesions on stem. Note pycnidia arranged in concentric rings.** (Photo by Sam Markell)

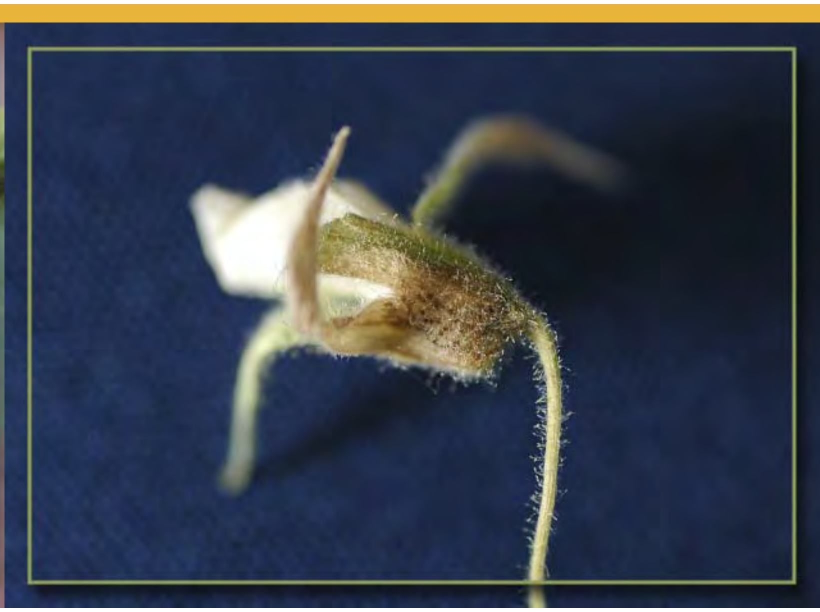

Figure 5. Ascochyta blight lesion with pycnidia on chickpea flower. (Photo by Sam Markell)

Management

Managing Ascochyta blight requires an integrated approach to achieve effective results. Integrated pest management steps include:

Resistance — At the time of printing, no chickpea varieties have complete resistance to Ascochyta blight. However, some varieties have moderate levels of resistance under North Dakota conditions. Variety selection is largely market driven, but selecting moderately resistant varieties, such as the small kabuli/desi-type chickpeas, will make disease management easier.

Rotation — Rotate crops so that chickpea is grown only on the same ground once every three years. If possible, avoid growing chickpeas adjacent to fields that had chickpeas planted the year before.

Certified Seed — Always plant certified disease-free chickpea seed. The Ascochyta blight pathogen grows from the seed to the seedling and even a few infected seedlings can be a source of disease spread throughout a field.

Seed Treatments — If bin-run seed is used, having it tested each year for Ascochyta blight infection is critical. Seed infection levels of less than 0.3 percent are considered acceptable, and we recommend that seed also be treated with a fungicide for Ascochyta blight. Fungicide seed treatments effective against Ascochyta blight are often different than seed treatment used for other soil-borne diseases, such as Pythium. For information regarding fungicide seed treatments, refer to the most current “North Dakota Field Crop Fungicide Guide” (PP-622) for information on registered products.

Fungicides — Under favorable environmental conditions for disease, fungicide applications are an integral component of control. However, fungicide selection and rotation should be approached conscientiously to obtain good disease control and to prevent the Ascochyta blight pathogen from developing fungicide resistance. Consult with your county agent or other knowledgeable personnel for the latest information on fungicide selection and use.

In general, preventative fungicides should be applied prior to flowering and before disease develops in a field. These fungicides will provide a barrier on the surface of the plant that prevents spores from causing infection. This can delay the onset of disease epidemics.

Fields should be scouted regularly to determine the onset of Ascochyta blight in the field. At flowering, or once disease has developed, fungicides with a systemic mode of action should be applied. These fungicides will move short distances in the plant from the site of deposition and help prevent disease infection and spread. Rotate fungicide **FRAC groups** so that fungicides with the same mode of action are not applied in consecutive sprays. This practice will reduce the selection pressure on Ascochyta blight that leads to fungicide resistance. FRAC group information is found on the front of the fungicide label and in the "North Dakota Field Crop Fungicide Guide" (PP-622). Always apply fungicides at label rates and follow label restrictions.

At the time of printing, fungicides in FRAC group 11 are not recommended. The Ascochyta blight pathogen first was found to have resistance to these fungicides in 2005 in North Dakota, and widespread fungicide resistance was observed in 2006 in North Dakota. FRAC group 11 fungicide resistance has also been observed in Montana. FRAC group 11 fungicides do not control Ascochyta blight in areas where the pathogen is resistant. In fungicide studies conducted in Minot, N.D., in 2007, yield from chickpea plots sprayed with FRAC 11 fungicides was the same the nontreated control, whereas yield from plots sprayed with other FRAC groups was two to three times higher.

The number of fungicide applications will vary depending on the variety of chickpea grown, as well as weather conditions and level of disease in the field. In general, if a field has low levels of disease and weather conditions are hot and dry, the length of time between fungicide applications can be increased. Varieties with moderate levels of resistance, such as the small kabuli or desi-type chickpeas, also may require fewer fungicide applications to manage disease.

Several foliar fungicides are available for use on Ascochyta blight of chickpea and these can be effective when used along with other disease management strategies. Refer to the most current "North Dakota Field Crop Fungicide Guide" (PP-622) for updated information on products and rates for application.

For more information on this and other topics, see: www.ag.ndsu.edu

1.5M-6-08

SDHI
Working Group

FRAC
FUNGICIDE RESISTANCE
ACTION COMMITTEE

List of fungal species with resistance reports towards SDHI fungicides and mutations in the succinate dehydrogenase gene (updated March 2012)

Species name	Reported from host	Origin	Resistance mechanism (Subunit-mutation)	Reference
Ustilago maydis	(Laboratory)	Laboratory mutants	B-H257L	1
Mycosphaerella graminicola	(Laboratory)	Laboratory mutants	B-H267Y/R/L, B-I269V, C-H152R, C-N86K, D-H139E and many others	2-6
Aspergillus oryzae	(Laboratory)	Laboratory mutants	B-H249Y/L/N, C-T90I, D-D124E	7
Botrytis cinerea	Different hosts	Laboratory mutants, Field	B-P225L/T/F, B-H272Y/R/L, B-N230I, D-H132R	8-11
Botrytis elliptica	Lilies	Field	B-H272Y/R	6, 12
Alternaria alternata	Pistachio	Field	B-H277Y/R, C-H134R, D-D123E, D-H133R	13, 14, 15
Ustilago maydis	(Laboratory)	Laboratory mutants	B-H257L	1

Species name	Reported from host	Origin	Resistance mechanism (Subunit-mutation)	Reference
Mycosphaerella graminicola	(Laboratory)	Laboratory mutants	B-H267Y/R/L, B-I269V, C-H152R, C-N86K, D-H139E and many others	2-6
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Botrytis cinerea	Different hosts	Laboratory mutants, Field	B-P225L/T/F, B-H272Y/R/L, B-N230I, D-H132R	8-11
Botrytis elliptica	Lilies	Field	B-H272Y/R	6, 12
Alternaria alternata	Pistachio	Field	B-H277Y/R, C-H134R, D-D123E, D-H133R	13, 14, 15
Corynespora cassiicola	Cucurbits	Field	B-H287Y/R, C-S73P, D-S89P	16, 17
Didymella bryoniae	Cucurbits	Field	B-H277R/Y	12, 18
Podosphaera xanthii	Cucurbits	Field	B-H->Y	12
Sclerotinia sclerotiorum	Oilseed rape	Field	D-H132R	5, 12, 19
Stemphylium botryose	Asparagus	Field	B-P225L, H272Y/R	12

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Crambe, Industrial Rapeseed, and Tung Provide Valuable Oils

In 1996, crambe is again being grown commercially, while industrial rapeseed acreage is down from previous years. Tung oil is being produced in the United States for the first time since 1973. Glycerine markets remain tight, as demand continues to outpace supply. Biodiesel commercialization faces a number of regulatory and market challenges in the United States.

Crambe Again in Commercial Production

The American Renewable Oilseed Association (AROA), an organization of crambe growers, contracted with 145 farmers in 1996 to grow 22,000 acres of crambe. No commercial acreage was planted in 1995 because much of the crambe oil produced in 1994 had not been sold prior to spring planting. Commercial crambe production began in North Dakota in 1990, and U.S. acreage peaked in 1993 at 57,683 acres (table 4). (See the June 1993 and the September 1995 issues of this report for more information on crambe supply and uses.)

All of the 1996 acreage is in North Dakota. As of mid-July, about 19,000 acres were in good to excellent condition. There is no predetermined contract price this year, but producers are likely to receive between 11.5 and 12 cents per pound of seed harvested. The crop will be toll processed by Archer Daniels Midland at its Enderlin, North Dakota, oilseed crushing plant. AROA has contracted with Witco Corporation, headquartered in Greenwich, Connecticut, to buy the crambe oil and will market the crambe meal to feed manufacturers for beef finishing rations.

AROA has set up a separate steering committee and business to develop a production, processing, and marketing infrastructure for novel oilseeds in the Northern Great Plains. The grower-owned company, AgGrow Oils, plans to offer stock to growers this December, construct a 200-ton-per-day crushing facility in 1997, and begin operation with the 1997 crop. Negotiations are underway that include contracting for 30,000 to 60,000 acres of crambe annually and other novel oilseeds such as high-oleic sunflower and safflower, flax, and possibly specialty canolas.

Table 4--Crambe acreage, United States, 1990-96 1/

Year	Planted area	Yield 2/	Production
	Acres	Pounds/acre	1,000 pounds
1990	2,359 3/	988	2,330 4/
1991	4,475 3/	1,153	5,160 4/
1992	23,204 5/	1,057	24,538 4/
1993	57,683 5/	972	56,090
1994	43,925 3/	1,350	59,200 6/
1995	400 7/	N.A.	N.A.
1996	22,000 3/	N.A.	N.A.

N.A. = Not available. 1/ Commercial acreage. 2/ North Dakota only. 3/ Contracted acreage. 4/ Net crop crushed. 5/ Acreage certified by the Farm Service Agency. 6/ Estimated. 7/ Acreage planted in 1995 was for seed production only.

Source: North Dakota State University.

U.S. Industrial Rapeseed Production Declines

Like crambe oil, industrial rapeseed oil contains high amounts of erucic acid. To meet industry requirements, industrial rapeseed oil must contain at least 45 percent erucic acid. In contrast, canola and other special types of rapeseed, such as high-lauric canola, have been bred or genetically engineered to contain different fatty acids in their oils. Canola oil is used for edible consumption and, according to Food and Drug Administration standards, must contain less than 2 percent erucic acid. Canola is the name generally applied to rapeseed that has low amounts of erucic acid in its oil and low levels of glucosinolates in its meal.

Cross pollination can occur if industrial rapeseed and canola are planted in adjacent fields, resulting in an oil with an intermediate erucic acid content that would be useless for either application. Visually, the seeds of the two types are identical; only testing can differentiate their characteristics. In the Pacific Northwest, where both types are grown, a couple of States have designated production regions to address the cross-pollination issue. Idaho established six production areas in 1986 and Washington State finalized rules and regulations for 12 production districts in 1988.

Industrial rapeseed has been grown in the Pacific Northwest for over 40 years. It was also produced in the South during the late 1980's and early 1990's. Harvested acreage of industrial rapeseed has declined from 19,400 acres in 1987/88 to 2,400 in 1995/96 (table 5). During the same period, domestic production has dropped from 22 million pounds to an estimated 3 million pounds.

In the Pacific Northwest, industrial rapeseed is produced for birdseed and oil. Historically, birdseed has accounted for at least 50 percent of production, according to Andrew Thostenson, a former merchandiser with Spectrum Crop Development, a canola and rapeseed merchandizing firm in Clarkston, Washington. After becoming familiar with canola, birdseed manufacturers now buy either industrial rapeseed or canola, whichever is cheaper.

The only known U.S. crusher of industrial rapeseed is Koch Agricultural Services of Great Falls, Montana. According to Steve Chambers, a marketing manager for the company, Koch contracts for seed and buys it on the open

Table 5--Industrial rapeseed, acreage planted, harvested, yield, production, and value, United States, 1987-95

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 pounds	Million dollars
1987	20.0	19.4	22.7	21,981	N.A.
1988	13.5	13.1	24.1	15,822	N.A.
1989	14.0	13.6	28.2	19,143	2.01
1990	15.0	14.6	31.2	22,717	2.33
1991	18.2	15.6	20.7	16,146	1.63
1992	12.0	9.8	29.5	14,455	1.45
1993	7.2	6.1	24.4	7,442	0.76
1994 1/	7.4	6.7	37.6	12,596	1.29
1995 2/	2.5	2.4	25.1	3,012	0.38

N.A. = Not available. 1/ Preliminary. 2/ Forecast.

market. In addition, unprocessed seed is exported to Japan, where it is crushed and the oil used as lubricants in the steel manufacturing industry and the meal used as fertilizer.

The Market for Erucic-Acid Oils Remains Tight

Charles Leonard, an oleochemical industry expert, estimates world consumption of high-erucic-acid oils for industrial applications at about 125 million pounds per year, with the United States accounting for about 35 million pounds. This is up from a 1991 industry estimate of 25 to 30 million pounds for the U.S. share. Other major industrial users are Europe and Japan.

Two 1996 articles in the *Chemical Marketing Reporter,* quoting industry sources, estimate the U.S. supply of industrial rapeseed oil at about 5 million pounds of domestic production and around 25 to 30 million pounds shipped in from Canada and Europe (*1*, *2*). This is similar to USDA estimates of industrial-rapeseed-oil production and imports for the late 1980's and early 1990's (table 19). However, according to USDA figures, U.S. rapeseed oil production has declined from 5.7 million pounds in 1991/92 to an estimated 836,000 pounds in 1995/96, while imports have averaged 9.8 million pounds during the same period.

Although no data are available from industry sources or USDA on U.S. crambe-oil production, crambe oil reportedly gained acceptance in the U.S. high-erucic-acid market in the early 1990's when Humko Chemical, a division of Witco Corporation, began relying on it as a domestic source of erucic acid. Humko currently uses both industrial rapeseed and crambe oils (*4*), but supplies of crambe oil are reported as limited.

World supplies of high-erucic acid oils have tightened in the last few years as older rapeseed varieties have been replaced with canola types. For example, Poland and the former East Germany historically have been heavy producers of industrial rapeseed oil because much was used for edible purposes. However, since the breakup of the Eastern Bloc, industrial rapeseed has yielded to canola because industrial rapeseed oil cannot be sold to European Union countries for edible purposes. Erucic acid-containing rapeseed varieties are now considered specialty crops in Canada and Europe. China, Russia, and India, however, still use high-erucic acid rapeseed oil for human consumption.

World supplies of industrial rapeseed oil are expected to remain tight. Although Canadian production is fairly stable, European production is below expectations again this year. According to a spokesman for Croda Universal, Inc., which is headquartered in the United Kingdom, the 1996 European harvest of industrial rapeseed will be 1,000 hectares short of what is needed (*1*). The U.S. market for high-erucic-acid oils will likely be served mostly by domestic production and imports from Canada. Calgene Chemical, a subsidiary of Calgene, Inc., of Davis, California, has an agreement with CanAmera Foods of Oakville, Ontario (North America's largest rapeseed processor) to distribute some of CanAmera's industrial rapeseed oil in the United States.

Prices for erucic-acid oils have increased as supplies have tightened (*1*, *2*). Higher world prices have been felt in erucic-acid product markets. Three producers of erucamide—Witco Corporation, Croda Universal, Inc., and Akzo Nobel Chemicals, Inc.—raised the prices of their erucamide products by 20 cents per pound in April and May 1995 due in part to high prices of high-erucic-acid oils. Because of current high prices and the prospects of continued tight supplies, the companies increased their erucamide prices again in May and June 1996, Akzo by 8 cents per pound and Witco and Croda by 25 cents per pound. While U.S.-based Witco uses both crambe and industrial rapeseed oils, the other two manufacturers use only industrial rapeseed oil.

High-Erucic-Acid Oils Have Traditional And Emerging Uses

The primary market for high-erucic-acid oils is erucamide. Plastic-film manufacturers have used erucamide for decades in bread wrappers and garbage bags. It lubricates the extruding machine during manufacture of thin plastic films. After processing, the erucamide migrates to the surface of the films and keeps them from clinging together. Two cheaper amides, stearamide and oleamide, cannot individually provide the critical properties that erucamide does. Therefore, erucamide is preferred, even at about twice the price.

Charles Leonard estimates that 48 million pounds of high-erucic-acid oils are used worldwide in making about 15 million pounds of erucamide per year (table 6). Erucamide is sold by a half dozen oleochemical producers in the United States, Europe, and Asia. Witco is the largest worldwide producer and marketer, supplying product from its Memphis, Tennessee, production facility. Leonard esti-

Table 6--Estimated worldwide use of high-erucic-acid oils for industrial applications

Derivative	Application	Volume of oil used	Volume of derivative produced
		1,000 pounds	
Erucamide	Slip agent	48,000	15,000
Erucyl alcohol	Emollient	30,000	10,000
Various fatty nitrogen derivatives	Hair care and textile softening	18,000	6,000
Behenyl alcohol	Pour point depressant	18,000	6,000
Esters and others	Lubricants	6,000	4,000-5,000
Gyceryl tribehenate	Food emulsifier	2,500-3,000	2,500-3,000
Silver behenate	Photography	~750	~250
Total		123,250-123,750	43,750-45,250

Source: Charles Leonard, "Sources and Commercial Applications of High-Erucic Vegetable Oils," Lipid Technology, July/August 1994.

mates that erucamide market growth roughly parallels the growth of polyolefin film sales, which in recent years has ranged from 4 to 6 percent per year.

Cationic surfactants that function as active ingredients in personal-care products, laundry softeners, and other household products appear to be an up-and-coming use for high-erucic-acid oils. Some companies in Japan and the United States are using cationic surfactants derived from 22-carbon fatty acids, such as those found in rapeseed, crambe, and meadowfoam oils, as the active ingredient in hair conditioners. At least two U.S. companies are doing research in this area. An estimated 18 million pounds of high-erucic-acid oils are used worldwide to manufacture roughly 6 million pounds of cationic surfactants.

Because rapeseed and crambe oils have a high degree of lubricity, they also are used either directly as lubricants or in lubricant formulations. They are used as spinning lubricants in the textile, steel, and shipping industries; as cutting, metal-forming, rolling, fabricating, and drilling oils; and as marine lubes. For example, Calgene Chemical offers a line of erucic-acid esters to the textile and automotive fluids industries. International Lubricants, Inc., of Seattle, Washington, sells erucic-acid-oil-based automatic transmission fluid additives, cutting oils, hydraulic oils, and power steering fluids. The transmission fluid additives are currently used by five European automobile manufacturers and U.S. transmission repair shops, and are newly available in retail auto parts stores.

One of the selling points of the erucic-acid-oil products offered by International Lubricants is their enhanced biodegradability compared to their petroleum-based counterparts. Thus, they are said to be more environmentally friendly. Several companies are reportedly in the market for industrial rapeseed and canola oils for lubricant applications because of their environmental attributes, which has caused a recent increase in demand (*2*).

Another use of erucic-acid oils in response to environmental concerns is in the production of concrete mold-release agents. Leahy-Wolf Company of Franklin Park, Illinois, has developed and patented a biodegradable concrete-release agent based on industrial rapeseed oil, and is marketing it through U.S. distributors. Construction companies and precasters of concrete structures, such as sewer pipes, vaults, and bunkers, coat their molds and forms with release agents to facilitate the release of the hardened concrete. Often these compounds, which are traditionally petroleum-based, leach out of the mold or concrete and end up in the groundwater. Construction firms and precasters have had to modify their operations, however, to meet increasingly strict State and local regulations that limit the release of petroleum-based chemicals into the environment.

Tung Oil Production Begins Again In the United States

Tung oil, a nonedible vegetable oil, is scheduled to be produced again in the United States beginning in December 1996. The sole U.S. producer will be American Tung Oil Corporation (ATO) of Lumberton, Mississippi. ATO was created 4 years ago by Blake Hanson of Industrial Oil Products (IOP) of Woodbury, New York, to revive domestic production of tung oil, which has not occurred since March 1973. IOP is the largest supplier of tung oil in the Western Hemisphere.

Tung oil, produced from the fruit (nut) of the tung tree, contains mainly eleostearic fatty acid, with smaller amounts of oleic, linoleic, and palmitic fatty acids. Tung oil's physical and chemical properties make it useful as a protective coating, solvent, and/or drying agent in various paints, varnishes, lacquers, resins, fiberboard, concrete sealers, electronic circuit boards, and printing inks. Its superior drying properties allow it to be sold at a price premium compared to other vegetable drying oils such as linseed oil (tables 37 and 40). Various new applications for tung oil and its byproducts also are being developed for use in products such as cosmetics, insecticides, and lubricants.

Tung oil is produced commercially mostly in subtropical regions, primarily in China and South America. Tung oil production is small compared with that of many other vegetable oils. Estimated world production averages 50,000 metric tons a year. Major producers include China (about 42,000 metric tons), Paraguay (about 4,000 metric tons), Argentina (about 3,000 metric tons), and Brazil (about 1,000 tons) (*3*).

The world supply of tung oil can be very volatile, as tung orchards can be greatly affected by adverse weather conditions and by age of the orchards. Though hearty, fast growing, and naturally resistant to disease and insects (tung trees require no fungicides or pesticides), tung trees are very sensitive to temperature levels during fruit-set. There is also some concern that aging orchards in South America

Table 7--U.S. imports of tung oil and its fractions, volume and value, by country, 1991-95

Country	1991	1992	1993	1994	1995
	Metric tons				
Argentina	2,380	3,455	2,137	1,627	2,797
Paraguay	3,085	823	1,557	2,526	1,235
China	179	318	546	1,206	379
Brazil	0	400	0	0	0
Other	0	0	30	42	16
Total	5,645	4,996	4,270	5,401	4,427
	Thousand dollars				
Argentina	2,584	6,828	4,175	1,881	2,739
Paraguay	3,051	825	2,801	2,438	1,044
China	206	709	926	1,201	382
Brazil	0	525	0	0	0
Other	0	0	70	43	18
Total	5,841	8,888	7,971	5,563	4,182

Source: U.S. Department of Commerce, Bureau of the Census.

may be losing productivity. In addition, Brazil produces primarily for domestic consumption and China uses as much as 25,000 metric tons of oil per year (*3*). A poor crop in any of the major producing countries often leads to volatile tung oil prices.

The current U.S. tung oil market is supplied largely by Argentina and Paraguay. During 1991-95, 50 percent of U.S. imports of tung oil came from Argentina, another 37 percent from Paraguay, and 11 percent from China (table 7). Small South American crops in 1991/92 and 1992/93 led to extremely high tung oil prices in the United States from mid-1992 through most of 1993 (table 40). Good crops in South America and China in 1993/94 helped prices decline in 1994. Decreased demand from Japan and Europe in 1994 and 1995 helped keep U.S. tung oil prices down, despite smaller crops the last two seasons.

However, U.S. tung oil prices have increased slightly this summer, and may rise even further, as South America and China are anticipating relatively small crops again this season. In addition, a lower supply of Chinese tung oil and renewed Japanese demand due to a strengthening economy are likely to put more upward pressure on prices for South American tung oil. How far prices will rise remains to be seen, but the market's continued volatility will likely encourage some companies to use other natural and synthetic alternatives in their product formulations.

Tung Production Is Centered in Mississippi

ATO is confident its revitalization of domestic production will help stabilize tung oil supply and prices. The company is currently planting its initial goal of 5,000 acres of tung trees, 500 acres of which will be company owned, and the rest contracted with individual growers. Current production of tung nuts is from several hundred acres of 3- to 4-year-old trees in southern Mississippi, although ATO is open to contracting with growers in other parts of the U.S. production region (a 100-mile wide area along the Gulf Coast extending from north central Florida into eastern Texas). The oil will be extracted at ATO's Tung Ridge Ranch mill near Poplarville, Mississippi, and will be distributed by IOP.

Blake Hanson, president of IOP, projects U.S. production for 1996 to be about 50,000 pounds of oil, which will have little impact on world markets. However, Mr. Hanson notes that as trees reach production maturity in about 4 to 5 years (when they will be 7 to 8 years old), the United States will be a significant producer of tung oil. He projects that in 5 years, U.S. production will be about 2 million pounds of oil. In 8 years, if all 5,000 acres are planted and producing, production could be over 4 million pounds. These trees could sustain commercial production for about 25 years, unless destroyed by natural disaster.

Prior U.S. production of tung oil occurred between the late 1930's and 1972, peaking in 1958 at 44.8 million pounds. Indicative of the tung oil industry, production during this period varied greatly from year to year, due primarily to the crop's natural bearing cycle and late frosts during budding. Weather will still be an important factor in this current production effort. However, higher fruit yields than were realized in previous decades are anticipated due to the use of heavy bearing varieties and improved farming methods. Harvesting costs will be reduced by mechanical harvesting, which is not used internationally and was not employed in the United States until the late 1960's. In addition, ATO plans to store surplus tung oil during years of over-production in an attempt to stabilize market prices during years of under-production. Under proper conditions, tung oil can be stored for several years.

Tung Oil Market Has Changed

The U.S. market for tung oil has changed dramatically during the past half-century. U.S. industrial use of tung oil peaked in 1947 at 130.4 million pounds, with over 75 percent used by the paint and varnish industry, and about 10 percent used by the resins industry. However, in the late 1940's, as the protective coatings industries shifted to lower cost substitutes, including synthetics and other oils, domestic consumption of tung oil declined dramatically. By 1961, domestic use had fallen to around 35.9 million pounds, with 73 percent consumed by the paint and varnish industry and 15 percent by the resins industry.

A general shift from the use of vegetable oil-based paints, which often require petrochemical solvents to reduce paint viscosity, in favor of water-based latex paints since the 1960's, contributed to a further decline in the use of tung oil. In 1994, domestic use was estimated at 9.3 million pounds, with 71 percent consumed by the resins and plastics industry, and 13 percent by the paint and varnish industry (table 30). The 1995 estimate for domestic use of tung oil is 20.2 million pounds, but this, according to industry sources, is likely overstated. One industry source estimates current tung oil use at around 10 million pounds, broken down as follows: 40 percent in paints, varnishes, and wood coatings; 40 percent in inks and overprint varnishes for graphic arts; 14 percent in fiberboard and other building materials; and 6 percent in miscellaneous items like caulk, concrete sealers, and brakepads (*3*).

Current and future uses of tung oil depend on several factors, including various regulations in the Clean Air Act Amendments of 1990 (CAAA) that require coatings manufacturers to reduce volatile organic compounds (VOC's) in their formulations. Petrochemicals such as toluene, xylene, methyl ethyl ketone, and methyl isobutyl ketone must be eliminated entirely. Chlorinated solvents must be removed from formulations because of their ozone-damaging potential. Because of these regulations, many companies are formulating new products, a number of which use tung oil because of its good drying ability and inherent solvency. However, these regulations have also caused the phaseout of some older tung-oil-containing products that include petrochemical solvents, which contain VOC's. Therefore, the net effects of CAAA regulations for the coatings industries will continue to play a major role in tung oil consumption. (For more information on VOC's and solvent replacements, see the fats and oils section of the June 1994 issue of this report).

In addition to air quality regulations, future uses of tung oil are likely to depend upon market stabilization, price reduction, and the development of new uses and new modified-tung oil products. Lower prices and the success of these new products will be vital to increasing the demand for tung oil.

Glycerine Uses Continue To Expand

Glycerine is a byproduct of producing soaps, fatty acids, and fatty esters from the triglycerides in vegetable oils and animal fats. Primary sources of glycerine include tallow, palm kernel oil, and coconut oil. Dow Chemical is presently the only U.S. manufacturer producing synthetic glycerine from petrochemicals.

Although the terms glycerine, glycerin, and glycerol often are used interchangeably, subtle differences in their definitions do exist. Glycerine is the commonly used commercial name in the United States for products whose principal component is glycerol. Glycerin refers to purified commercial products containing 95 percent or more of glycerol. Glycerol is the chemical compound 1,2,3-propanetriol.

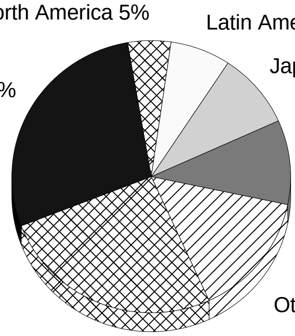
Worldwide production and consumption of glycerine is estimated at 1.5 billion pounds in 1995, up 10 percent from a year earlier. Europe and the United States account for over half of the consumption volume (figure 3). The supply of natural glycerine is directly related to fatty-acid and fatty-ester production. More sources of byproduct glycerine have been identified in recent years as uses for vegetable oils have increased, including processes for manufacturing biodiesel, fat substitutes, and polyols. In Europe, an estimated 100 million pounds of glycerine is currently produced in biodiesel production plants.

In 1995, the United States had an estimated glycerine production capacity of 522.5 million pounds. Roughly 25 percent of that is synthetic glycerine. Procter & Gamble and Dow Chemical are the two largest U.S. producers. In the United States, eight natural glycerine producers, including Procter & Gamble, currently have 15 production plants in operation. Dow has one synthetic glycerine plant.

Glycerine is used in over 1,500 applications and end products. It has an extensive list of traditional uses that include drugs, cosmetics, resins, polymers, explosives, toothpaste, tobacco processing, paints, paper manufacturing, lubricants, textiles, and rubber (see the December 1993 issue of this report for more information). Pharmaceuticals, toothpaste, and personal-care products were major uses in 1995 (figure 4), and more applications are being developed all the time. For example, because of its environmentally friendly characteristics, glycerine has potential in new-generation fabric softeners, deicing fluids, and drilling fluids.

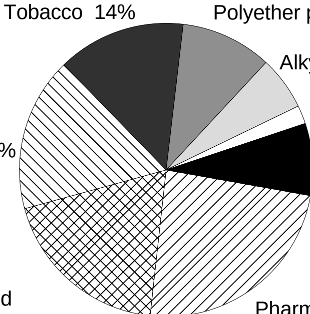
The glycerine market has been tight since 1992. While world production has increased, rising demand continues to outpace supply. Glycerine competes with sorbitol and propylene glycol in food, beverage, and tobacco applications, but these and other glycerine substitutes may not be readily accepted by consumers because of their taste. Although tight supply conditions are expected to continue, declining cellophane and explosive use will compensate for some of the projected growth in newly identified applications, such as fabric softeners, sports drinks, and

Figure 3
Estimated World Consumption of Glycerine, By Country, 1995 1/



1/ Worldwide glycerine production and consumption is estimated at 1.5 billion pounds in 1995.
Source: Irshad Ahmed, Booz-Allen and Hamilton Inc., McLean, Virginia, July 1996.

Figure 4
Estimated End Uses of Glycerine In the United States, 1995 1/



1/ U.S. glycerine production capacity is estimated at 522.5 million pounds in 1995.
Source: Irshad Ahmed, Booz-Allen & Hamilton Inc., McLean, Virginia, July 1996.

deicing fluids.

Glycerine prices fluctuate widely, depending on supply and demand factors. Historically, glycerine prices have ranged from 51 cents to $1.08 per pound. Current prices are between $1.05 and $1.08 per pound. High 1996 prices are due to a worldwide shortage of glycerine estimated at roughly 100 million pounds. Demand is strong because of new applications, an unwillingness on the part of end-product manufacturers to switch to substitutes, and environmental pressures to enhance end-product biodegradability.

To satisfy the rising demand for glycerine, producers are boosting capacity by an estimated 50 million pounds through expansion and debottlenecking of existing facilities. Henkel Corporation, which is headquartered in Germany, is investing $60 million to add 10 to 20 percent to its worldwide glycerine capacity.

U.S. demand in 1995 is estimated at 420 million pounds. The market is expected to grow 3 to 4 percent per year through 2000, higher than its historical growth rate of 2 to 3 percent per year, due to a wide variety of newer applications and product lines. By the year 2000, demand is projected to reach 500 million pounds. Glycerine prices are expected to remain high because of continued increases in demand.

Fuel and Environmental Regulations Offer Challenges for Biodiesel

One potential source of glycerine in the United States is biodiesel. However, despite new market opportunities for alternative fuels created by CAAA and the Energy Policy Act of 1992 (EPACT), biodiesel commercialization still faces a number of regulatory and market barriers.

One challenge stems from EPACT's alternative-fuel, motor-fleet regulations that require Federal, State, and alternative fuel providers to increase their purchases of alternative-fueled vehicles. In a March 1996 final rule on the Alternative Fuel Transportation Program, the U.S. Department of Energy (DOE) concluded that neat (100 percent) biodiesel meets EPACT's criteria as an alternative fuel for this program (*5*). However, biodiesel is an expensive fuel and to lower its cost, potential users want to blend it with petroleum diesel. The most common blend used today is a mixture of 20-percent biodiesel and 80-percent petroleum diesel (B20). However, B20 vehicles have been disqualified from the Program based on the March 1996 final rule. In the absence of a special ruling on B20 or some other blend, it is unlikely that an immediate demand for biodiesel will be created through the Alternative Fuel Transportation Program. Biodiesel advocates are working with DOE to establish an appropriate blend level that will qualify as an alternative fuel.

Like most fuel producers, manufacturers of biodiesel and biodiesel blends have to meet CAAA fuel-property definitions and satisfy health-effect requirements. Hence, another regulatory hurdle stems from the U.S. Environmental Protection Agency's (EPA) current rule-making process of defining a standard diesel fuel. This definition will enable fuel manufacturers to determine whether their diesel fuels are substantially similar (sub-sim) to EPA's definition of diesel fuel in terms of chemical composition. When the final rule is implemented, most fuel manufacturers, including those of biodiesel and biodiesel blends, must either be able to prove that their fuels are sub-sim to the diesel standard or receive a waiver under CAAA Section 211(f). If fuel manufacturers are able to show that biodiesel has the same emission characteristics and the same engine degradation properties as EPA's definition of diesel fuel, they may be able to get a waiver for biodiesel. EPA expects to propose definitions for diesel fuel in December 1996, with an expected final rule in December 1997.

Biodiesel producers also have to overcome the potential public-health-effect data requirements under CAAA Section 211(b) and (c). These provisions require manufacturers to gather preliminary research data on their fuels to evaluate the potentially harmful human health effects of fuel emissions and submit this information to EPA by May 1997. Biodiesel analysts are currently conducting research that will help biodiesel comply with both the sub-sim and health-effect requirements. Negative findings from these data could delay commercialization and require the biodiesel industry to conduct a new round of expensive health-effect testing to address EPA concerns.

Another regulatory challenge for biodiesel relates to EPA's requirements on implementing particulate matter (PM) standards for pre-1994-model-year urban buses in areas with a 1980 population of more than 750,000. Finalized in 1993, the Urban Bus Retrofit Rebuild Program is designed to reduce PM exhaust emissions from older-model urban buses. Although the standards were to become effective when engines are rebuilt or replaced after January 1, 1995, EPA delayed enforcement for 1 year.

EPA has developed two compliance options to provide some flexibility to bus operators in meeting the new PM standards. The standards in both options are based on what PM reductions can be achieved by equipment certified by EPA. The first option requires an operator to install certified PM-reduction equipment on each of their buses when bus engines are rebuilt or replaced. (An urban bus engine generally undergoes two or three rebuilds during its 15-year lifetime.) The second option requires that PM levels for the entire bus fleet be below a yearly average target level at the beginning of each year. This target level can be calculated by urban bus operators through a computer program provided by EPA. Average target levels will vary by engine age and PM-reduction requirements for the various engine types within the fleet.

To date, five technologies in the form of rebuild kits and/or catalytic converters have been certified by EPA for the Urban Bus Retrofit Rebuild Program. In June 1995, Twin Rivers Technologies, a Massachusetts-based company, submitted a certification package to EPA different from the five technologies. This package aims to lower PM in some bus engines through the combined use of B20 and a catalytic converter. Even with EPA certification, the B20 package still faces an economic challenge, because under the first compliance option, the certified rebuild kits and catalytic converters are cheaper to use than the B20 package. Biodiesel may have a better opportunity under the second option, depending on how the B20 package affects fleet operators' average PM target levels.

Additional Research Is Needed

Research is needed to help biodiesel comply with government regulations, including exploring its environmental and health benefits and economic feasibility. USDA, DOE, and the National Biodiesel Board (NBB) have been working together to investigate these topics. For example, representatives from these organizations, along with university and other researchers, recently attended a biodiesel workshop at Mammoth Hot Springs, Wyoming, May 21-22, 1996. DOE, through its Pacific Northwest and Alaska Regional Bioenergy Program, and the University of Idaho's National Center for Advanced Transportation Technology sponsored the event, entitled Commercialization of Biodiesel: Environmental and Health Effects Workshop. The workshop's purpose was to assess the health and environmental effects associated with emissions from compression ignition engines and to identify the benefits to be gained by using biodiesel.

Workshop participants agreed that, when compared to petroleum diesel, neat biodiesel generally offers the following known environmental and health benefits: biodegradability; reductions in soot, greenhouse gases, and some emission levels; and a positive energy balance. Several other benefits were identified, such as reduced toxicity and lower amounts of ozone precursors and mutagenic and carcinogenic compounds. However, additional data are needed to verify these potential benefits and how they change when blended with petroleum diesel. Workshop organizers hope to use these known and potential environmental and health benefits to help meet CAAA health-effect data requirements and as an education campaign to boost biodiesel commercialization.

An important opportunity to show biodiesel's net environmental benefits will be an analysis of biodiesel's life-cycle. The main purpose of this joint USDA-DOE study is to compare the environmental effects of biodiesel versus petroleum diesel. Life-cycle analysis accounts for all production activities and raw materials involved in producing a product. For example, with biodiesel, the analysis begins with assessing the environmental effects of growing soybeans, including the production of seed, fertilizer, and other inputs used on the farm. After the inputs aspect is analyzed, the environmental effects are then examined through the product's manufacturing, followed by consumption, and finally the waste stage (recycling or disposal). A final report is expected before the end of the year. [*Crambe and industrial rapeseed*: Lewrene Glaser, ERS, (202) 219-0091, lkglaser@econ.ag.gov. *Tung*: Charles Plummer, ERS, (202) 219-0717, cplummer@econ.ag.gov, and Sandra Pyles, ERS. *Glycerine*: Irshad Ahmed, Booz-Allen & Hamilton, (703) 917-2060, 71332.3160@compuserve.com. *Biodiesel*: Anton Raneses, ERS, (202) 219-0752, araneses@econ.ag.gov; Jim Duffield, ERS/OENU, (202) 501-6255, duffield@econ.ag.gov; Leroy Watson, NBB, (202) 331-7373; and Craig Chase, Technical and Engineering Management, (307) 527-6912, 104723.623@compuserve.com.]

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PATHOGEN RISK LIST

(December 2005)

Purpose

Information is provided about the risk of pathogens to develop resistance to fungicides under specific agronomic conditions.

Introduction

Because no scientific criteria are available to accurately determine the risk of a pathogen to develop resistance, our classification is based on experience and reported resistance claims over the last 40 years. Generally, the risk increases when a pathogen undergoes many and short disease cycles per season, the dispersal through spores over time and space is high, sexual recombination is mandatory in the disease cycle and the competitive ability of resistant individual is at least as high as that of the wild type (in the absence of selection pressure). Furthermore, the risk is considered as high when resistance evolved already after few years of product use.

Examples to illustrate pathogen risk

It is quite easy to detect single isolates of a pathogen with reduced sensitivity to a given fungicide but only their frequency over time and space will decide whether product performance will be affected significantly. Therefore, we consider the pathogen risk as medium to high only if resistance was reported in commercial situations for more than one fungicide class.

Wheat powdery mildew is considered as high risk pathogen because resistance evolved to six different chemical classes within 2 to 5 years, whereas wheat brown rust is a low risk pathogen because no resistance evolved to the major fungicide classes (DMIs, QoIs, morpholines) used against this pathogen, even not after 25 year (DMIs). Eyespot in wheat bears a medium risk, resistance evolved to MBCs and prochloraz (DMIs) only after 10 to 15 years.

An interesting case is *Phytophthora infestans* that developed resistance quite rapidly to the phenylamide fungicides but not at all to dimethomorph, iprovalicarb, fluazinam, cymoxanil, azoxystrobin and fenamidone (QoI fungicides), cyazofamid (QiI fungicide), propamocarb, and organotins. Therefore, we re-classified P. infestans as high risk pathogen for the RNA polymerase target only and as a medium risk pathogen for all other modes of action (see Table 1 and 2).

Pathogen risk classes

The following plant pathogens (Table 1) from major world markets have evolved resistance to fungicides in a time span sufficiently short to be a serious threat to the commercial success of more than one fungicide class.

Table 1: Plant pathogens accepted as showing a high risk of development of resistance to fungicides (adapted from EPPO 2002, FRAC Monograph No. 3, Russell, 2003)

Pathogen	**Crop**	**Disease**
Botryotinia fuckeliana (Botrytis cinerea)	various, especially grapevine	grey mould
Erysiphe (=Blumeria) graminis	wheat/barley	powdery mildew
Mycosphaerella fijiensis	banana	black sigatoka
Penicillium spp.	citrus, various	post harvest rot
Phytophthora infestans (RNA polymerase)	potato/tomato	late blight
Plasmopara viticola	grapevine	downy mildew
Pseudoperonospora cubensis and related spp.	cucurbits, various	downy mildews
Pyricularia spp.	rice, turf	rice blast, leaf spot
Sphaerotheca fuliginea and related spp.	cucurbits, various	powdery mildews
Venturia spp.	apple, pear	scab

The following pathogens (Table 2) are regarded as posing a much lower risk because resistance is not a major problem or has been slow to develop. In some cases this due to the pattern of product use. Cases of specific isolates being classed as resistant may be known in some instances, but in commercial practice resistance has not created major disease control problems. The EPPO Guideline does not list these and decisions on baseline production must be made on individual case reviews.

Table 2: Plant pathogens accepted as showing a medium risk of development of resistance to fungicides

Pathogen	**Crop**	**Disease**
Bremia lactucae	lettuce	downy mildew
Cercospora spp.	sugar beet, peanuts, various	leaf spots
*Gibberella fujikuori**	rice	bakanae
Monilinia spp.	various	Monilia rot
Mycosphaerella graminicola (Septoria tritici)	wheat	leaf spot
Mycosphaerella musicola	banana	yellow sigatoka
Peronospora spp.	various	downy mildews
Phytophthora infestans (target outside RNA polymerase)	potato/tomato	late blight
Pyrenophora teres	barley	net blotch
Rhynchosporium secalis	barley	leaf blotch/scald
Sclerotinia spp. (especially *homoeocarpa, sclerotiorum*)	various (turf, oil seed rape)	Sclerotinia diseases, dollar spot
Tapesia spp.	wheat/barley	eyespot
*Uncinula (= Erysiphe) necator**	grapevine	powdery mildew
** The EPPO Guideline lists these pathogens as high risk pathogens of which baseline sensitivity is normally requested*		

In some cases the financial outlay in establishing baselines will not be justified by the small markets involved irrespective of their risk of resistance development. Typical pathogens and diseases are given in Table 3. Pathogens in this group are of local importance, but in commercial market terms are considered as minor pathogens. Decisions on baseline production must be made on a case by case basis. For certain pathogens (e.g. *Phytophthora infestans*), resistance occurred only to one chemical class (phenylamides) but not to others and therefore, the pathogen is considered as low risk pathogen.

Table 3: Plant pathogens with low risk of development of resistance to fungicides or of minor commercial importance

Pathogen	**Crop**	**Disease**
Alternaria spp.	various	leaf spots
Colletotrichum spp.	various	anthracnose
Fusarium and related spp.	various	Fusarioses
Hemileia vastatrix	coffee	rust
Leptosphaera (=Stagonospora) nodorum	wheat	leaf spot
Phytophthora spp. (soil borne)	various	damping off
Podosphaera leucotricha	apple	powdery mildew
Puccinia and related rust spp.	wheat/barley, various	rusts
Pythium spp.	various	damping off
Rhizoctonia spp.	various	foot and root rot
Sclerotium spp.	various	blight
Tilletia spp.	cereals	bunts
Ustilago spp.	cereals	smuts

When the pathogen risk is plotted against the inherent resistance risk of the fungicide class, the combined resistance risk for each pathogen/fungicide combination can be estimated (Figure 1).

Figure 1: Combined resistance risk diagram based on inherent fungicide risk and inherent pathogen risk (* only most important classes and groups mentioned) (according to FRAC Monograph No. 2, by K.J. Brent and D.W. Hollomon, 1998, ** QoI fungicides have been moved from medium to high risk)

Fungicide Classes *	**Fungicide Risk**	**Combined Risk**		
benzimidazoles dicarboximides phenylamides QoI fungicides **	high = 3	**3**	**6**	**9**
carboxamides SBI fungicides anilinopyrimidines phenylpyrroles phosphorothiolates	medium = 2	**2**	**4**	**6**
multi site fungicides (e.g.dithiocarbamates Copper, Sulphur) MBI-R inhibitors SAR inducers	low = 1	**1**	**2**	**3**
	Pathogen risk	low = 1	medium = 2	high = 3
	Pathogen groups *	seed borne pathogens (e.g. *Pyrenophora* spp. *Ustilago* spp.) soil-borne pathogens (e.g. *Phytophthora* spp.) rust fungi *Rhizoctonia* spp. *Tapesia* spp.	*Rhynchosporium secalis* *Septoria tritici*	*Erysiphe graminis* *Botrytis cinerea* *Penicillium* spp. *Magnaporthe grisea* *Venturia inaequalis* *Mycosphaerella fijiensis* *Phytophthora infestans*

The pathogen risk should be estimated also in regard to the local intensity of disease development that is based on weather conditions, fertilization, irrigation, cultural practices and degree of resistance of cultivars. Therefore, we propose to modify the risk diagram in the following manner (Figure 2). Detail can be found in the article written by KH Kuck, “Fungicide Resistance Management in a New Regulatory Environment”, in the Proceedings of the Reinhardsbrunn Symposium 2004 (Modern fungicides and antifungal agents, Dehne, Gisi, Kuck, Russell, eds., BCPC 2005).

Figure 2: Combined resistance risk diagram based on inherent fungicide risk, inherent pathogen risk, and agronomic risk (* only most important classes and groups mentioned) (according to Kuck, 2005)

Fungicide Classes *	**Fungicide Risk**	**Combined Risk**			**Agronomic Risk**
benzimidazoles dicarboximides phenylamides QoI fungicides	high = 6	**6** **3** **1,5**	**12** **6** **3**	**18** **9** **4,5**	high = 1 medium = 0.5 low = 0.25
carboxamides SBI fungicides anilinopyrimidines phenylpyrroles	medium = 4	**4** **2** **1**	**8** **4** **2**	**12** **6** **3**	high = 1 medium = 0.5 low = 0.25
multi site fungicides (e.g.dithiocarbamates) MBI-R inhibitors SAR inducers	low = 1	**1** **0,5** **0,25**	**2** **1** **0,5**	**3** **1,5** **0,75**	high = 1 medium = 0.5 low = 0.25
Pathogen risk		low = 1	medium = 2	high = 3	
Pathogen groups *		seed borne pathogens (e.g. *Pyrenophora* sp. *Ustilago* sp.) soil-borne pathogens (e.g. *Phytophthora* sp.) rust fungi *Rhizoctonia sp.* *Fusarium* sp.	*Uncinula necator* *Gibberella fujikuori* *Tapesia* sp. *Rhynchosporium secalis* *Pyrenophora teres* *Septoria tritici* *Sclerotinia* sp. *Monilinia* sp. *Cercospora* sp. *Phytophthora infestans*/other modes of action	*Erysiphe graminis* *Botrytis cinerea* *Plasmopara viticola* *Magnaporthe grisea* *Venturia inaequalis* *Mycosphaerella fijiensis* *Phytophthora infestans*/RNA polymerase	

cerexagri

TOPSIN® M 70WP

THIOPHANATE-METHYL FUNGICIDE
70% Wettable Powder

ACTIVE INGREDIENT: Thiophanate-methyl (dimethyl[1,2-phenylene)–bis(iminocarbonothioyl)]bis[carbamate])*	70.0%
OTHER INGREDIENTS:	30.0%
TOTAL	100.0%

*Also known as dimethyl 4,4´-o-phenylenebis[3-thioallophanate]

TOPSIN is a registered trademark of Nippon Soda Company, Ltd., and is licensed to NISSO TM LLC, and is covered by one or more of the following U.S. Patents: 3,769,308; 3,856,847; 4,020,095; and 4,029,813.

KEEP OUT OF REACH OF CHILDREN
CAUTION

FIRST AID:

If swallowed:
- Call a poison control center or doctor immediately for treatment advice.
- Have person sip a glass of water if able to swallow.
- Do not induce vomiting unless told to by a poison control center or doctor.
- Do not give anything by mouth to an unconscious person.

If in eyes:
- Hold eye open and rinse slowly and gently with water for 15-20 minutes.
- Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye.
- Call a poison control center or doctor for treatment advice.

If on skin or clothing:
- Take off contaminated clothing.
- Rinse skin immediately with plenty of water for 15-20 minutes.
- Call a poison control center or doctor for treatment advice.

If inhaled:
- Move person to fresh air.
- If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible.
- Call a poison control center or doctor for further treatment advice.

Have the product container or label with you when calling a poison control center or doctor or going for treatment.

EPA REGISTRATION NO. 73545-11 **EPA ESTABLISHMENT NO. 66196-CA-1**

Net Weight: ________ Pounds (________ Kgs.)

Sold By:

Cerexagri, Inc.
630 Freedom Business Center, Suite 402, King of Prussia, PA 19406
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PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS (AND DOMESTIC ANIMALS)

CAUTION

HARMFUL IF SWALLOWED, INHALED, OR ABSORBED THROUGH SKIN. CAUSES MODERATE EYE IRRITATION. Avoid contact with skin, eyes, or clothing. Avoid breathing dust or spray mist.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

WPS Uses: Applicators and other handlers who handle this pesticide for any use covered by the Worker Protection Standard, 40 CFR Part 170, must wear: long-sleeved shirt and long pants, chemical-resistant gloves made from any waterproof material, and shoes plus socks.

Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

USER SAFETY RECOMMENDATIONS

Users should:

- Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

ENVIRONMENTAL HAZARDS

This pesticide is toxic to fish.

Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not apply where runoff is likely to occur. Do not contaminate water when disposing of equipment washwaters.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your State or Tribe, consult the agency responsible for pesticide regulation.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about personal protective equipment (PPE), and restricted-entry interval. The requirements in this box only apply to uses of this product that are covered by the Worker Protection Standard.

Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 12 hours unless otherwise noted on this label for specific crops.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil, or water, is: coveralls, chemical-resistant gloves made from any waterproof material, shoes plus socks.

STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal.

PESTICIDE STORAGE: Store in the original container in a dry area. Do not store in a manner where cross-contamination with other pesticides, fertilizers, food or feed could occur. If spilled during storage or handling, sweep up spillage and dispose of in accordance with the Pesticide Disposal Instructions listed below.

PESTICIDE DISPOSAL: Pesticide wastes are toxic. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal Law. If these wastes cannot be disposed of according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.

CONTAINER DISPOSAL: After bag has been emptied, dispose of empty bag in a sanitary landfill or by incineration, or if allowed by State and local authorities, by burning. If burned, stay out of smoke.

GENERAL INSTRUCTIONS AND INFORMATION

Apply Topsin M 70WP with ground or aerial equipment, using sufficient volume of spray to provide thorough coverage. Add required amount of Topsin M 70WP to partially filled tank agitated by mechanical or hydraulic means, and then add remaining required amount of water. Continuous agitation is required to keep the material in suspension. Cerexagri does not recommend tank mixes with highly alkaline pesticides, such as Bordeaux mixture or lime sulfur. No claim of compatibility with other pesticides is implied. Use the higher rate under conditions of severe disease pressure. Also, see local State Extension Service recommendations for application schedules.

Use the LBS/ACRE rate for concentrate sprays (less than 400 gallons on apples, less than 300 gallons on stonefruit). Use the LBS/100 GAL rate for dilute ground applications. For aerial applications, use a minimum of 5 gallons/A for row crops, and a minimum of 10 gallons/A for tree and vine crops. Higher spray volume will generally result in better coverage and better disease control.

Chemigation instructions follow. Do not apply through any irrigation system unless these instructions are followed.

For crops without labeled uses of thiophanate-methyl, observe a 30-day plantback restriction.

Use on all labeled non-bearing tree fruit, tree nuts, and grapes: Topsin M 70WP may be used for control of the diseases listed on the label for these crops during the non-bearing years of new plantings, and on nursery stock. All use directions and limitations must be followed, except for the PHI, which is not applicable for non-bearing stock. Begin applications as disease is first observed or expected. Tank mixing with a protectant fungicide is strongly recommended for resistance management.

RESISTANCE MANAGEMENT: To avoid the development of tolerant or resistant strains of fungi, Topsin M 70WP should always be tank-mixed with a fungicide of different chemistry, and/or a fungicide of different chemistry should be alternated with Topsin M 70WP. DO NOT USE PRODUCTS CONTAINING THIABENDAZOLE OR OTHER PRODUCTS CONTAINING THIOPHANATE-METHYL IN COMBINATION, IN ROTATION, OR AS A SUBSTITUTE FOR TOPSIN M 70WP AS THEY ARE OF SIMILAR CHEMISTRY AND WILL CONTRIBUTE TO THE DEVELOPMENT OF RESISTANCE. If after using Topsin M 70WP as recommended, and the treatment is not effective, a tolerant or resistant strain of fungi may be present. Discontinue the use of Topsin M 70WP for at least one season. As long as these precautions are followed, Topsin M 70WP can be useful for disease control, even if resistant strains are present.

MIXING INSTRUCTIONS

If other materials are to be added to the tank, especially fertilizers high in nitrogen or boron, wait until the Topsin M 70WP is fully dissolved before adding them. Once all materials have been added, fill the tank with the remaining volume of water. Maintain continuous agitation at all times, and use the spray suspension as soon as possible.

TOPSIN® M 70WP

CROP/ RESTRICTIONS	DISEASES	LBS/ ACRE	LBS/ 100 GAL	REMARKS/ RESTRICTIONS
Almonds	Brown Rot Blossom Blight **(Monilinia)** Scab **(Cladosporium)** Jacket Rot **(Monilinia, Sclerotinia, Botrytis)** Leaf Blight **(Seimatosporium)**	1-1½		Apply as needed between pink bud and petal fall. Topsin M 70WP may be applied alone at pink bud for Brown Rot control. For all other applications, Topsin M 70WP should be applied with a contact fungicide, such as a ziram product (e.g. Ziram 76DF) or a maneb product (e.g. Maneb 75DF), for broad spectrum control and resistance management. Do not apply more than 3 lbs. of product (2.1 lbs. a.i.)/A/season.
Apples	Apple Scab **(Venturia)** Black Pox* **(Helminthosporium papulosum)** Flyspeck **(Zygophiala)** Powdery Mildew **(Podosphaera)** Sooty Blotch **(Gloeodes)** Black Rot **(Botryosphaeria obtusa)** Brooks Fruit Spot **(Mycosphaerella)** White Rot* **(Botryosphaeria dothidia)**	1-1½	¼-⅜	Apply at 5- to 10-day intervals from green tip through petal fall; continue at 7- to 14-day intervals in cover sprays. Do not apply more than 4 lbs. of product (2.8 lbs. a.i.)/A/season. Follow resistance management guidelines under Directions for Use.
Beans, dry and succulent Including: Lima bean Snap bean Kidney bean Mung bean Navy bean Pinto bean Wax bean Broad bean Fava bean Asparagus bean Blackeyed pea Cowpea Sweet lupine White lupine White Sweet lupine Grain lupine Chick pea Garbanzo bean	White Mold **(Sclerotinia)** Gray Mold **(Botrytis)** Anthracnose **(Colletotrichum)**	1½-2 **OR** 1-1½		For one application: Apply when 100% of plants have at least one open bloom or when conditions are favorable for disease development. **OR** For multiple applications: Make the first application when 10% to 30% of plants have at least one open bloom and follow with sequential applications on a 4- to 7- day interval. Apply prior to the development of disease for best results. Do not apply more than 4 lbs. of product (2.8 lbs. a.i.)/A/season. Pre-harvest interval: **California only,** 14 days for succulent beans, 28 days for dry beans and lima beans. Pre-harvest interval: **all other States,** 14 days for succulent beans and lima beans, 28 days for dry beans.
Cucurbits (Cantaloupe, Casaba, Cucumbers, Melons, Pumpkins, Summer and Winter Squash, and Watermelons)	General information			Do not apply more than 3 lbs. of product (2.1 lbs. a.i.)/A/season from any combination of application timings. Topsin M 70WP can be used in a tank mix with Penncozeb® (mancozeb) or chlorothalonil for additional disease control and resistance management. Follow resistance management guidelines under Directions for Use.
	Acremonium/ Cephalosporium Hypocotyl Rot	½		Apply in-furrow, on top of the seeds at planting. Do not use less than 10 gallons of water per acre.
	Anthracnose* **(Colletotrichum)** Gummy Stem Blight* **(Didymella)** Powdery Mildew **(Erysiphe, Sphaerotheca, Podosphaera)** Target Spot* **(Corynespora)**	½		Begin applications when plants begin to run or when disease first appears, and repeat at 7- to 14-day intervals or as needed. For Target Spot, use at 7-day intervals as needed.
	Belly Rots* **(Rhizoctonia, Fusarium)**	½		Apply in sufficient volume to allow runoff to the soil. Will not control Pythium or Phytophthora.
	Suppression of Vine Decline* **(Monosporascus)** Charcoal Rot* **(Macrophomina)**	½		Apply through buried drip irrigation (chemigation) to the root zone. For disease suppression, apply at 14-day intervals, beginning at emergence and continuing to harvest. Applications weekly or biweekly, beginning 4-6 weeks prior to harvest will also offer suppression, but may not be as effective as a season-long program.

NOTE: Dilute sprays are not to exceed maximum rate per acre. *continued*
*Not for this use in California.

CROP/ RESTRICTIONS	DISEASES	LBS/ ACRE	LBS/ 100 GAL	REMARKS/ RESTRICTIONS
Garlic (clove treatment)	Penicillium Clove Rot		1	Completely immerse garlic cloves in suspension for at least 5 minutes. Continuously agitate the solution tank by hydraulic or mechanical means. After treatment, remove cloves from solution and drain. Dry cloves after treatment and prior to planting.
Grapes Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 7 days unless appropriate PPE for early entry is worn.	General information			Do not apply more than 4 lbs. of product (2.8 lbs. a.i.)/A/season. Pre-harvest interval: 14 days. Follow resistance management guidelines under Directions for Use.
	WEST OF THE ROCKY MOUNTAINS: Bunch Rot **(Botrytis)** Powdery Mildew **(Uncinula)**	1-1½		Apply at first bloom and repeat 14 days later or as needed if severe disease conditions exist. Make an additional application 3 to 4 weeks before harvest or when sugar begins to build; repeat 14 days later if conditions favorable for disease persist. For Powdery Mildew continue applications through the season. Use in combination or rotation with a sulfur product such as Microthiol® Disperss® and/or other systemic fungicides.
	EAST OF THE ROCKY MOUNTAINS: Bitter Rot **(Melanconium)** Black Rot **(Guignardia)** Powdery Mildew **(Uncinula)** Phomopsis Cane and Leaf Spot **(Phomopsis)**	¾-1½		Apply when foliage first develops and repeat at 14- to 21-day intervals or as needed.
	Bunch Rot **(Botrytis)**	1-1½		For Bunch Rot, apply at first bloom and repeat 14 days later or as needed if severe disease conditions exist. Make an additional application 3 to 4 weeks before harvest or when sugar begins to build, repeat 14 days later if conditions favorable for disease persist. Do not use where resistant strains of Botrytis are present.
Onions* Garlic (In furrow)	White Rot **(Sclerotium cepivorum)**	2 broadcast		Spray directly into the open furrow at the time of planting seed, sets or bulbs. Not for this use through any type of irrigation system.
Peanuts	Early Leaf Spot **(Cercospora)** Late Leaf Spot **(Cercosporidium)** Rust **(Puccinia)** Limb Rot **(Rhizoctonia)** Web Blotch **(Ascochyta)**	½		Begin applications when disease first appears and repeat at 7- to 14-day intervals as needed. Use the 7-day interval under severe disease pressure. Do not apply more than 2 lbs. of product (1.4 lbs. a.i.)/A/season. Pre-harvest interval: 14 days. Topsin M 70WP should not be used alone. Use only in combination with a non-benzimidazole fungicide such as Penncozeb® 75DF (mancozeb) at 1½ lbs. per acre or chlorothalonil. Follow resistance management guidelines under Directions for Use.
Pears Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 3 days unless appropriate PPE for early entry is worn.	Pear Scab **(Venturia)** Sooty Blotch **(Gloeodes)** Flyspeck **(Zygophiala)** Powdery Mildew **(Podosphaera)** Leaf Spot **(Fabraea)**	1	¼	Apply at 5- to 10-day intervals from green tip through petal fall; continue at 7- to 14-day intervals in the cover sprays. Do not apply more than 4 lbs. of product (2.8 lbs. a.i.)/A/season. Pre-harvest interval: 1 day. REI: 3 days Follow resistance management guidelines under Directions for Use.
Pecans	Brown Spot **(Cercospora)** Downy Spot **(Mycosphaerella)** Liver Spot **(Gnomonia)** Powdery Mildew **(Microsphaera)** Scab **(Fusicladium)** Stem End Blight **(Botryosphaeria)** Zonate Leaf Spot **(Cristulariella)**	1		Begin applications when first leaves are showing and repeat at 3- to 4-week intervals until shuck split. Do not apply after shuck split. Do not apply more than 3 lbs. of product (2.1 lbs. a.i.)/A/season. Follow resistance management guidelines under Directions for Use.

NOTE: Dilute sprays are not to exceed maximum rate per acre. *continued*
*Not for this use in California.

CROP/ RESTRICTIONS	DISEASES	LBS/ ACRE	LBS/ 100 GAL	REMARKS/ RESTRICTIONS
Pistachios Do not enter or allow worker entry into treated areas during the restricted entry interval (REI) of 3 days unless appropriate PPE for early entry is worn	Shoot Blight **(Botrytis, Botryosphaeria)**	1½-2		Apply at bloom. Apply in a minimum of 100 gallons per acre by ground or 20 gallons per acre by air. For aerial application, fly over every row or center. Do not apply more than 2 lbs. of product (1.4 lbs. a.i.)/A/season. REI: 3 days
Potatoes	White Mold **(Sclerotinia sclerotiorum)**	1-1½		Make first application just prior to row closure. Repeat the application within 7 to 14 days and at 7- to 14-day intervals if conditions for disease development are favorable. Thorough coverage of the flowers, stems, and branches is essential for disease control. Use a minimum of 6 gallons/A for aerial application. Do not apply more than 4 lbs. of product (2.8 lbs. a.i.)/A/season. Pre-harvest interval: 21 days. May be tank mixed with Penncozeb® (mancozeb) for Early and Late Blight control.
Soybeans	General Information			Do not apply more than 2 lbs. product (1.4 lbs. a.i.)/A/season. Do not graze or feed treated vines or hay to livestock.
	Anthracnose **(Colletotrichum)** Brown Spot **(Septoria)** Frogeye Leaf Spot **(Cercospora)** Pod and Stem Blight **(Diaporthe, Phomopsis)** Purple Seed Stain **(Cercospora)**	½-1		Apply from full bloom to when pods are ⅛" to ¼" in length. Make a second application 14- to 21- days later. Do not make the second application later than 14 days after pods average ¼" in length or when beans form in the pod. Use the high rate under severe disease pressure. **FOR SEED BEANS ONLY–**For seed quality, make a single application at the high rate (1 lb. per acre) when beans form in the pod.
	White Mold **(Sclerotinia)**	¾-1		Make one application at early bloom (R-1 to R-2 stage) followed by a second application 14 days later if conditions are favorable for continued disease pressure. Thorough coverage of the flowers, stems, and branches is essential for disease control. Use a minimum of 5 gallons water/A by air.
	Aerial Blight (suppression)	1		Make initial application when disease threatens and repeat 14 to 21 days later if needed.
Stone Fruit	General Information			Do not apply more than 4 lbs. of product (2.8 lbs. a.i.)/A/season. Pre-harvest interval: 1 day. Follow resistance management guidelines under Directions for Use.
–Apricots	Brown Rot Blossom Blight Fruit Brown Rot **(Monilinia)**	1-1½ (in CA use 1½)	⅓-½	Apply at early bloom (red bud). Make a second application at full bloom. If needed, under severe disease pressure, apply additional sprays at 10- to 14-day intervals between full bloom and final pre-harvest sprays.
–Cherries Sweet and Sour	Brown Rot Blossom Blight Fruit Brown Rot **(Monilinia)**	1-1½ (in CA use 1½)	⅓-½	Apply at early bloom (early popcorn). Make a second application at full bloom. If needed under severe disease pressure, apply additional sprays at 10- to 14-day intervals between full bloom and final pre-harvest sprays.
	Cherry Leaf Spot **(Coccomyces)**	1⅛-1½	⅜-½	Applications may be made at petal fall or before (when leaves first unfold) and at first, second, and third cover at 10- to 14-day intervals and one spray 14 to 21 days after harvest.
	Powdery Mildew **(Podosphaera)**	1-1½ (in CA use 1½) **PLUS** 1⅛-1½	⅓-½ **PLUS** ⅜-½	Apply at early bloom (early popcorn). Make a second application at full bloom. **PLUS** Apply at shuck fall and first cover.

NOTE: Dilute sprays are not to exceed maximum rate per acre.

continued

CROP/ RESTRICTIONS	DISEASES	LBS/ ACRE	LBS/ 100 GAL	REMARKS/ RESTRICTIONS
Stone Fruit (cont'd)				
–Nectarines	Brown Rot Blossom Blight Fruit Brown Rot **(Monilinia)**	1-1½ (in CA use 1½)	⅓-½	Apply at early bloom (pink bud). Make a second application at full bloom if conditions favor disease development. If needed under severe disease pressure, apply additional sprays at 10- to 14-day intervals between full bloom and final pre-harvest sprays.
–Peaches	Brown Rot Blossom Blight Fruit Brown Rot **(Monilinia)**	1-1½ (in CA use 1½)	⅓-½	Apply at early bloom (pink bud). Make a second application at full bloom if conditions favor disease development. If needed under severe disease pressure, apply additional sprays at 10- to 14-day intervals between full bloom and final pre-harvest sprays.
	Peach Scab **(Cladosporium)**	1-1½ (in CA use 1½) **PLUS** 1⅛-1½	⅓-½ **PLUS** ⅜-½	Apply at early bloom (pink bud). Make a second application at full bloom if conditions favor disease development. **PLUS** Apply at shuck split and first cover sprays.
–Plums and Prunes	Brown Rot Blossom Blight Fruit Brown Rot **(Monilinia)**	1-1½ (in CA use 1½)	⅓-½	Apply at early bloom (green tip). Make a second application at full bloom. If needed under severe disease pressure, apply additional sprays at 10- to 14-day intervals between full bloom and final pre-harvest sprays.
	Black Knot **(Dibotryon)**	1-1½ (in CA use 1½)	⅓-½	Apply at pre-bloom, petal fall, and at first, second, or third cover sprays at 10- to 14-day intervals.
	Leaf Spot **(Coccomyces)**	1-1½ (in CA use 1½)	⅓-½	Applications may be made at petal fall, shuck split, and at first, second, and third cover sprays at 10- to 14-day intervals and 1 spray 14- to 21-days after harvest.
Strawberries	Fruit Rot **(Botrytis)** Leaf Blight **(Dendrophoma)** Leaf Scorch **(Diplocarpon)** Powdery Mildew **(Sphaerotheca)**	¾-1		Begin applications at early bloom and continue at 7- to 10-day intervals. Use the higher rate under conditions of severe disease pressure. Do not apply more than 4 lbs. of product (2.8 lbs. a.i.)/A/season. Pre-harvest interval: 1 day. Follow resistance management guidelines under Directions for Use.
Sugar Beets	General Information			Do not apply more than 3 lbs. product (2.1 lbs. a.i.)/A/season. Pre-harvest interval: 21 days. Follow resistance management guidelines under Directions for Use.
	Cercospora Leaf Spot **(Cercospora)**	½-1 (in CA use ½)		Apply when conditions become favorable for disease development before the disease appears and follow with a non-benzimidazole fungicide within 14 days of application or as needed. Topsin M 70WP should be tank mixed with a protectant fungicide such as a mancozeb product (e.g. Penncozeb®) or a triphenyl tin hydroxide product when resistant strains of Cercospora are present in the field. Do not make more than one application per season for Cercospora Leaf Spot.
	Powdery Mildew **(Erysiphe)**	½-1		Apply as soon as disease symptoms appear and follow with a non-benzimidazole fungicide at a 14-day interval or as needed. Topsin M 70WP can be tank mixed with sulfur products such as Microthiol® Disperss® at 5 to 10 lbs./A for additional disease control and resistance management.
Triticale and Fall-seeded Wheat **For this use in Idaho, Oregon, and Washington ONLY**	Foot Rot, Strawbreaker, Eye Spot **(Pseudocercosporella)**	1		Apply Topsin M 70WP at the rate indicated in a single application by air or ground after tillering but before stem elongation has begun. Use sufficient water to obtain thorough coverage. Do not apply more than 1 lb. of product (0.7 lb. a.i.)/A/season. Do not cut for hay within 90 days of application. Do not allow livestock to graze in treated areas before harvest.

NOTE: Dilute sprays are not to exceed maximum rate per acre.

DIRECTIONS FOR USE ON CONIFERS

(Not for this use in California)

CROP	DISEASE	LIMIT/ ACRE/ CROP	RATE, MINIMUM GALLONAGE	REMARKS
CONIFERS (Pine) Austrian Red Scots Christmas Trees	Tip Blight (**Diplodia**)	48 oz. (3 lb.)	16 oz./A 100 gal./A	Apply at bud break. Repeat 10 to 14 days later, just before needles emerge from sheath; repeat again 10 to 14 days after needle emergence.
(Fir) Douglas	Swiss Needle Cast (**Phaecryptopus**) Rhabdocline Needle Cast	80 oz. (5 lb.)	16 oz./A 50 gal./A	Apply initially in early May. Repeat at 4-week intervals.
• Add a spreader/sticker to improve coverage. • Use minimum gallonage with mist-blower types of sprayers and higher gallonage with conventional sprayers. • Do not graze livestock in treated areas.				
CONIFERS (seedling treatment) Longleaf	Brown Needle Blight (**Scirrhia**)	N/A	1 oz./9.5 oz. dry Kaolinite clay for seedling roots	Wet seedling roots in clean water, then apply TOPSIN M/Kaolinite mixture to wet roots. Do not apply mixture to seedling foliage.
Loblolly Longleaf Slash	Fusarium and Rhizoctonia Root Rot	N/A	2 oz./50 oz. Kaolinite clay, plus enough water to make a slurry	Thoroughly cover seedling roots with TOPSIN M/Kaolinite slurry. Do not apply mixture to seedling foliage.
• During treatment, avoid excessive drying of roots or exposure to temperatures greater than 90°F or less than 32°F. • TOPSIN M does not control Pythium or Phytophthora.				

DIRECTIONS FOR USE THROUGH CHEMIGATION SYSTEMS

NOT FOR THIS USE IN CALIFORNIA

GENERAL INSTRUCTIONS

Apply this product only through sprinkler irrigation systems including center pivot, lateral move, end tow, side (wheel) roll, traveler, solid set or hand move; or drip (mini-micro sprinklers, strip tubing, trickle) irrigation systems. Do not apply this product through any other type of irrigation system.

Crop injury, lack of effectiveness, or illegal pesticide residues in the crop can result from nonuniform distribution of treated water.

If you have any questions about calibration, you should contact State Extension Service specialists, equipment manufacturers or other experts.

A person knowledgeable of the chemigation system and responsible for its operation, or under the supervision of the responsible person, shall shut the system down and make necessary adjustments should the need arise.

Do not connect chemigation system to any public water system. Public water system means a system for the provision of piped water for human consumption if such a system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year.

SYSTEM REQUIREMENTS

Systems utilizing a pressurized water and pesticide injection system must meet the following requirements:

The system must contain a functional check valve, vacuum relief valve, and low pressure drain appropriately located on the irrigation pipeline to prevent water source contamination from backflow.

The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump. The pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.

The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops.

The irrigation line or water pump must include a functional pressure switch that will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected.

Systems must use a metering pump, such as a positive displacement injection pump (e.g., diaphragm pump) effectively designed and constructed of materials that are compatible with pesticides and capable of being fitted with a system interlock.

APPLICATION INSTRUCTIONS

Observe the requirements in the System Requirements section above.

Apply Topsin M 70WP only through systems containing anti-syphon and check valves designed to prevent water source contamination or overflow of the mix tank and containing interlocking controls between the metering device and the water pump to insure simultaneous shut-off.

Maintain a gentle continuous agitation in mix tank during mixing and application to assure a uniform suspension.

Greater accuracy in calibration and distribution will be achieved by injecting a larger volume of a more dilute suspension per unit time.

Application of more than recommended quantities of irrigation water per acre may result in decreased product performance.

Do not apply when wind speed favors drift, when system connections or fittings leak, when nozzles do not provide uniform distribution or when lines containing the product cannot be flushed and must be dismantled and drained. In a center pivot system, block the nozzle set nearest the well/pivot/injection unit to prevent spray being applied to this area.

Where sprinkler distribution patterns do not overlap sufficiently, unacceptable disease control may result.

Allow sufficient time for pesticide to be flushed through all lines and all nozzles before turning off irrigation water.

Topsin M 70WP may be applied in conjunction with chemically neutral liquid fertilizers. Application in conjunction with highly alkaline fertilizers, such as aqueous ammonia, may cause a degradation of the pesticide, resulting in reduced performance and should be avoided.

SPRAY PREPARATION

Remove scale, pesticide residues, and other foreign matter from the chemical tank and entire injector system. Flush with clean water. Prepare a suspension of Topsin M 70WP in a mix tank. Fill the tank with ½ or ¾ the desired amount of water. Start mechanical or hydraulic agitation. Slowly add the required amount of Topsin M 70WP and then the remaining volume of water.

Sprinkler Irrigation - Notes

Observe all System Requirements and Application Instructions above.

Set sprinkler system to deliver a maximum of 0.4 inch of water per acre. Volumes of water higher than this may reduce efficacy. Start sprinkler and then uniformly inject the suspension of Topsin M 70WP into the irrigation water line so as to deliver the desired rate per acre. The suspension of Topsin M 70WP should be injected with a positive displacement pump into the main line ahead of a right angle turn to insure adequate mixing. When treatment with Topsin M 70WP has been completed, do not irrigate the treated area for 24 to 48 hours to prevent washing the chemical off the crop.

Do not apply when wind speed favors drift beyond the area intended for treatment.

Where sprinkler distributed patterns do not overlap sufficiently, unacceptable disease control may result.

Check local restrictions and requirements regarding sprinkler irrigation applications, as they may vary from state to state.

Drip (Mini-Micro Sprinklers, Strip Tubing, Trickle) Irrigation - Notes

Observe all System Requirements and Application Instructions above.

A pesticide supply tank is recommended.

EMERGENCY TELEPHONE NUMBERS:

CHEMTREC: (800) 424-9300

MEDICAL: (303) 623-5716 Rocky Mountain Poison Control Center

WARRANTY AND DISCLAIMER

Cerexagri, Inc. warrants that this material conforms to the chemical description on the label and is reasonably fit for the purposes referred to in the Directions for Use, subject to the risks referred to therein. CEREXAGRI, INC. MAKES NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS OR MERCHANTABILITY OR ANY OTHER EXPRESS OR IMPLIED WARRANTY. IN NO CASE SHALL CEREXAGRI, INC. OR SELLER BE LIABLE FOR CONSEQUENTIAL, SPECIAL OR INDIRECT DAMAGES RESULTING FROM THE USE OR HANDLING OF THIS PRODUCT INCLUDING, BUT NOT LIMITED TO, LOSS OF PROFITS, BUSINESS REPUTATION, OR CUSTOMERS; LABOR COST; OR OTHER EXPENSES INCURRED IN PLANTING OR HARVESTING.

Cerexagri, Inc. and seller offer this product and the buyer and user accept it subject to the foregoing conditions of sale and warranty which may be varied only by agreement in writing signed by a duly authorized representative of Cerexagri, Inc.

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Topsin is a registered trademark of Nippon Soda Company, Ltd.
Penncozeb, Microthiol, and Disperss are registered trademarks of Cerexagri, Inc.

Wild Blueberry Research Program
David Percival (Ph.D., P.Agr.)
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Telephone: 893-7852, E-mail: dpercival@nsac.ca

Rationale for Using Proline in Blueberry Use

From a pathogen perspective, the *Septoria* that is affecting the wild blueberry starts sporulating in early to mid May, and continues into July. Visible, water soaked lesions generally don't appear until late June/early July. Given this lag between sporulation and visible lesion symptoms, present disease management practices rely on the use of Bravo® (a.i. chlorothalonil) applications in mid June (2^{nd} to 3^{rd} week) followed by a subsequent Bravo® application in late July for rust suppression. By following these practices, producers are presently faced with problems of: (i) not knowing if *Septoria* infection has occurred and potentially wasting fungicide inputs and reducing yield potential due to increased tracking of fields (fields consist of a mat of blueberry stems with stem densities typically ranging from 600 to $1{,}000^{+}$ stems per square meter); (ii) a high proportion of fungicides being applied not reaching target areas due to the stems in the vegetative year of production only being ~1/2 grown at the time of the initial fungicide application (a large portion of the fungicide ultimately comes in direct contact with the soil surface); and (iii) not attaining good levels of *Septoria* suppression if infection has occurred due to a protectent fungicide being used resulting in significant defoliation of the canopy. This subsequently results in loss of berry yield the following year due to insufficient carbohydrates being available during floral bud growth and development (which occurs throughout the autumn of the vegetative year of production).

Therefore, from disease suppression perspective, the use of Proline™ 480SC provides the opportunity to wait until the initial early symptoms of *Septoria* are present, also provide suppression of rust (which will is infecting the plant in July), and provide for more judicious use of fungicide inputs (and have less of an environmental impact). Presently, the wild blueberry industry does not have a DMI (triazole) fungicide registered for leaf diseases, thus the registration of this product will provide a much needed mode of action and efficaceous compound for both *Septoria* and rust.

With the majority of wild blueberries being produced in Canada being exported to markets in the United States, the European Union and Japan, the registration of Proline™ 480SC will also provide the wild blueberry industry with a fungicide that will be accepted by all international end users. This is of particular concern in the European Union, with the introduction of a harmonized pesticide regulatory system and associated upcoming legislation placing a significant array of fungicides presently used (e.g., propiconazole) and in the evaluation process (e.g., metconazole) under scrutiny. Upon reviewing the risk assessment documentation from the European Union (EU) and corresponding with EU berry processors, it is not anticipated that Proline™ 480SC use will be jeopardized.

BioSafe Systems LLC

See packet for full instructions

OxiDATE®

Broad Spectrum Bactericide/Fungicide

ACTIVE INGREDIENT:
Hydrogen Dioxide 27.00%
OTHER INGREDIENTS 73.00%
TOTAL 100.00%

KEEP OUT OF REACH OF CHILDREN
DANGER-*PELIGRO*

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

[illegible]

	FIRST AID
If in eyes	[illegible]
If on skin or clothing	[illegible]
If swallowed	[illegible]
If inhaled	[illegible]
[illegible]	

OxiDate®

Broad Spectrum Bactericide/Fungicide

Preventative treatment for seeds, growing plants, fruits, nuts and vegetables.

A treatment for the prevention and control of plant pathogenic diseases in field grown crops, commercial greenhouses, and storage sites.

FOR AGRICULTURE USE ONLY

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMAN AND DOMESTIC ANIMALS – DANGER: Corrosive. Concentrate causes irreversible eye damage. Concentrate may be fatal if swallowed or absorbed through skin. Concentrate causes skin burns or temporary discoloration on exposed skin. Do not breathe vapor of concentrate. Do not get concentrate in eyes, on skin or on clothing. Wear protective eyewear such as goggles or face shield. Wash thoroughly with soap and water after handling. Remove and wash contaminated clothing before reuse.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

When handling concentrate wear protective eyewear (goggles or face shield) and rubber gloves. Applicators and handlers must wear coveralls over long-sleeved shirt, long pants, and chemical resistant footwear plus socks. Follow manufacturer's instructions for cleaning/maintaining PPE. If no such instructions exist for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

USER SAFETY RECOMMENDATIONS

Users should wash hands thoroughly with soap and water before eating, drinking, chewing gum, using tobacco or using the toilet. Users should remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing. Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

ENVIRONMENTAL HAZARDS

This pesticide is toxic to birds and fish. Do not contaminate water when disposing of equipment washwaters or rinsate. Exposed treated seed may be hazardous to birds and other wildlife. Dispose of all excess treated seed and seed packaging by burial away from bodies of water.

This product is highly toxic to bees and other beneficial insects exposed to direct contact on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting the treatment area. Do not apply this product or allow it to drift to crops where beneficials are part of an Integrated Pest Management strategy.

PHYSICAL AND CHEMICAL HAZARDS

Corrosive. Strong oxidizing agent. Do not use in concentrated form. Mix only with water in accordance with label instructions. Never bring concentrate in contact with other pesticides, cleaners or oxidative agents.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your State or Tribe, consult the agency responsible for pesticide regulation.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. This standard contains requirements for the protection of agricultural workers on farms, forests, nurseries and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on this label about Personal Protective Equipment (PPE), notification to workers, and Restricted-Entry Interval (REI). The requirements in this box only apply to the uses of this product that are covered by the Worker Protection Standard.

For enclosed environments:

There is a restricted entry of one (1) hour for this product when applied via fogging or spraying to growing plants, surfaces, equipment, structures, and non-porous surfaces in enclosed environments such as glasshouses and greenhouses.

There is a restricted entry of zero (0) for pre-plant dip, seed treatment, soil drench, mop, sponge, dip, soak, rinse or other non-spraying or fogging application methods when used in enclosed environments such as glasshouses and greenhouses.

PPE requirement for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated, such as plants, soil or water, is safety goggles or visor, coveralls worn over long-sleeved shirt and pants, waterproof gloves and chemical resistant shoes plus socks.

For field applications:

Keep unprotected persons out of treated areas until sprays have dried.

Non-Agricultural Use Requirements

The requirements in this box apply to uses of this product that are not within the scope of the Worker Protection Standard for agricultural pesticides (40 CFR Part 170). The WPS applies when this product is used to produce agricultural plants on farms, forests, nurseries or greenhouses.

Keep unprotected persons out of treated areas until sprays have dried.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

PESTICIDE STORAGE: Store in original containers in a cool, well-vented area, away from direct sunlight. Do not allow product to become overheated in storage. This may cause increased degradation of the product, which will decrease product effectiveness. In case of spill, flood area with large quantities of water. Do not store in a manner where cross-contamination with other pesticides or fertilizers could occur.

PESTICIDE DISPOSAL: Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility. Open dumping is prohibited. If wastes cannot be disposed of according to label directions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste Representative at the nearest EPA Regional Office for guidance.

CONTAINER DISPOSAL: Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

DIRECTIONS FOR USE:

- OxiDate works best when diluted with water containing low levels of organic or inorganic materials, and with water having a neutral pH. Thoroughly rinse out tank with water before mixing concentrate. OxiDate will readily mix with clean, neutral water and does not require agitation.

- Before tank mixing OxiDate with fertilizers, fungicides, or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or increased pressure are an indication of incompatibility.

- OxiDate is formulated with a minimal amount of surfactant for plants having waxy or hairy surfaces. The use of additional surfactant is acceptable.

- OxiDate works by surface contact with the plants and materials being treated. It is important to ensure that all surfaces are thoroughly wetted. OxiDate does not produce any visible residue, distinct odor, or deleterious effects to plants or to post harvest commodities when used in accordance with label directions. Do not use at stronger than suggested dilution rates as leaf burn may result.

- OxiDate may be applied up to and including the day of harvest.

Do not apply this product through any irrigation system unless directed by the label.

APPLICATION DIRECTIONS:

Pre-Plant Dip Treatment -

Use OxiDate for the control of damping-off, root disease and stem rot disease caused by *Pythium, Phytophthora, Rhizoctonia, Fusarium* or *Thielaviopsis*, on seeds, seedlings, bulbs, or cuttings.

1) Mix 64 fl. oz. OxiDate per 50 gallons of water.
2) Immerse plants or cuttings; actual time required will vary depending plant type and organic loading, remove and allow to drain. Do not rinse.

Seed Treatment –

Use OxiDate for the control of damping-off, root disease and stem rot disease caused by *Pythium, Phytophthora, Rhizoctonia, Fusarium* or *Thielaviopsis*, on seeds of seed sprout crops such as mung bean, red clover, soybeans and alfalfa, and on crops grown exclusively for seed for planting.

1) Mix 64-fl. oz. OxiDate per 50 gallons of water
2) Immerse seeds and let soak for two minutes; remove and allow to drain. Do not rinse.

Do not use treated seed for food or feed purposes or process for oil. Treat only those seeds needed for immediate use, minimizing the interval between treatments at planting. Do not store excess treated seeds beyond planting time.

Seed treatment on agricultural establishments in hopper-box, planter-box or other seed treatment application at or immediately before planting is within the scope of WPS, while commercial treatment of seeds is not within the scope.

For treatment of tank and spray system water in bean sprout production process and packing lines, refer to the label section entitled "For direct injection into dump tanks, hydro coolers, spray system and process waters."

Soil Drench -

OxiDate is effective for the control of soil-borne plant diseases such as *Pythium, Phytophthora, Rhizoctonia, Thielaviopsis or Fusarium*. Use as a soil drench at the time of seeding or transplanting, as well as a periodic drench throughout the plant's life. Use OxiDate on potting soil and growing mediums prior to planting.

1) Mix 1¼ fl. oz. OxiDate per gallon of clean water.
2) Apply to soil or growing media to the point of saturation.
3) Wait fifteen minutes before planting or watering.

Foliar Spray Treatments for field grown crops, crops grown in commercial greenhouses or crops grown in other similar sites -

OxiDate works immediately on contact with the plant surface for control of plant diseases – see Application Instructions chart. Good coverage and wetting of the foliage is required.

<u>Foliar Applications: Plant Sensitivity Testing:</u>

For foliar applications, be sure to use OxiDate at labeled dilutions as solutions more concentrated can result in leaf necrosis for some crops (i.e., do not use dilutions stronger than 1:100 for foliar treatments). OxiDate has been designed to provide a balanced source of the active ingredient directly to the plant surface. OxiDate has been used and tested on many varieties of plant material. However, the nature of the target plant, environmental conditions, plant vigor, and the use of other pesticides can all affect plant sensitivity to OxiDate. Therefore, it is recommended before treating large numbers of plants, test OxiDate on a few plants for sensitivity.

Application of OxiDate for curative control of obligate organisms living in the plant tissue (such as Downy and Powdery Mildew) can result in lesions on plant tissue. OxiDate will oxidize parasitic organisms living in plant tissue that are not always visible to the naked eye. Resulting oxidative effects can include spotting, or drying of the plant tissue where organisms inhabited tissue.

For clean, hard, non-porous surfaces –

Pots, flats, trays: Use a dilution of 1:100 – 1:300 or 1¼ - ½ fl. oz. of OxiDate per gallon of clean water. Spray until runoff. The use of additional surfactant is acceptable.

Cutting tools: Use a dilution of 1:100 – 1:300 or 1¼ - ½ fl. oz. of OxiDate per gallon of clean water. Soak tools to ensure complete coverage. The use of additional surfactant is acceptable.

Benches and work areas: Sweep and remove all plant debris. Use power sprayer to wash all surfaces to remove loose dirt. Use a dilution of 1:100 – 1:300 or 1¼ - ½ fl. oz. of OxiDate per gallon of clean water. Use a dilution of 1:50 or 2½ fl. oz. of OxiDate per gallon of clean water if surfaces that are to be treated have not been pre-cleaned with water to remove organic deposits. The use of additional surfactant is acceptable.

For surfaces, equipment and structures –

Use OxiDate to suppress/control bacteria, fungi, and slime forming algae on hard, non-porous surfaces, equipment, and structures such as plastic, floors, walls, fan blades, watering systems, vats, tanks, coolers, storage rooms, elevators, storage areas, spray equipment, conveyors, irrigation systems, process equipment, process water systems, trucks, structures, and related equipment. Follow treatment of any food contact surfaces, equipment, or structures with a potable water rinse.

1. Sweep and remove all plant debris. Use a power sprayer to wash all surfaces to remove loose dirt and /or organic material.
2. Use a dilution of 1:100 – 1:300 or 1¼ - ½ fl. oz. of OxiDate per gallon of clean water. Use a dilution of 1:50 or 2½ fl. oz. of OxiDate per gallon of clean water if surfaces that are to be treated have not been pre-cleaned with water to remove organic deposits. The use of additional surfactant is acceptable.
3. Apply solution with mop, sponge, power sprayer, or fogger to thoroughly wet all surfaces. Allow treated surfaces to stay wet with solution for 10 minutes.

   Fog enclosed areas as an adjunct to manual surface application. Wear protective eyewear (goggles or face shield) when fogging. Prior to fogging, pre-clean surfaces with water to remove any organic deposits. Fog the desired areas using a dilution of 1:50 or 2½ fl. oz. per gallon of water of OxiDate, using any type of fogging equipment including, but not limited to, cold foggers, thermal foggers, low pressure air assisted and high pressure fog systems. Solutions are corrosive to materials that are easily oxidized such as natural rubber, copper, galvanized and black iron pipe. Test solutions on surfaces prior to use.
4. Follow treatment of any food contact surface, equipment, or structures with a potable water rinse.
5. Scrub off heavy growths of algae and fungi following application. Use a solution of OxiDate to wash away dead growth.
6. Reapply as often as needed for control.

For foot bath mats, make a solution using ¾ fl. oz. of OxiDate per gallon of water and fill foot bath mat to capacity. Change solution as needed.

Packinghouses: Apply OxiDate to surfaces and equipment found in commercial packinghouses including dump tanks, drenches, containers, conveyors, storages, walls, floors, and process lines.

1. Remove loose soil or organic matter with clean water and/or detergent rinse.
2. Use OxiDate at a dilution of 1:600 to 1:800 or 16.0 fl. oz. to 21.3 fl. oz. per 100 gallons of water. Apply as a coarse spray until runoff.
3. Allow OxiDate treated surfaces to air dry. Do not rinse.

For agricultural spray irrigation and drainage water and ditches -
Use OxiDate to suppress / control algae and bacteria in agricultural irrigation and drainage water and ditches. For irrigation water, apply 4 to 8 fluid ounces of OxiDate per 1000 gallons of water. Product can be simply added to the body of water as the residual control will allow for even distribution throughout the water column. Where existing algae mats are present at time of treatment, the most effective control will be obtained by breaking up mats and/or evenly dispersing diluted OxiDate over the algae mats. Apply OxiDate as needed to control and prevent algae growth, apply more frequently in times of higher water temperatures.

For stock tanks and livestock water –
Use OxiDate to suppress / control algae and bacteria in stock tanks, stock watering ponds, tanks and troughs, and livestock water. Apply 2 fluid ounces of OxiDate per 250 gallons of water for algae control. Product can be simply added to the body of waters as the residual control will allow for even distribution throughout the water column. Where existing algae mats are present at time of treatment, the most effective control will be obtained by breaking up mats and/or evenly dispersing diluted OxiDate over the algae mats. Apply OxiDate as needed to control and prevent algae growth; apply more frequently applications in times of higher water temperatures.

Drip system application for livestock watering tanks: Tanks fed by a continuous flow of spring or well water can be equipped with a chemical drip system designed to meter-in OxiDate based upon water flow rates. Pre-dilute OxiDate at a 100: 1 rate or 4-mL/minute water flow rate. Treat continuously or as needed to control and prevent algae regrowth.

Crops	Disease	Dilution Rate	Application Rate	Directions
Asparagus	Phytophthora	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Bananas **Plantains**	Sigatoka	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Beans Lima beans Peas Snap & Dry Soybeans	Anthracnose Botrytis Downy Mildew Early & Late Blight Fusarium Phytophthora Powdery Mildew Pythium Rhizoctonia Sclerotinia Rust White Mold	1:100– 1:2000	See Beans – Snap and Dry Application Instructions.	For specific application instructions, see Beans – Snap and Dry Application Instructions.

Crops	Disease	Dilution Rate	Application Rate	Directions
Berries, including but not limited to: Blackberry Blueberry Cranberry Raspberry Strawberry (see Strawberry Application Instructions)	Alternaria Angular Leaf Spot Botrytis Crown Rot Downy Mildew Fruit Rot Leaf Blight Powdery Mildew	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 25–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Celery	Early Blight Late Blight	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Citrus Crops, including but not limited to: Grapefruit Kumquat Lemon Orange Tangerine	Alternaria Anthracnose Brown Rot Phytophthora Powdery Mildew Rust Scab	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 50–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
	Citrus Canker	1:100 – 1:600	*See Citrus Canker Application Instructions.*	*For specific application instrucions, see Citrus Canker Treatment Application Instructions.*

Crops	Disease	Dilution Rate	Application Rate	Directions
Cole Crops, including but not limited to: Broccoli Brussels Sprouts Cabbage Cauliflower Collards	Alternaria Leaf Spot Downy Mildew Early Blight Late Blight Powdery Mildew	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 50–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Cucurbit crops, including but not limited to: Cucumber Melons Pumpkin Squash	Alternaria Anthracnose Belly Rot Downy Mildew Fusarium Wilt Gummy Stem Blight Leaf Spot Phytophthora Powdery Mildew Pythium Rot Rhizoctonia Root Rots	1:100 – 1:2000	See Curcurbit Application Instructions.	For specific application instructions, see Cucurbit Application Instructions.
Filberts Almonds	Alternaria Brown Rot Bacterial Blight Bacterial Canker E. Filbert Blight Jacket Rot	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Pre-Bloom:** Begin applications at ¼ - ½ inch green tip and continue on a five to seven day schedule through bloom. **Curative:** Spray diseased trees for three consecutive days and continue treatments on five to seven day intervals.

Crops	Disease	Dilution Rate	Application Rate	Directions
Garlic **Leeks** **Onions** GreenOnion Scallions Shallots	Botrytis Downy Mildew Powdery Mildew	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	4-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Grapes	Black Rot Botrytis Downy Mildew Powdery Mildew Sour Rot	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Grasses grown for seed or sod	Leaf Rust Leaf Spot Stem Rust	1:100 – 1:300	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	Use sufficient water to achieve good coverage. Begin applications during stem elongations. Repeat weekly or as needed. Livestock can graze treated areas.

Crops	Disease	Dilution Rate	Application Rate	Directions
Herbs and Spices, including but not limited to: Basil Chives Cilantro Coriander Dill Mint Rosemary Sage	Anthracnose Downy Mildew Powdery Mildew Pythium Rot	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
		1:500– 1:1000	Direct Injection at a dilution ratio of 1:500 – 1:1000.	**Direct Injection:** Inject directly into misting systems for continual treatment during propagation.
Leafy Vegetables	Brown Rot Botrytis Downy Mildew Early Blight Late Blight Phytophthora Powdery Mildew Rust	1:100	100 gallons of water; apply30–100 128 fl. oz. of OxiDate per gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Mushrooms	Bacterial Blotch Mycogene Necrotic Spot Trichoderma Verticillium Spot	1:100	1¼ fl. oz. of OxiDate per gallon of water; apply 6 gallons of solution per 1000 sq. ft.	**Curative:** Spray diseased mushrooms using 1¼ fl. oz. of OxiDate per gallon of water for one to three consecutive days.
		1:300	½ fl. oz. of OxiDate per gallon of water; apply 6 gallons of solution per 1000 sq. ft.	**Preventative:** Spray mushrooms using ½ fl. Oz/ of OxiDate per gallon of water on five to seven day intervals. Begin at pinning stage and continue through harvest.

Crops	Disease	Dilution Rate	Application Rate	Directions
Peanuts	Early Blight Late Blight Rust	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Peppers & Tomatoes	Alternaria Anthracnose Bacterial Speck Bacterial Spot Botrytis Cladosporium Mold Early Blight Late Blight Leaf Spot Phytophthora Powdery Mildew Pythium Rhizoctonia	1:100 – 1:2000	*See Tomato and Pepper Application Instructions*	*For specific application instructions, see <u>Tomato and Pepper Application Instructions.</u>*
Pome Fruit, including but not limited to: Apples Pears	Powdery Mildew Rusts Scab	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 - 1:300	40-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.

Potatoes	Early Blight Late Blight	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest.
Potatoes (Seed)	Fusarium	1:50	2½ fl. oz. of OxiDate per gallon of water.	Dip whole or cut tubers into tank of working solution. Let soak for a period of five minutes before removing seed pieces.

Crops	Disease	Dilution Rate	Application Rate	Directions
Root Crops, including but not limited to: Beets, Carrots, Ginseng, Horseradish, Sweet-potato, Yams	Alternaria, Crown Rot, Early Blight, Late Blight	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40-128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Preventative:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest
Stone Fruits, including but not limited to: Cherries, Nectarines, Peaches, Plums, Prunes	Brown Rot, Downy Mildew, Powdery Mildew	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30-100 gallons of spray solution per treated acre.	**Pre-Bloom:** Begin applications at ¼ - ½ inch green tip and continue on a five to seven day schedule through bloom. **Curative:** Spray diseased trees for three consecutive days and continue treatments on five to seven day intervals.
Sugar Beets	Alternaria, Bacterial Leaf Spot, Crown Rot, Leaf Blight, Leaf Spot, Powdery Mildew, Rhizoctonia	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 - 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest

Crops	Disease	Dilution Rate	Application Rate	Directions
Tobacco (Field)	Blue Mold	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest
Tobacco (Float Beds)	Blue Mold, Fusarium, Pythium, Phytophthora	1:500– 1:1000	1¼ – 2½ fl. oz. of Oxidate per 10 gallons.	**Curative:** Initial treatment of float bed water
		1:5,000- 1:10,000	6 – 24 fl. oz. of Oxidate per 1000 gallons.	**Preventive:** Treat water on a regular basis or maintain a residual 100 ppm concentration.
Tomatoes	*(See Peppers Section)*			
Tropical Fruit, including but not limited to: Casaba, Coconut, Dates, Guava, Kiwi, Mango, Passion Fruit, Pineapple, Poi, Star Fruit	Alternaria, Anthracnose, Leaf Blight, Powdery Mildew, Rhizoctonia, Sooty Mold, Stem Rot	1:100	128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Curative:** Spray diseased plants using 128 fl. oz. of OxiDate per 100 gallons of water for one to three consecutive days and continue treatments on five to seven day intervals.
		1:100 – 1:300	40–128 fl. oz. of OxiDate per 100 gallons of water; apply 30–100 gallons of spray solution per treated acre.	**Preventive:** Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 40 fl. oz. of OxiDate per 100 gallons of water after the completion of third treatment and maintain 5-day interval spray cycle until harvest

Directions, Rates and Usage

(Technical Bulletin) Tomato and Pepper Application Instructions

Seed Treatment

For control of Bacterial Speck and Bacterial Spot-

Rate	Application	Notes
1:100 or 1 gallon of OxiDate to 100 gallons of water.	• If seed has not been treated by the seed company, immerse seed in the OxiDate solution for one minute, remove seed and allow to drain.	• Rinsing of the seed after application is not required.

Seedling Production Treatment

For control of Bacterial Speck, Bacterial Spot, Damping-Off Pythium, Early Blight, Late Blight, and Phytophthora-

Rate at Seeding	Application	Notes
1/2 to 1 1/4 fl. oz. OxiDate per gallon of water.	• Apply one application of OxiDate to the point of saturation.	• Apply on newly seeded plug trays, seed flats or beds with the initial watering.
Rate for Post Emergence	**Application**	**Notes**
½ fl. oz. of OxiDate per gallon of water.	• Apply OxiDate at the 2 to 4 true leaf stage as a foliar spray with sufficient water to achieve complete coverage.	• Repeat at 7-day intervals.

At Planting Application

For control of Early Blight, Late Blight, Phytophthora and Pythium-

Rate	Application	Notes
½ to 1 gallon of OxiDate per treated acre in 50-200 gallons of water.	• Add OxiDate to transplant water or starter fertilizer and make in-furrow or dibble application just prior to plant set.	• In fields with a history of disease pressure, use the high rate. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.

Surface Application

For control of Early Blight, Late Blight, Phytophthora and Pythium-

Rate- Foliar Spray	Application	Notes
1/3 to 1 gallon of OxiDate per 100 gallons of water.	• Apply OxiDate as a foliar spray with sufficient water to achieve runoff to soil. • Repeat applications every 7 days through infectious season.	• Typical applications use 30 to 100 gallons of spray solution per acre. • During periods of wet, cloudy or rainy weather use a stronger rate and volumes and reduce spray intervals.
Rate- Irrigation Systems	**Application**	**Notes**
½ to 1 gallon of OxiDate per treated acre in 500 to 1000 gallons of water.	• Apply through drip trickle, center pivot, lateral move, end tow, side wheel roll, traveler, solid set, hand move or flood basin irrigation systems.	

Foliar Applications

For control of Anthracnose, Bacterial Speck and Spot, Botrytis, Early Blight, Late Blight, Powdery Mildew and Rhizoctonia Fruit Rot-

Rate- Foliar Spray	Application	Notes
1/3 to 1 gallon of OxiDate per 100 gallons of water. Complete coverage is essential.	• Begin applications of OxiDate prior to or in the early stages of disease development and continue throughout the season. • Spray at first appearance or when conditions are favorable for disease development. • Repeat applications at 7-day intervals.	• Under severe disease conditions, and during periods of rainy weather, apply immediately following each rain, reduce spray intervals, and use stronger rate. • Use sufficient water to obtain complete coverage. • Before tank mixing OxiDate with other fertilizers, fungicides, or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.
Rate- Irrigation Systems	**Application**	**Notes**
½ to 1 gallon of OxiDate per treated acre in 500-1000 gallons of water.	• Apply through center pivot, lateral move, end tow, side-wheel roll, traveler, solid set, or hand move irrigation systems.	• Do not spray OxiDate during conditions of intense heat, drought or poor vine canopy.

Directions, Rates and Usage

(Technical Bulletin) Cucurbit Application Instructions

At Planting Application

For control of Belly Rot, Root Rots, Fusarium Wilt, Pythium, Phytophthora, and Rhizoctonia-

Rate	Application	Notes
½ to 1 gallon of OxiDate per treated acre in 50-200 gallons of water.	• Make in-furrow applications just before seed is covered. • Make band applications to soil surface after seed is covered.	• In fields with a history of disease pressure, use higher rates.

Banded Application

For control of Belly Rot, Root Rots, Fusarium Wilt, Pythium, Phytophthora, and Rhizoctonia-

Rate for Spray Application	Application	Notes
1/3 to 1 gallon of OxiDate per 100 gallons of water.	• Apply OxiDate as a foliar spray with sufficient water to achieve runoff to soil when vines begin to run. • Repeat every seven days through infectious season.	• Typical applications use 30-100 gallons of spray per acre. During periods of wet, cloudy or rainy weather, use stronger rates and volumes and reduce spray intervals. • Before tank mixing OxiDate with other fertilizers, fungicides, or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.
Rate for Irrigation App.	**Application**	**Notes**
½ to 1 gallon of OxiDate per treated acre in 500-1000 gallons of water	• Apply through drip trickle, center pivot, lateral move, end tow, side wheel roll, traveler, solid set, hand move or flood basin irrigation systems.	

Foliar Applications

For control of Alternaria, Anthracnose, Downy Mildew, Gummy Stem Blight, Leaf Spot, and Powdery Mildew-

Rate for Spray Application	Application	Notes
1/3 to 1 gallon of OxiDate per 100 gallons of water. Complete coverage is essential.	• Begin applications of OxiDate prior to or in early stages of disease development and continue throughout the season. • Spray at first appearance or when conditions are favorable for disease development. • Repeat at 7-day intervals using sufficient water to obtain complete coverage.	• Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility. • Under severe disease conditions, and during periods of rainy weather, apply immediately after each rain, reduce spray intervals, and use stronger dilution rate. • Do not spray OxiDate during conditions of intense heat, drought or poor vine canopy.
Rate for Irrigation App.	**Application**	**Notes**
½ to 1 gallon of OxiDate per treated acre in 500-1000 gallons of water	• Apply through center pivot, lateral move, end tow, side-wheel roll, traveler, solid set, or hand move irrigation systems.	• Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility. • Do not spray OxiDate during conditions of intense heat, drought or poor vine canopy.

Directions, Rates and Usage

(Technical Bulletin) Beans – Snap and Dry Application Instructions

At Planting Application

For control of Early Blight, Late Blight, Phytophthora, Pythium, Rhizoctonia, Fusarium Root-Rot and Sclerotinia-

Rate	Application	Notes
½ to 1 gallon of OxiDate per treated acre in 50-200 gallons of water.	• Add OxiDate to setting water or starter fertilizer and make in-furrow application just prior to seed drop.	• In fields with a history of disease pressure, use the high rate. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.

Surface Application

For control of Early Blight, Late Blight, Phytophthora, Pythium, Rhizoctonia, Fusarium Root-Rot and Sclerotinia-

Rate- Foliar Spray	Application	Notes
1/3 to 1 gallon of OxiDate per 100 gallons of water.	• Apply OxiDate as a foliar spray with sufficient water to achieve runoff to soil. • Repeat applications every 7 days through infectious season.	• Typical applications use 30 to 100 gallons of spray solution per acre. During periods of wet, cloudy or rainy weather use a stronger rate and volumes and reduce spray intervals.
Rate- Irrigation Systems	**Application**	**Notes**
½ to 1 gallon of OxiDate per treated acre in 500 to 1000 gallons of water.	• Apply through drip trickle, center pivot, lateral move, end tow, side wheel roll, traveler, solid set, hand move or flood basin irrigation systems.	

Foliar Application

For control of Anthracnose, Bacterial blights, Botrytis, Powdery Mildew, Rhizoctonia, Rust, and White mold-

Rate- Foliar Spray	Application	Notes
1/3 to 1 gallon of OxiDate per 100 gallons of water. Complete coverage is essential.	• Begin applications of OxiDate prior to or in the early stages of disease development and continue throughout the season. • Spray at first appearance or when conditions are favorable for disease development. • Repeat applications at 7-day intervals.	• Under severe disease conditions, and during periods of rainy weather, apply immediately following each rain, reduce spray intervals, and use stronger dilution rate. • Use sufficient water to obtain complete coverage. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.
Rate- Irrigation Systems	**Application**	**Notes**
½ to 1 gallon of OxiDate per treated acre in 500-1000 gallons of water.	• Apply through center pivot, lateral move, end tow, side-wheel roll, traveler, solid set, or hand move irrigation systems.	• Do not spray OxiDate during conditions of intense heat, drought or poor vine canopy.

Directions, Rates and Usage

(Technical Bulletin) Strawberry Application Instructions

Pre-Plant Dip or Spray Application

For control of Botrytis, Crown Rot and Powdery Mildew -

Rate	Application	Notes
64 fl. oz. of OxiDate per 100 gallons of water	• Thoroughly wet transplants by dipping or spraying prior to planting.	• Excessive foaming or bubbling during the dipping process is an indication of high levels of disease contamination. • Remove dead or dying foliage prior to dipping. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.

Setting Water Application

For control of Botrytis-

Rate	Application	Notes
½ to 1 gallon of OxiDate in 50 – 200 gallons of water per treated acre.	• Add OxiDate to transplant water or starter fertilizer and make in-furrow or dibble application at the time of plant set.	• OxiDate is chemically compatible with most water soluble fertilizers. Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir test solution vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.

At-Planting Foliar Application

For control of Powdery Mildew, Leaf Blight, Angular Leaf Spot, Crown Rot and Botrytis-

Rate	Application	Notes
40 – 128 fl. oz. of OxiDate per 100 gallons of water. Complete coverage is essential.	• Immediately following planting, apply OxiDate as a foliar spray with sufficient water to achieve runoff to soil or plastic.	• Typical applications use 30 to 100 gallons of spray solution per treated acre. In fields with a history of disease pressure, use the high rate. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.

Existing Plantings – Foliar and Crown Disease Control
For control of Powdery Mildew, Leaf Blight, Angular Leaf Spot, Crown Rot and Botrytis-

Rate- Foliar Spray	Application	Notes
40 – 128 fl. oz. of OxiDate per 100 gallons of water. Complete coverage is essential.	• Begin applications of OxiDate prior to or in the early stages of disease development and continue throughout the season. • Spray at first appearance or when conditions are favorable for disease development. • Repeat applications at 7-day intervals.	• Typical applications use 30 to 100 gallons of spray solution per treated acre. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility. • Under severe disease conditions, and during periods of rainy weather, apply immediately following each rain, reduce spray intervals, and use astronger dilution rate. • Use sufficient water to obtain complete coverage. • OxiDate may be applied up to and including the day of harvest.

Botrytis Control on Existing Plantings-

Rate- Foliar Spray	Application	Notes
40 – 128 fl. oz. of OxiDate per 100 gallons of water. Complete coverage is essential.	• Apply OxiDate at the first growth flush. Repeat applications at 10% bloom, full bloom and at late or extended bloom. • Use additional sprays in late winter just after plant bed cleaning.	• Typical applications use 30 to 100 gallons of spray solution per treated acre. • Use sufficient water to obtain complete coverage. • Remove dead plant growth from the beds immediately prior to making an OxiDate application. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility.

Directions, Rates and Usage

(Technical Bulletin) Citrus Canker Application Instructions

Existing Plantings – Foliar and Tree Treatment
Citrus Crops including but not limited to grapefruit, kumquat, lemons, limes, oranges and tangerines.
For control of Citrus Canker

Rate- Foliar Spray	Application	Notes
20 – 128 fl. oz. of OxiDate per 100 gallons of water. Complete coverage is essential.	• Begin applications of OxiDate prior to or in the early stages of disease development and continue throughout the season. • Spray at first appearance or when conditions are favorable for disease development. • Repeat applications at 7-day intervals.	• Spray diseased plants using OxiDate treatment solution for one to three consecutive days and continue treatments on five to seven day intervals. • Spray entire tree including trunk, branches, leaf canopy. • Spray all areas where branches have been pruned, grafted or have become damaged or have apparent lesions or breaks in bark. • In groves with a history of disease pressure, use the stronger rate. • Typical applications use 30 to 100 gallons of spray solution per treated acre. • Before tank mixing OxiDate with other fertilizers, fungicides or bactericides, conduct a compatibility test for each combination. Make a test solution and shake or stir vigorously. Excessive bubbling and/or pressure are an indication of incompatibility. • Under severe disease conditions and during periods of wet, cloudy or rainy weather, apply immediately following each rain, reduce spray intervals and use stronger dilution rate. • Use sufficient water to obtain complete coverage. • OxiDate may be applied up to and including the day of harvest.

For vehicles, field equipment, tools, personnel clothing – Surface Treatment
For Citrus Canker

Rate- Surface Treatment	Application	Notes
16.0 – 21.3 fl. oz. of Oxidate™ per 100 gallons of water. Complete coverage is essential.	• Apply to field equipment such as pickers, trailers, trucks (including truck body parts and tires), bins, packing crates, ladders, power tools, pruning shears, gloves, rubber boots, Tyvek suits or other equipment that can transfer *Xanthomonas* bacterial species including citrus canker. • Apply to equipment and surfaces found in commercial packing houses including dump tanks, drenches, crates, containers, conveyors, storages, walls, floors, and process lines.	• Remove loose soil or organic matter with clean water or detergent/rinse. Use a power sprayer to remove loose dirt and organic matter. • Apply solution as a coarse spray or by mop, sponge, power sprayer, portable sprayer or fogger. Apply until run off. • Allow treated surfaces to air dry, do not rinse

CHEMIGATION:

General Requirements -

1) Apply this product only through a drip system or sprinkler including center pivot, lateral move, end tow, side (wheel) roll, traveler, big gun, solid set, hand move, flood (basin), furrow, border or drip (trickle) irrigation systems. Do not apply this product through any other type of irrigation system.

2) Crop injury, lack of effectiveness, or illegal pesticide residues in the crop can result from non-uniform distribution of treated water.

3) If you have questions about calibration, you should contact State Extension Service specialists, equipment manufacturers or other experts.

4) Do not connect an irrigation system (including greenhouse systems) used for pesticide application to a public water system unless the pesticide label-prescribed safety devices for public water systems are in place.

5) A person knowledgeable of the chemigation system and responsible for its operation, or under the supervision of the responsible person, shall shut the system down and make necessary adjustments should the need arise.

6) Posting of areas to be chemigated is required when 1) any part of a treated area is within 300 feet of sensitive areas such as residential areas, labor camps, businesses, day care centers, hospitals, in-patient clinics, nursing homes or any public areas such as schools, parks, playgrounds, or other public facilities not including public roads, or 2) when the chemigated area is open to the public such as golf courses or retail greenhouses.

7) Posting must conform to the following requirements:

• Treated areas shall be posted with signs at all usual points of entry and along likely routes of approach from the listed sensitive areas.

• When there are no usual points of entry, signs must be posted in the corners of the treated areas and in any other location affording maximum visibility to sensitive areas.

• The printed side of the sign should face away from the treated area towards the sensitive area. The signs shall be printed in English.

• Signs must be posted prior to application and must remain posted until foliage has dried and soil surface water has disappeared.

• Signs may remain in place indefinitely as long as they are composed of materials to prevent deterioration and maintain legibility for the duration of the posting period.

• All words shall consist of letters at least 2.5 inches tall, and all letters and the symbol shall be a color which sharply contrasts with their immediate background

• At the top of the sign shall be the words KEEP OUT, followed by an octagonal stop sign symbol at least 8 inches in diameter containing the word STOP.

• Below the symbol shall be the words PESTICIDES IN IRRIGATION WATER.

Specific Requirements for Chemigation Systems Connected to Public Water Systems -

1) Public water system means a system for the provision to the public of piped water for human consumption if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year.

2) Chemigation systems connected to public water systems must contain a functional, reduced-pressure zone, backflow preventer (RPZ) or the functional equivalent in the water supply line upstream from the point of pesticide introduction. As an option to the RPZ, the water from the public water system should be discharged into a reservoir tank prior to pesticide introduction. There shall be a complete physical break (air gap) between the outlet end of the fill pipe and the top or overflow rim of the reservoir tank of at least twice the inside diameter of the fill pipe.

3) The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump.

4) The pesticide injection pipeline must contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid
from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.

5) The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops, or in cases where there is no water pump, when the water pressure decreases to the point where pesticide distribution is adversely affected.

6) Systems must use a metering pump, such as a positive displacement injection pump (e.g., diaphragm pump) effectively designed and constructed of materials that are compatible with pesticides and capable of being fitted with a system interlock.

7) Do not apply when wind speed favors drift beyond the area intended for treatment.

Specific Requirements for Sprinkler Chemigation -

1) The system must contain a functional check valve, vacuum relief valve and low-pressure drain appropriately located on the irrigation pipeline to prevent water source contamination from backflow.

2) The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump.

3) The pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.

4) The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops.

5) The irrigation line or water pump must include a functional pressure switch which will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected.

6) Systems must use a metering pump, such as a positive displacement injection pump (e.g., diaphragm pump) effectively designed and constructed of materials that are compatible with pesticides and capable of being filled with a system interlock.

7) Do not apply when wind speed favors drift beyond the area intended for treatment.

Specific Requirements for Flood (Basin), Furrow and Border Chemigation -

1) Systems using a gravity flow pesticide dispensing system must meter the pesticide into the water at the head of the field and downstream of a hydraulic discontinuity such as a drop structure or weir box to decrease potential for water source contamination from backflow if water flow stops.

2) The systems utilizing a pressurized water and pesticide injection system must meet the following requirements.

a. The system must contain a functional check valve, vacuum relief valve and low-pressure drain appropriately located on the irrigation pipeline to prevent water source contamination from backflow.

b. The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump.

c. The pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.

d. The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops.

e. The irrigation line or water pump must include a functional pressure switch which will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected.

f. Systems must use a metering pump, such as a positive displacement injection pump (e.g., diaphragm pump) effectively designed and constructed of materials that are compatible with pesticides and capable of being filled with a system interlock.

Specific Requirements for Drip (Trickle) Chemigation -

1) The system must contain a functional check valve, vacuum relief valve and low-pressure drain appropriately located on the irrigation pipeline to prevent water source contamination from backflow.

2) The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump.

3) The pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.

4) The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops.

5) The irrigation line or water pump must include a functional pressure switch which will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected.

6) Systems must use a metering pump, such as a positive displacement injection pump (e.g., diaphragm pump) effectively designed and constructed of materials that are compatible with pesticides and capable of being filled with a system interlock.

Application Instructions -

1) Remove scale, pesticide residues, and other foreign matter from the chemical supply tank and entire injector system. Flush with clean water. Failure to provide a clean tank, void of scale or residues may cause product to lose effectiveness or strength.

2) Determine the treatment rates as indicated in the directions for use and make proper dilutions.

3) Prepare a solution in the chemical tank by filling the tank with the required water and then adding product as required. The product will immediately go into suspension without any required agitation.

4) Do not apply OxiDate in conjunction with any other pesticides or fertilizers; this has the potential to cause reduced performance of the product. Avoid application in this manner.

WARRANTY - This material conforms to the description on the label and is reasonably fit for the purposes referred to in the directions for use. Timing, method of application, weather, watering practices, nature of soil, potting medium, disease problem, condition of crop, incompatibility with other chemicals, pre-existing conditions and other conditions influencing the use of this product are beyond the control of the seller. Buyer assumes all risks associated with the use, storage, or handling of this material not in strict accordance with directions given herewith. NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS OR MERCHANTABILITY IS MADE.

BioSafe Systems LLC

For additional information on OxiDate, call us toll-free: 1-888-273-3088

or visit our website: www.biosafesystems.com

WATERMELON (*Citrullus lanatus* 'Imagination')
Fusarium wilt; *Fusarium oxysporum* f. sp. *niveum*

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Field evaluation of fungicides applied through drip tape for control of Fusarium wilt of watermelon, 2009.

The experiment was established in a field of Norfolk "A" loamy sand soil at the University of Maryland's Lower Eastern Shore Research and Education Center, Salisbury. The field had a history of severe losses to Fusarium wilt and contained mixed populations of races 1 and 2 of *Fusarium oxysporum* f. sp. *niveum*. The experiment was conducted as a randomized complete block design with four replications. Plots consisted of single-row beds that were 40 ft long, 5.9 in. high, spaced 6 ft apart, and covered with 1.25-mil black plastic under which a single drip irrigation tube was placed. Nine fungicide treatments were applied through the drip irrigation tube in the trial. All treatments except Garlic GP were applied immediately after transplanting, and again at 2 and 4 weeks after transplanting. Garlic GP was applied immediately after transplanting and again 2 weeks later. The watermelon cv. 'Imagination', which is susceptible to Fusarium wilt, and the pollenizer cv. 'SP-4', were seeded in a greenhouse on 8 and 12 May, respectively. On 16 Jun seedlings of both cultivars were transplanted 18 in. apart in a row, with 'SP-4' planted after every two 'Imagination'. A 20-20-20 starter solution was applied at planting. Before bedding, fertilizer at 700 lb/A of 15-0-15 plus S (5%) and B (0.2%) was applied and incorporated into soil. For pre-emergent weed control, Curbit 3E (2 pt/A) and Sinbar WP (3 oz/A) were applied over the beds on 3 Jun. Weeds were managed by tractor or manual cultivation on 22, 23, and 30 Jun and 6, 7, 13, 23, and 30 Jul. Foliar diseases were managed with Bravo Weather Stik 720SC (2 pt/A), applied on 10 Aug. Plots were irrigated through drip tape as needed. Wilt incidence, defined as the percentage of plants showing symptoms of Fusarium wilt, was assessed on 17 Jul and 1 Aug. Plot vigor, a visual assessment of percent foliage cover compared to a healthy plot, was assessed on 7 Aug. Vine length (longest runner on each plant) was measured for three randomly selected plants per plot on 8 Jul. Marketable fruit were weighed and counted on 12 Aug.

Fusarium wilt was severe in all plots. In nontreated plots, 78% of plants had wilt symptoms by 1 Aug. On 17 July, plots treated with Proline alone had significantly less wilt incidence than nontreated plots. By 1 Aug, the differences were more pronounced: all plots where Proline was applied alone, or in combination with Actigard and/or Topsin M, had significantly less wilt than nontreated plots as well as plots where Actigard or Topsin M were applied alone or in combination. Plot vigor and yield were also numerically highest in plots where Proline was applied alone or in combination with other fungicides, although not significantly higher than in some treatments. There were no significant differences in vine length on 8 Jul or in number of marketable fruit on 12 Aug, among treatments (data not shown). Garlic GP applied through the drip did not reduce wilt nor did it increase vigor or yield. No phytotoxicity was observed in any treatment.

	Fusarium wilt count/plot[z]		Plot vigor (%)[y]	Fruit wt. Lb/plot
Treatment and rate/A	17 July	1 Aug	7 Aug	12 Aug
Non treated	10.0 abc[x]	14.0 a	19.0 e	80.8 abcd
Actigard 50WG 0.25 oz	13.0 a	12.3 a	35.5 bcd	36.5 e
Proline 480SC 5.7 fl oz	5.0 d	6.3 b	45.0 b	105.7 a
Topsin M 4.5FL 10 fl oz	10.8 ab	14.0 a	19.0 e	73.4 cd
Actigard 50WG 0.25 oz + Proline 480SC 5.7 fl oz	7.0 cd	8.5 b	38.0 bc	100.3 abc
Actigard 50WG 0.25 oz + Topsin 4.5FL 10 fl oz	9.8 bc	12.3 a	26.0 cde	75.4 bcd
Actigard 50WG 0.25 oz + Proline 480SC 5.7 fl oz + Topsin 4.5FL 10 fl oz	7.5 cd	6.8 b	62.5 a	103.8 a
Topsin 4.5FL 10 fl oz + Proline 480SC 5.7 fl oz	7.3 cd	7.8 b	47.5 ab	102.8 ab
Garlic GP 14 fl oz/gal	12.5 ab	14.0 a	21.0 de	58.3 de
P>F	0.0002	0.0001	0.0001	0.0002

[z]Mean percentage of Fusarium wilt includes wilted and dead plants.
[y]Plot vigor is a visual assessment of percent of foliar coverage of the whole plot.
[x] Mean values in each column followed by the same letter are not significantly different at $P = 0.05$ based on Fisher's protected LSD test.

Managing Fusarium Wilt of Watermelon with Fungicide Drenches and Seed Treatments

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Introduction

Fusarium wilt, caused by *Fusarium oxysporum* f.sp. *niveum* (FON) is one of the most important pests of watermelon in the U.S. Losses due to Fusarium wilt have been increasing recently, because (1) race 2 of FON, for which there is no resistance in commercial varieties, is becoming more widespread (Egel et al. 2005, Zhou and Everts et al., 2003); (2) there has been an increase in the report of Fusarium wilt in greenhouse situations, raising the possibility of an increase in the incidence of seedborne transmission of Fusarium wilt (*Dan Egel, personal observation*); (3) Crop rotation does not eliminate the problem since FON produces resilient spores capable of surviving years in the absence of the host and there is a lack of suitable land for rotation. Management of Fusarium wilt via cultural methods is limited due to the resilient spores mentioned above and host resistance is not a suitable option for many producers because of the race situation for FON. There are currently no fungicides labeled for Fusarium wilt of watermelon. The $328 million watermelon industry is threatened by Fusarium wilt, for which there are few management options. The proposed research described below will compare hymexazol (trade name Tachigaren 30L) against the compounds thiophanate-methyl, fludioxonil and acibenzolar-S-methyl for efficacy as a drench or seed treatment on Fusarium wilt of watermelon.

Methods and Materials

Drench Experiments

Seeds of the open pollinated variety Black Diamond were planted in Jiffy soilless mix in polystyrene transplant trays. After the seedlings had reached the two true leave stage, the seedlings were transplanted into a 4:1:1 sand:peat:vermiculite mix (v:v:v) in polystyrene pots of 15 cm diameter and 1700 cc volume. Immediately after transplanting, the seedlings were drenched with 125 ml of one of the fungicides listed in Table 1 and 2 or water. 72 hours after transplanting to the pots, the seedlings were drenched with 150 ml of a 1 x 10^5 solution of *Fusarium oxysporum* fsp. *niveum* (FON) conidia per ml solution or water. The inoculum was produced by adding five 1-cm cores of a FON colony grown on PDA to a mineral salts liquid medium (Esposito and Fletcher, 1961) grown in shake culture. The strain used for all experiments, 03-15, was an Indiana FON race 1 strain (Egel et al., 2005). Conidia were adjusted to the appropriate concentration with the assistance of a Spencer hemacytometer.

All seedlings were fertilized with 100 ml of a Peter's 20-20-20 solution about 6 days post inoculation.

When symptoms of Fusarium wilt began to be observed, about 7 days post inoculation, each seedling was rated approximately every other day using the Horsfall-Barratt rating scale (Horsfall and Barratt, 1945). Seedlings were rated for the percent of the foliage of each plant that had symptoms of Fusarium wilt such as wilt or necrosis. The area under the disease progress curve (AUDPC) was calculated from the Horsfall-Barratt values using trapezoidal integration (Shaner and Finney, 1977).

The main effects, fungicide treatment and inoculation, as well as interaction effects of fungicide treatment by inoculation were analyzed by analysis of variance (ANOVA). A mean separation test was used on means significantly different at P=0.05 (Fisher's protected least significantly different difference).

The experiment was conducted two different times, February and March 2007 at the greenhouse facility at the Southwest Purdue Ag Center, Vincennes, IN. The temperatures for the February experiment ranged from 8 C to 25 C. In March the temperatures ranged from 8 C to 27 C. Each treatment was replicated 5 times. The experimental design was completely randomized.

Seed experiments

In preliminary seed coat inoculation experiments, conidia of FON were applied to the seed coat of untreated Black Diamond seeds. In these experiments, a rate of 160 conidia per seed was determined to be useful. However, the symptoms that resulted from these inoculations differed from those that had been observed previously in commercially produced transplants. Therefore, in addition to inoculating the seed coat, seedlings produced from treated seed were root dipped in an FON solution (see below).

Seed treatments: seed coat inoculation

Conidia of FON produced as above were applied to the untreated seed of Black Diamond watermelon as follows: 2 ml of a 1×10^4 suspension of FON conidia were added drop wise to 125 seeds in a 300 cc plastic coffee container. Water was added to the controls. The seeds were constantly mixed as the suspension was added. The seeds were then allowed to dry in a plastic weigh boat for 24 hours.

After the 24-hour drying period, the fungicides were applied at the rates listed in tables 3 and 4. The solutions were mixed in 2 ml of deionized water with 25 ul red food coloring added. The solution was added drop wise as above. Water was added to the controls. The seeds were then allowed to dry in a plastic weigh boat for 24 hours.

When the fungicide had dried on the seed, the seed was planted in polystyrene trays with 9 cm^3 cells filled with Jiffy soilless mix. 25 seed of each treatment were planted for each of 5 replications. The experimental design was completely randomized.

The most common symptoms observed on the inoculated seeds were lesions on the hypocotyls or cotyledon. These symptoms as well as emergence were counted for each treatment.

The first seed coat experiment was conducted in March and the second in April. The temperatures for the March experiment ranged from 9 C to 25 C. In April the temperatures ranged from 7 C to 26 C.

Seed treatments: root dip inoculation

Since the seed coat experiments described above did not produce typical Fusarium symptoms, a root dip experiment was conducted using a method modified from Latin and Snell (1986).

Untreated Black Diamond watermelon seeds were treated with fungicide as above and planted in polystyrene transplant trays of the type described above. The trays were placed on about 5 cm of the sand mix described above so that the roots could grow into the sand mixture. At approximately 14 days post seeding (when the first true leaf was fully expanded), the trays were gently lifted from the sand, the roots washed and then dipped in a suspension of 1×10^5 FON conidia produced and quantified as described above. The trays were then returned to the sand mix with care taken to insure the roots were covered with the mix.

7 days post inoculation, the seedlings began to show typical symptoms of Fusarium wilt. All treatments inoculated with FON exhibited symptoms of Fusarium wilt while the controls remained healthy.

Seedlings were rated for symptoms of Fusarium wilt approximately every other day using the Horsfall-Barratt rating scale. All seedlings in one 9-cell flat were considered a replication. There were 5 replications. The experimental design was a randomized complete bloc with the replications of each treatment occurring in one sand bed. AUDPC and statistics were conducted as described above.

Emergence in field soil: 100 seeds treated as in the seed coat experiments above but uninoculated, were planted 2.5 cm deep in soil collected from a commercial watermelon field (Bloomfield loamy fine sand). The seeds were not inoculated in any way with FON. The experiment was completely randomized with 3 replications. The temperatures ranged from a low of 8 C to a high of 23 C. Emergence data were collected and statistics were performed as above.

Results

Drench experiments

Symptoms typical of Fusarium wilt began to be observed approximately 7 days post inoculation. No symptoms of Fusarium wilt were observed in the uninoculated controls. Seedlings treated with Actigard exhibited phytotoxicity symptoms that were similar to Fusarium wilt symptoms, however. At the termination of both drench experiments, FON was isolated from all inoculated treatments, but not from any of the uninoculated treatments.

The Fusarium wilt symptoms observed in the Topsin 4.5L inoculated treatments did not differ significantly from the uninoculated controls in either experiment (Tables 1 and 2). The high rate of Tachigaren 30L treatments had significantly less symptoms than the controls in either experiment. This treatment also had significantly more symptoms than the Topsin treatments. Seedlings treated with the low rate of Tachigaren had significantly reduced symptoms than the inoculated control in the first experiment, but there was no significant difference in the second experiment.

As the experiment progressed, it became apparent that the fungicide treatments affected the seedling growth. In Table 3, the growth of those seedlings that were not inoculated with FON is compared between treatments. The greatest width of the leaves and the greatest height was measured in cm. Actigard reduced the growth of seedlings significantly compared to all other treatments in March and all the treatments except for the water control in the April experiment. Seedlings treated with Topsin were significantly reduced in size compared with the Cannonball or either rate of the Tachigaren treatment in the March experiment. Seedlings treated with either rate of Tachigaren were not significantly smaller than any other treatment in either experiment.

Seed treatments: seed coat inoculation

Emergence of seedlings was unaffected by fungicide seed treatment in the first seed coat inoculation experiment (Table 4). In the second experiment (Table 5), both the inoculated and the uninoculated controls had significantly lower emergence than any of the fungicide treatments, which were not significantly different from each other. In both experiments (Tables 4 and 5), the only significant difference in symptom development was that the inoculated control had significantly more symptoms than any other treatment. However, the symptoms were not typical of Fusarium wilt.

Seed treatments: root dip inoculation

At approximately 7 days post inoculation, typical Fusarium wilt symptoms were observed on seedlings inoculated with FON. The Tachigaren seed treatment did not suppress the symptoms of Fusarium wilt significantly better than the untreated, inoculated control in either experiment (Tables 6 and 7). In experiment 1 (Table 6), Topsin treated seed significantly reduced Fusarium wilt symptoms compared with the untreated, inoculated control. However, in experiment 2 (Table 7), Topsin did not reduce symptoms compared with the untreated, inoculated control.

Seed treatments: field soil

Seeds treated with Tachigaren had significantly more emergence than any other treatment (Table 8). Seeds treated with Topsin did not differ significantly in emergence from the water control.

Discussion

Tachigaren 30L, 6 ml/m^2 shows promise as a fungicide drench. Although Tachigaren 30L, 6 ml/m^2 did not perform as well as the Topsin drench treatment, the latter exhibited some phytotoxicity in the form of stunting and leaf cupping. No phytotoxicity was observed with Topsin used at the same rate in a field trial in 2006 (data not shown), therefore, the phytotoxicity observed in these trials may be related to the inability of the roots in pots to explore new soil. Seedlings grown in a greenhouse pot, which has been drenched with fungicide, are likely to encounter a higher percentage of soil with fungicide residue than seedlings grown in the field treated with fungicide at the same rate. This is because seedlings grown in the field are able to explore a greater volume of soil than seedlings grown in a pot in the greenhouse. For the same reason, the amount of disease reduction accompanied by a fungicide drench may be greater in a greenhouse pot, than in the field.

The low rate of Tachigaren 30L used as a drench may not be sufficient to manage Fusarium wilt of watermelon since in one trial (Table 2) control at the low rate failed.

Seedborne Fusarium wilt of watermelon usually occurs at rates of less than 10 percent (McLaughlin and Martyn, 1982). Therefore, it is not practical to use naturally infested seed to test seed treatments. In this study, two different methods were used to artificially infest seed. When FON conidia were applied directly to watermelon seeds, the symptoms observed on the seeds were not typical of Fusarium wilt. Instead the symptoms usually consisted of lesions on the hypocotyls and cotyledons. This may indicate that when FON is seedborne in watermelon seeds, the usual placement of the fungus is not on the seed coat. When the roots of seedlings in transplant trays were inoculated by root dip, typical wilt symptoms were observed.

Systemic fungicide treatments on seed do not penetrate the seed coat. Instead, the fungicide on the seed washes off with watering so that the fungicide residue exists in the soil for the roots to take up. In this manner, the fungicide treated seed in the root dip experiments described here are able to reduce the amount of wilt observed in the seedling.

There were few differences between Topsin and Tachigaren in the experiments where the seed coat was inoculated with FON directly. In both of the experiments (Table 5 and 6), both fungicides equally controlled the Fusarium symptoms. However, the incidence of symptoms was low.

Tachigaren did not significantly reduce the Fusarium wilt symptoms in either of the root dip experiments that tested fungicide seed treatments (Tables 3 and 4). Since Topsin worked in the first experiment and did not in the second, there may have been a fungicide application problem in the second experiment. It would be interesting to know if the Tachigaren 30L formulation would have worked better than the 70 WP formulation, since the 30L formulation had obvious activity in the drench experiments.

Tables

Table 1: Fungicide drenches applied to 4-week-old black diamond seedlings for the management of *Fusarium* wilt of watermelon. This experiment was performed in 15 cm diameter pots filled with a 4:1:1 mixture (v:v:v) of sand, peat and vermiculite, in February 2007.

Treatment, rate[z]	**Inoculation**[y]	**AUDPC**[x]
No fungicide ---	Yes	679.89 a [w]
Cannonball 50 WP, 0.50 lb/A	Yes	607.62 a
Tachigaren 30L, 3 ml/m^2	Yes	365.37 b
Tachigaren 30L, 6 ml/m^2	Yes	252.13 c
Actigard 50 WG, 0.33 oz/A	No	220.90 c
Actigard 50 WG, 0.33 oz/A	Yes	220.90 c
Topsin 4.5L, 10 fl oz/A	Yes	15.35 d
Cannonball 50 WP, 0.50 lb/A	No	0.00 d
Topsin 4.5L, 10 fl oz/A	No	0.00 d
Tachigaren 30L, 3 ml/m^2	No	0.00 d
Tachigaren 30L, 6 ml/m^2	No	0.00 d
No fungicide ---	No	0.00 d

[z] Each fungicide drench treatment of 125 ml was applied at planting. Untreated controls received water. Rate per acre was calculated on the assumption of 1,400 plants per acre.

[y] Seedlings were inoculated with a 150 ml solution of 1 x 10^5 conidia of *Fusarium oxysporum* fsp. *niveum* 72 hours after the fungicide drench treatment. Controls received water.

[x] Area Under the Disease Progress Curve.

[w] Means within each column with a letter in common are not significantly different (*P*=0.05, LSD).

Table 2: Fungicide drenches applied to 4-week-old black diamond seedlings for the management of *Fusarium* wilt of watermelon. This experiment was performed in 15 cm diameter pots filled with a 4:1:1 mixture (v:v:v) of sand, peat and vermiculite, in March 2007.

Treatment, rate[z]	**Inoculation**[y]	**AUDPC**[x]
Tachigaren 30L, 3 ml/m^2	Yes	563.76 a [w]
No fungicide, ---	Yes	531.10 a
Cannonball 50 WP, 0.50 lb/A	Yes	353.51 b
Tachigaren 30L, 6 ml/m^2	Yes	348.22 b
Actigard 50 WG, 0.33 oz/A	Yes	140.42 c
Actigard 50 WG, 0.33 oz/A	No	136.22 c
Cannonball 50 WP, 0.50 lb/A	No	0.00 d
Topsin 4.5L, 10 fl oz/A	No	0.00 d
Tachigaren 30L, 3 ml/m^2	No	0.00 d
Tachigaren 30L, 6 ml/m^2	No	0.00 d
Topsin 4.5L, 10 fl oz/A	Yes	0.00 d
No fungicide, ---	No	0.00 d

[z] Each fungicide drench treatment of 125 ml was applied at planting. Untreated controls received water. Rate per acre was calculated on the assumption of 1,400 plants per acre.

[y] Seedlings were inoculated with a 150 ml solution of 1 x 10^5 conidia of *Fusarium oxysporum* fsp. *niveum* 72 hours after the fungicide drench treatment. Controls received water.

[x] Area Under the Disease Progress Curve.

[w] Means within each column with a letter in common are not significantly different (*P*=0.05, LSD).

Table 3: Comparison of the area of the plant tops (height x diameter) of uninoculated, greenhouse grown Black Diamond watermelon seedlings treated with the fungicides listed below for two different experiments (March 12 and April 6).

	Plant size (cm^2)[z]	
Treatment, rate	**March 12[y]**	**April 6**
Actigard 50WP, 0.33 oz/A	118.8 c[x]	350.4 c
Cannonball 50WP, 0.5 lb/A	310.2 a	756.8 a
Topsin 4.5L	213.1 b	637.3 ab
Tachigaren 30L, 3 ml/m^2	311.7 a	712.4 a
Tachigaren 30L, 6 ml/m^2	307.5 a	653.8 ab
Water	237.2 ab	501.8 bc

[z] The height and the maximum width of the leaves were measured in cm and the result multiplied to give an area.
[y] Two different experiments were conducted; the final measurements of the first experiment was completed on 12 March and the second experiment on 6 April.
[x] Means within each column with a letter in common are not significantly different (*P*=0.05, LSD).

Table 4: Untreated black diamond seed were inoculated with a solution of 1 x 10^4 *Fusarium oxysporum* fsp. *niveum* conidia per ml or water. 24 hours later the seed was treated with one of the fungicides listed below or water. March 2007.

Treatment, rate	**Inoculation**	**Emergence**^{z}	**Symptomatic Seedlings**^{y}
Water control	Yes	24.0	6.2 a^x
Water control	No	24.2	0.0 b
Tachigaren 70WP, 8g/kg	Yes	24.4	1.0 b
Tachigaren 70WP, 8g/kg	No	24.2	0.0 b
Topsin 4.5L, 5.7 fl oz/100 lb seed	Yes	25.0	0.4 b
Topsin 4.5L, 5.7 fl oz/100 lb seed	No	24.4	0.0 b

^{z} Emergence of seedlings from the soil 14 days after planting out of 25 total.
^{y} The number of seedlings with symptoms of *Fusarium* inoculation.
^{x} Means within each column with a letter in common are not significantly different (*P*=0.05, LSD).

Table 5: Untreated black diamond seed were inoculated with a solution of 1 x 10^4 *Fusarium oxysporum* fsp. *niveum* conidia per ml or water. 24 hours later the seed was treated with one of the fungicides listed below or water. April 2007.

Treatment, rate	**Inoculation**	**Emergence**^{z}	**Symptomatic Seedlings**^{y}
Water control	Yes	22.8 c	2.0 a^x
Water control	No	23.4 c	0.0 b
Tachigaren 70WP, 8g/kg	Yes	24.6 a	0.2 b
Tachigaren 70WP, 8g/kg	No	24.2 ab	0.0 b
Topsin 4.5L, 5.7 fl oz/100 lb seed	Yes	24.4 ab	0.0 b
Topsin 4.5L, 5.7 fl oz/100 lb seed	No	24.0 ab	0.0 b

^{z} Emergence of seedlings from the soil 10 days after planting out of 25 total.
^{y} The number of seedlings with symptoms of *Fusarium* inoculation.
^{x} Means within each column with a letter in common are not significantly different (*P*=0.05, LSD).

Table 6: Comparison of fungicide seed treatments against *Fusarium* wilt of watermelon, February 2007. Black diamond watermelon seed treated with fungicides as listed below were planted in polystyrene transplant trays filled with a peat based greenhouse mix. The roots were allowed to grow from the tray into a 4:1:1 (v:v:v) sand:peat:vermiculate mix. At the appearance of the first true leaf, the roots were lifted, inoculated with a suspension of 1 x 10^5 *Fusarium oxysporum* fsp. *niveum* conidia per ml or water and replaced on the sand mix.

Treatment, rate	**Fusarium Inoculation**	**AUDPC**[z]
No fungicide, --	Yes	320 a[x]
Tachigaren 70 WP, 8 g/kg seed	Yes	259 a
Topsin 4.5L, 5.7 oz/100 lb seed	Yes	150 b
Tachigaren 70 WP, 8 g/kg seed	No	0 c
Topsin 4.5L, 5.7 oz/100 lb seed	No	0 c
No fungicide, --	No	0 c

[z] Area Under the Disease Progress Curve.
[x] Means within each column with a letter in common are not significantly different (*P*=0.05, LSD).

Table 7: Comparison of fungicide seed treatments against *Fusarium* wilt of watermelon, March 2007. Black diamond watermelon seed treated with fungicides as listed below were planted in polystyrene transplant trays filled with a peat based greenhouse mix. The roots were allowed to grow from the tray into a 4:1:1 (v:v:v) sand:peat:vermiculate mix. At the appearance of the first true leaf, the roots were lifted, inoculated with a suspension of 1 x 10^5 *Fusarium oxysporum* fsp. *niveum* conidia per ml or water and replaced on the sand mix.

Treatment, rate	**Fusarium Inoculation**	**AUDPC**[z]
No fungicide, --	Yes	279 a[x]
Tachigaren 70 WP, 8 g/kg seed	Yes	277 a
Topsin 4.5L, 5.7 oz/100 lb seed	No	261 a
Tachigaren 70 WP, 8 g/kg seed	No	0 b
Topsin 4.5L, 5.7 oz/100 lb seed	No	0 b
No fungicide, --	No	0 b

[z] Area Under the Disease Progress Curve.
[x] Means within each column with a letter in common are not significantly different *P*=0.05, LSD).

Table 8: Comparison of the emergence of black diamond seedlings from seed treated with the fungicides listed below or water and planted in field soil in polystyrene trays in a greenhouse.

Treatment, rate	**Final Emergence (%)[z]**
Tachigaren 70WP, 8g/kg seed	66.3 a[x]
Water control	14.3 b
Topsin 4.5L, 5.7 fl oz/100 lb/seed	11.0 b

[z] Percent emergence of 100 seeds planted in a Bloomfield loamy fine sand 14 days after seeding.
[x] Means within each column with a letter in common are not significantly different (*P*=0.05, LSD).

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UT Extension

Southern Blight of Vegetables

Steve Bost, Professor
Entomology and Plant Pathology

Southern blight, also known as southern stem blight, is a serious disease of many vegetable crops, causing an almost certain death of affected plants. It is caused by the soil-borne fungus, *Sclerotium rolfsii*, and attacks a number of vegetable crops including bean, cantaloupe, carrot, potato, pepper, tomato, eggplant, sweetpotato, tomato, watermelon and others.

Symptoms

Southern blight is one of the most common causes of a sudden wilting and death of a plant. Mild yellowing of the leaves may occur prior to wilting. Under humid conditions, a thin, white, fan-shaped mold forms on affected stem tissues and adjoining surface soil (see photo). Even under dry conditions, at least a trace of the white mold should be evident on the stem surface. Soon after mold formation, seed-like bodies (sclerotia) develop in the mold. The sclerotia begin white, turning tan, then bronze. When the plant is pulled up, a brown, dry rot of the lower stem and upper roots is apparent. In vegetables in which the fruit contact the ground, such as pumpkin and cantaloupe, the fruit are rotted, beginning with the side of the fruit in contact with the soil. On the surface of the edible roots of sweetpotatoes are 1/4 to ½ inch circular, sunken, dark gray spots.

Disease Cycle

The fungus overwinters as sclerotia in the soil and in plant debris. A characteristic of the fungus is that it is generally restricted to the upper 2 or 3 inches of soil and will not survive at greater depths. The fungus is more active in hot, wet weather, and it requires the presence of undecomposed plant residue to initiate infection. *S. rolfsii* is more active under acidic soil conditions. The fungus does not have an air-borne spore, so all infections result from contact of the plant tissue with soil. It is spread when infested soil particles are moved, as with cultivation. The fungal body is so strong that it is capable of growing across the soil surface to reach a plant, if old plant debris is available.

Control

- In gardens, remove affected plants, including roots and a small amount of soil surrounding the plant. Be careful not to scatter debris as the material is removed. Place the material in a place that will not be used for a garden in the future.
- Do not plant susceptible crops where southern blight occurred the previous year.
- Control weeds, which can allow buildup of the fungus.
- Prepare the land properly. The previous crop must be well decomposed prior to planting, and this may require disking or rototilling the field several times in the fall and in the spring.
- Bury the previous crop litter with a moldboard plow to a depth below later cultivation equipment movements (8-12 inches). The crop litter should be below a 3 to 5 inch depth. None of the buried litter should ever be brought back near the soil surface during the current season by cultivation.
- Do not throw soil with debris against plant parts during the growing season if southern blight is a problem.
- Control foliar diseases since dead leaves on the ground may trigger infection. Weeds should also be controlled early in the season for the same reason.
- Avoid using organic mulches where southern blight is a problem.
- For commercial growers, soil fumigation is an option. It will reduce, but not eliminate, southern blight.
- Terraclor (PCNB) can be used at planting time for tomatoes, peppers, potatoes, and beans. Refer to the label for proper use instructions. Terraclor will reduce southern blight when used preventively and cannot be used after planting.

Valdensinia leaf spot of lowbush blueberry

Valdensinia leaf spot, caused by the fungus *Valdensinia heterodoxa*, has become a serious disease of lowbush blueberry in the last few years. It was first observed in 1997 and has since spread to numerous fields throughout Nova Scotia, New Brunswick, Prince Edward Island and with new observations occurring in Quebec and Maine in 2009.

Symptoms

The disease appears on leaves of sprout and fruiting stems as circular, brown lesions sometimes with a purple-red border and variable in size up to 1 cm in diameter (Figure 1). A single spore in the centre of a lesion may be visible on either side of the leaf with a hand lens. Infected leaves fall rapidly from the plant while still green. When the disease is serious, many fallen green leaves with lesions can be seen on the soil surface. Infections early in the season appear on leaves on lower portions of stems, but with time, symptoms appear progressively higher on stems eventually reaching the upper leaves. This leads to defoliated patches which become visible from a distance. Affected localized areas continue to expand and merge resulting in large defoliated areas in fields. Severely affected fruiting fields may have poor yields. Severely affected sprout fields may appear to recover a few weeks later, but this is due to vegetative re-growth from the leaf axils where fruit buds would normally form and so reduced yields may result in the following year.

Figure 1. Large, circular brown lesions with a dark border.

The disease frequently appears in the shade of wooded areas, but in seasons with long wet periods, the disease can appear anywhere in the field. All blueberry clones are susceptible and all highbush cultivars tested so far are susceptible. The fungus can often be seen causing spots on many other plants in blueberry fields, but this is not important since the fungus does not easily produce spores or overwinter on these infected hosts. Such plants include sheep sorrel, bunchberry, birch, wild strawberry and raspberry.

Life cycle

The fungus overwinters in infected blueberry leaves from the previous season and produces its first spores in early-mid June, but sometimes later in the season. About 3 days of continuous wetness are required for the first crop of spores to be produced and released. Once released, spore infection occurs rapidly within about 6-10 hours of continued leaf wetness. Relatively few spores are produced, but each spore is highly aggressive and will cause a large lesion. Lesions reach about 5-10 mm in diameter in 24-48 hours after which leaves begin to drop. At this point, a further 48 hours of wetness are required for new spores to be produced on the infected leaves. As a result, multiple spore production/infection cycles can occur during a week of wet weather. If the weather clears, spore production and infection stops, but will resume if wet weather returns. As the season progresses, the leaves tend to become more resistant. While infection still occurs, lesions tend to be smaller and leaves tend not to drop as quickly. However, any new re-growth on stems still remains highly susceptible.

Spore production occurs at 10-25 °C with an optimum at 15-20 °C. No spores are produced at 5 °C and 30 °C. Spores infect rapidly within 6-8 hours of wetness at temperatures of 15-25 °C with an optimum at 20 °C. Infection is moderate at 10 °C (12 hours of wetness), slow at 5 °C (24 hours of wetness), and does not occur at 30°C. After the leaves drop, the fungus will colonize the mid vein of leaves where it overwinters. The fungus can survive in infected leaves for at least two years.

The spores of the fungus are forcibly discharged from infected leaves. They can be propelled upward about 30 cm and then fall downward due to their very large size if they have not impacted a leaf on the upward trajectory. This type of discharge results in localized areas of disease which then expand as the spores continue to jump to healthy plants. The spores are not spread by wind or rain, and so the disease often remains confined to affected fields. However, under wet conditions, the infected leaves become very soft and stick to machinery, tires and footwear and so the fungus is easily spread from field to field or within fields by mechanical transmission.

Figure 2. Severely infected sprout field with extensive leaf loss.

Disease management

Growers should thoroughly inspect their fields for signs of disease when the canopy is dry. If a diseased patch is discovered, it is important to flag the area and then leave the area ensuring that no leaves are sticking to footwear or pant legs (Figure 3). It is key not to spread the disease by human activity. Work activities in affected areas should be planned so that they are completed last or affected fields should not be entered at all until other healthy fields have been worked. After exiting affected fields, equipment should be power or steam washed to remove all leaves before entering healthy fields.

Figure 3. Diseased leaves stick to footwear and machinery and so the fungus can be easily spread within and between fields under wet conditions.

If disease is found on a small scale, an immediate, thorough burning with a hand held weed burner under dry conditions may be adequate to destroy infected foliage thereby eradicating the disease.

If disease is found on a larger scale, a thorough field burn may reduce disease the following year. However, the burn must be intense and uniform enough to destroy the leaf litter and so must be done under ideal burning conditions. Despite these measures, the disease may return if infected blueberry plants in nearby wooded areas are harbouring the disease.

If the disease is widespread in a field, fungicide applications will reduce the effect of the disease, but will not eradicate it from fields. For optimum disease control, the first application must be made when disease symptoms first occur and wet weather is forecasted. A second application may be necessary 10-14 days later if wet weather persists or before the next forecasted period of extended wet weather. Good spray coverage is essential. Consult pest management guides for fungicide recommendations. Research is in progress to identify economically effective fungicides.

Currently, another unidentified leaf spot pathogen is causing symptoms which are similar to those caused by *Valdensinia*. However, this pathogen does not spread rapidly and does not cause extensive defoliation and so it is not considered a threat. However, because of its similarity to Valdensinia leaf spot, it is important to obtain an accurate diagnosis of the leaf spots to avoid needless and costly control measures.

Prepared by P.D. Hildebrand and W.E. Renderos, Agriculture and Agri-Food Canada, Kentville, NS; R.W. Delbridge, Delbridge Disease Management, Kentville, NS; P. Burgess, AgraPoint, Truro, NS; and theWild Blueberry Producers Association of Nova Scotia, Debert, NS.

March 2010

Wild Blueberry Newsletter

August 2011

WILD BLUEBERRY CROP PROSPECTS

Maine - The blueberry plants in Maine came through the winter well with little or no winter injury. We had a late spring, initially plant growth was about a week later than average and consequently, bees were put in the field too early. We had wet and cold conditions at the beginning of pollination so fields in the mid-coast areas had less than adequate pollination. Pollination weather improved at the end of May and early June so set was very good in Downeast fields which invested in pollinators. Tony Jadzack indicated 64,219 hives entered Maine for wild blueberry crop pollination this spring. Hives originated from: AR, CA, FL, GA, NC, SC, OK, MI, LA and TX. When Maine wintered hives (non-migratory, operated by Maine commercial and sideline beekeepers) are included approximately 65,149 hives were used in 2011, this was close to the record 69,298 hives used in 2008. Fewer Maine wintered hives were used for blueberry pollination this spring because of high winter mortality. We did have a number of infection periods for mummy berry disease with either rain or high winds, so it was difficult to get the fungicide applications on to prevent the disease. There was some infection but in many of the fields the damage was minimal, but those that did not apply fungicides experienced extensive damage. In Jonesboro, we received only 4.98 and 4.94 inches of rain in April and May respectively but only got 2.38 inches in June and had only1.55 inches total for July. High temperatures early this spring put the plants under stress and there was more herbicide injury observed this year than in the past. Rainfall was inadequate in both June and early July. I have seen plants with leaf burn and leaf drop caused by the lack of rainfall. The showers in early August have helped and if we get adequate moisture for the remainder of the summer, the crop in Maine could be slightly below average at 75 to 80 million pounds.

Nova Scotia – Nova Scotia had a good winter, with good snow cover which resulted in low winter damage. Plant development was delayed compared to last year and was closer to a normal year. There were extended wet periods throughout early bud stage and into bloom. This caused various problems and many producers were required to put on two blight applications. As a result there were some fields with heavy *Monilinia* infections. The cool wet weather also made it a challenge to put on both fungicide and herbicide applications. The bloom and sprout fields developed quickly over a short period of time and put growers under a time crunch for many input applications. As a result some sprout fields did not receive Velpar at an ideal time and some damage has been observed. Bloom through most of the province was not ideal. There was evidence of a lot of native pollinators, but not many ideal flying days for honeybees may have reduced pollination of a decent looking bloom. Fruit set is variable throughout the province and poor weed control in 2010 is the cause for some of this. *Septoria* and *Valdensinia* are visible in fields and weather conditions from now through harvest will influence their effect on the crop. Early July brought on dry, hot weather which is beginning to stress the crop. Two rainfall events in mid- July helped size the fruit and maintain plant health for a week or two. Nova Scotia looks to be close to the average of the last several years, with some potential to move up from the 33 million pounds from last year, so estimate is at 35 million pounds.

Quebec – The wild blueberry plants in Québec came through the winter with very little to no damage. This spring, we received a lot of water and the crop was delayed at least 10 days compared to last year. At the end of May and June we experienced drought, but it provided good pollination weather. Also, we had no significant spring frost compared to last year. Quebec bee hives over-wintered with little or no loss. Unfortunately, because of the dry summer in 2011, blueberry plants are a lot smaller than normal. Therefore we expect to have less fruit per stem, so the Québec crop is estimated to be 40 million pounds or less.

New Brunswick –The blueberry plants came through the winter with very little winter injury. Plants emerge closer to the normal timing for bud development in the spring, with the northeast region being delayed by about one week. It was a very wet spring and there were several *Monilnia* blight infection periods. Generally growers who applied two applications of a fungicide at the correct timing had very good control. Fields with no fungicide application had a high level of *Monilinia* flower blight. The wet condition persisted throughout flowering, however there were likely enough days for the bees to visit flowers. Fewer honey bee hives were rented by blueberry growers because they were not available. Early indication is of an okay fruit set with a good yield potential. Rain showers have occurred weekly, and the fields are very lush with growth. *Septoria* and *Valdensinia* leaf spot symptoms are now visible on the leaves. Overall, the 2011 production will be near provincial average of 27 million pounds

Prince Edward Island – Most blueberry fields wintered well in PEI with only small pockets of winter/salt injury reported in areas along the north shore of the province. A long wet spring provided good conditions for *Monilinia* blight infections even though temperatures remained cool. Most crop fields were covered twice with fungicides. This weather pattern seemed to delay crop development marginally with pollination season beginning the first of June. The majority of June saw cooler temperatures and wet periods. However, there were some very good flying days for the bees, but this occurred during late bloom. Despite the weather, fruit set was achieved over an extended period of time. This may result in uneven maturity and subsequent losses at harvest time. Isolated low lying areas were subjected to frost down to 29°F on June 1st . This will have minimal impact on the overall crop. Pest pressures remain low although spanworm and leaf tier problems have been noted. Weed pressure remains high with sheep sorrel and hawkweed being well established throughout all growing regions. Cut-backs in production inputs during the spring of 2010 have resulted in problems for a few growers who anticipated lower 2010 field prices at that time. Some herbicide damage has been reported in low-lying areas. With blueberry land continuing to mature, PEI expects to match its all-time crop record of 12 million pounds in 2011.

Wild Blueberries: Total wild crop is estimated below average at about 189 million pounds.

CROP SITUATIONS IN OTHER AREAS

Cultivated Blueberries - Total cultivated production is estimated at about 500 million pounds, which is below the 540 million pounds produced last year. About 70% will be sold fresh and 30% processed as an effort is continuing to be made to market more of the crop as fresh.

Michigan/Indiana – The crop is estimated at 75 million pounds which is much less than last year’s 118 million pounds with about half sold fresh and the remainder frozen.

Northeast (New Jersey, NY, ON) - Estimated crop for the Northeast is 63 million pounds.

Pacific Northwest (WA,OR, BC, CA) - Estimate a good crop with 233 million pounds with BC estimating a bumper crop of 100 million pounds.

Southern States (NC, GA, AR, FL, MS, AL) – Florida produced a large crop at 22 million pounds that went all to fresh and NC had 41 million pounds. The total estimate for the South is 129 million pounds with 99 fresh and 30 processed.

NORTH AMERICAN BLUEBERRY PRODUCTION IN MILLIONS OF POUNDS 2006-2010

			CULTIVATED HIGHBUSH			
REGION	**2006**	**2007**	**2008**	**2009**	**2010**	**5-YR AVG**
Midwest						
Michigan, IL, IN, other	86.4	94.4	113.8	106.2	118.6	**103.9**
Northeast						
New Jersey	52	54	59	53	49	**53.4**
NY an others	2.2	2.5	2.5	4.6	2.3	**2.8**
West						
British Columbia	63	70	70	89	90	**76.4**
OR, WA, CA	64.6	91.9	89.1	109	120.8	**95.1**
South						
North Carolina	25.5	14.5	28.5	34.1	39.1	**28.3**
AR,FL,GA,AL,MS	45.4	26.7	56	85	120.1	**66.6**
Total Cultivated	**339.1**	**354.0**	**418.9**	**480.9**	**539.9**	**426.6**
			WILD LOWBUSH			
Maine	74.6	76.5	90	88.5	83	**82.5**
Quebec	69.2	44	72	70	15	**54**
Maritime Provinces						
Nova Scotia	30.6	26.4	41.5	24	33.2	**31.1**
New Brunswick	20.4	26.1	33.6	33	33.4	**29.3**
Newfoundland	1	0.5	0.6	0.5	0.5	**0.6**
Prince Edward Island	8.4	8.3	9.8	10.3	12.4	**9.8**
Total Wild	**204.2**	**181.8**	**247.5**	**226.3**	**177.5**	**207.3**
			TOTAL COMBINED PRODUCTION			
Cultivated and Wild	**543.2**	**535.8**	**666.4**	**707.2**	**717.4**	**634.0**

Sincerely,

Dave

David E. Yarborough
Extension Blueberry Specialist

Nova Scotia Agricultural College

NSAC. Embrace Your World.

Valdensinia Leaf Spot Suppression Research Update

David Percival, Holly Hines and Rishi Burlakoti

Department of Environmental Sciences

Nova Scotia Agricultural College, Truro, NS

Wild Blueberry Producers Association of Nova Scotia Annual Meeting

November 21, 2009

Nova Scotia Agricultural College

NSAC. Embrace Your World.

Agenda

- *Valdensinia* overview
- Objectives
- Methods and Materials
  - Initial Suppression Trial (Folly Lake)
  - Main and Interactive Active ingredient trial (Sutherland's Lake)
- Results & Discussion
- Summary & Conclusions

Valdensinia Leaf Spot

- In the family *Sclerotiniaceae*.
- Known to be in Canada for 20^+ years, USA for ~15 years, and 50^+ years in Europe.
- First reported in wild blueberries in 1997, and has been increasing in severity for the past four years.
- Also known to be a pest for other eraceceous plants, bunch berry, strawberries, maple, birch, cherries, etc.
- Cool, wet conditions are conducive to development of the disease

Valdensinia Leaf Spot

- Is the single most limiting factor hindering bilberry production in Sweden and Norway.
- Biological control for salal in western Canada.
- Exists in forested areas and this can also be a source of innoculum for the disease.

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7/28/09 | 10 comments

Maine's wild blueberry crop imperiled by leaf spot fungus

By Sharon Kiley Mack
BDN Staff

PHOTO BY SEANNA ANNIS

Valdensinia leaf spot, caused by Valdensinia heterodoxa, causes early leaf drop in low-bush blueberries and in pruned fields can cause complete leaf drop so that no flower buds are produced by infected stems.

TRESCOTT, Maine — With fog swirling around her, Seanna Annis, a blueberry pathologist at the University of Maine, scanned the low bushes along a gravel road through the blueberry fields Sunday evening. She stopped, brought out a magnifying lens and pinched a leaf from a plant.

"Yes," she said, seconds after examining the spotted leaf.

With that, the farmer knew his field was lost. Even though the plants are lush with fat blueberries just days from harvest, they must be burned.

In this field and six others in

Blueberry fungus found in some Maine fields

July 28, 2009

TRESCOTT, Maine—Blueberry growers in Maine are finding evidence of a leaf fungus that has devastated crops in Nova Scotia and New Brunswick and can only be cured by burning the fields.

Valdensinia leaf spot spreads easily and quickly in damp weather. It causes leaves to drop off the plant and interrupts the normal cycle of bud set for the next season.

Seanna Annis, a blueberry pathologist at the University of Maine, tells the Bangor Daily News that not only will the fungus damage many fields this year, if it goes undetected in larger barrens, it could destroy the crop next year.

Annis said the blueberries are unaffected and can be eaten, but those fields must be burned to halt the spread of the fungus to other, healthy fields.

Information from: Bangor Daily News, http://www.bangornews.com ■

More articles in Maine

Valdensinia Leaf Spot (cont.)

- Fungus overwinters in leaf litter and starts producing spores typically in early to mid June.
- Spores are forcibly projected into the air by means of the radiating arms
- Spores adhere to the surface of leaves or other objects by means of their sticky central cushion and germinate rapidly in the presence of films of water.
- Approximately 3 days of continual wetness are required for spores to be produced and released.

Valdensinia Leaf Spot (cont.)

- Multiple spore production and infection cycles can occur within a week of wet weather.
- Lesions can attain a size of 5 to 10 mm within 24 to 48 hours after which defoliation may occur.
- It is possible for the stems to develop new leaf tissue from axillary buds, but this is often to the detriment of floral bud formation.

Symptoms begin in early June

Courtesy of P. Hildebrand, AAFC Kentville

Control Strategy

- Presently dependent upon applications of the fungicide Pristine™.
- Bravo® is also known to suppress *Valdensinia*.
- Problems:
  - Cost of Pristine™(~$90/acre)
  - Lack of persistence and subsequent suppression

Study Objective

- To try and find a more efficaceous, persistent and cost effective fungicide to suppress *Valdensinia*
  - Different modes of action

Fungicide Modes of Action and Resistance Susceptibility

FRAC Code	Mode of Action	Active Ingredient	Resistance Susceptibility
1	ß-Tubuline assembly in mitosis	Thiophanate-methyl	High
7	Respiration	Boscalid	Medium
11	Respiration	Pyraclostrobin	High
3	Sterol biosynthesis in membranes	Fenbuconazole Propiconazole Myclobutanil	High High High
9	Amino acid and protein synthesis	Cyprodinil	Medium
12	Signal transduction	Fludioxonil	Low to medium
M4 M5	Multi-site contact activity	Captan Chlorothalonil	Low Low

Fungicides: Modes of Action

Spore germination	Penetration (initial plant infection)	Mycelial growth	Pre-sporulation	Sporulation
Protectant compounds including Bravo®				
Strobiluron (curative compounds including Pristine™ & Cabrio™)				
Triazoles/DMI inhibitors (curative and partial erradicant compounds including Topas®, Funginex™, Proline™)				
Tank Mix				

Highly effective

Not effective

Methods and Materials

- 2 Sites
  - Folly Lake, Nova Scotia
  - Sutherland's Lake, Nova Scotia
- 2 Trials:
  - Preliminary, multi-active ingredient trial
  - Main & interactive active ingredient trial
- Fungicide Applications:
  - Occurred before initial infection and at 7 to 10 day intervals depending on infection periods

Methods and Materials (cont.)

- Randomized complete block design, 5 replications, 4 x 6 m plot size, and 2 m buffers
- Research grade, 2 m boom sprayer was used in the application of treatments
- Disease assessments occurred ~2 weeks after fungicide application.

Results

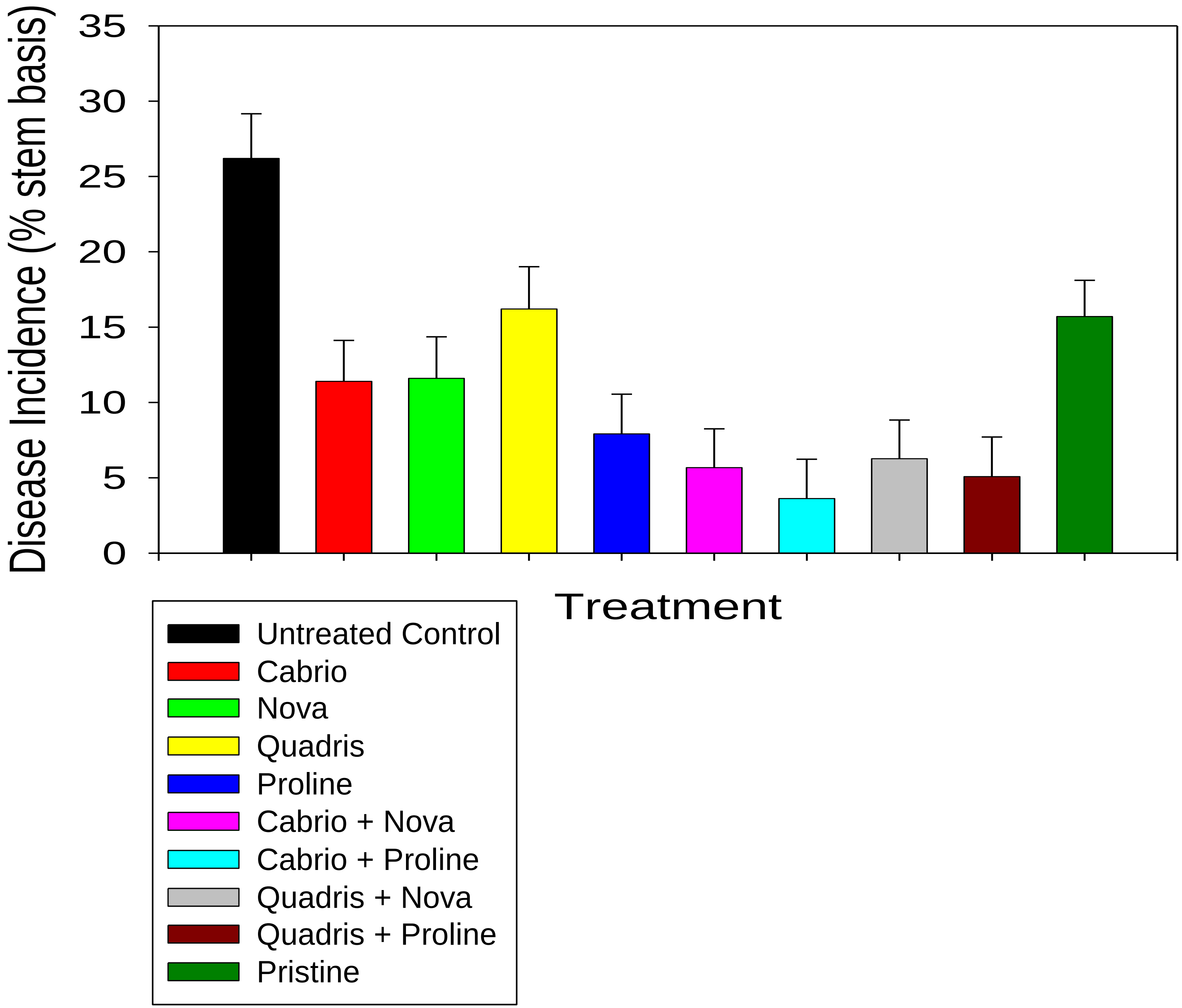
Valedensinia Results: Folly Lake

Treatment	Incidence of *Valdensinia* (July 7)	Incidence of *Valdensinia* (August 6)	Stem Length (cm)	Floral Bud Number
Untreated control	24.6a	35.1a	16.3b	4.00a
Quadris® (azoxystrobin) + Senator® (thiophanate-methyl)	7.21cd	7.48c	15.8b	4.01a
Quadris® + Vangard® (cyprodinil)	18.6ab	21.6b	15.9b	3.89a
Quadris® + Nova® (myclobutanil) + Vangard®	6.83cd	7.21c	18.4a	5.25a
Proline™ + Quadris®	2.18d	1.86d	16.0b	4.34a
Proline™ + Quadris® + Vangard®	2.31d	1.97d	16.3b	4.45a
Inspire™ (difenoconazole) + Quadris® + Vangard®	17.6abc	18.2b	15.7b	4.08a

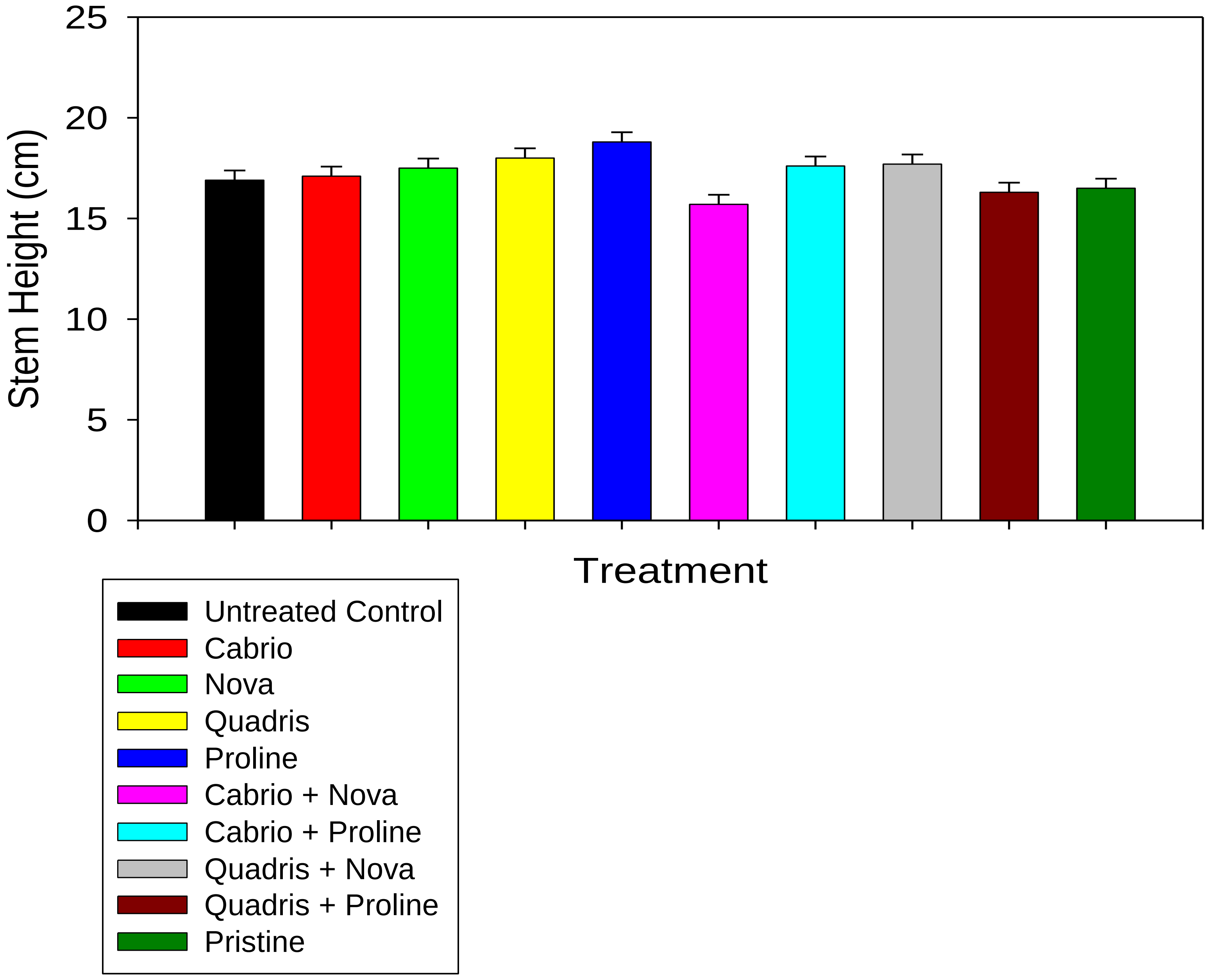
Main and Interactive Active Ingredient Trial – Sutherland's Lake

- Treatments:
  1. Untreated control
  2. Cabrio™ (pyraclostrobin)
  3. Nova™ (myclobutanil)
  4. Quadris® (azoxystrobin)
  5. Proline® (prothioconazole)
  6. Cabrio™ + Nova™
  7. Cabrio™ + Proline®
  8. Quadris® + Nova ™
  9. Quadris® + Proline®
  10. Pristine™ (pyraclostrobin + boscalid)

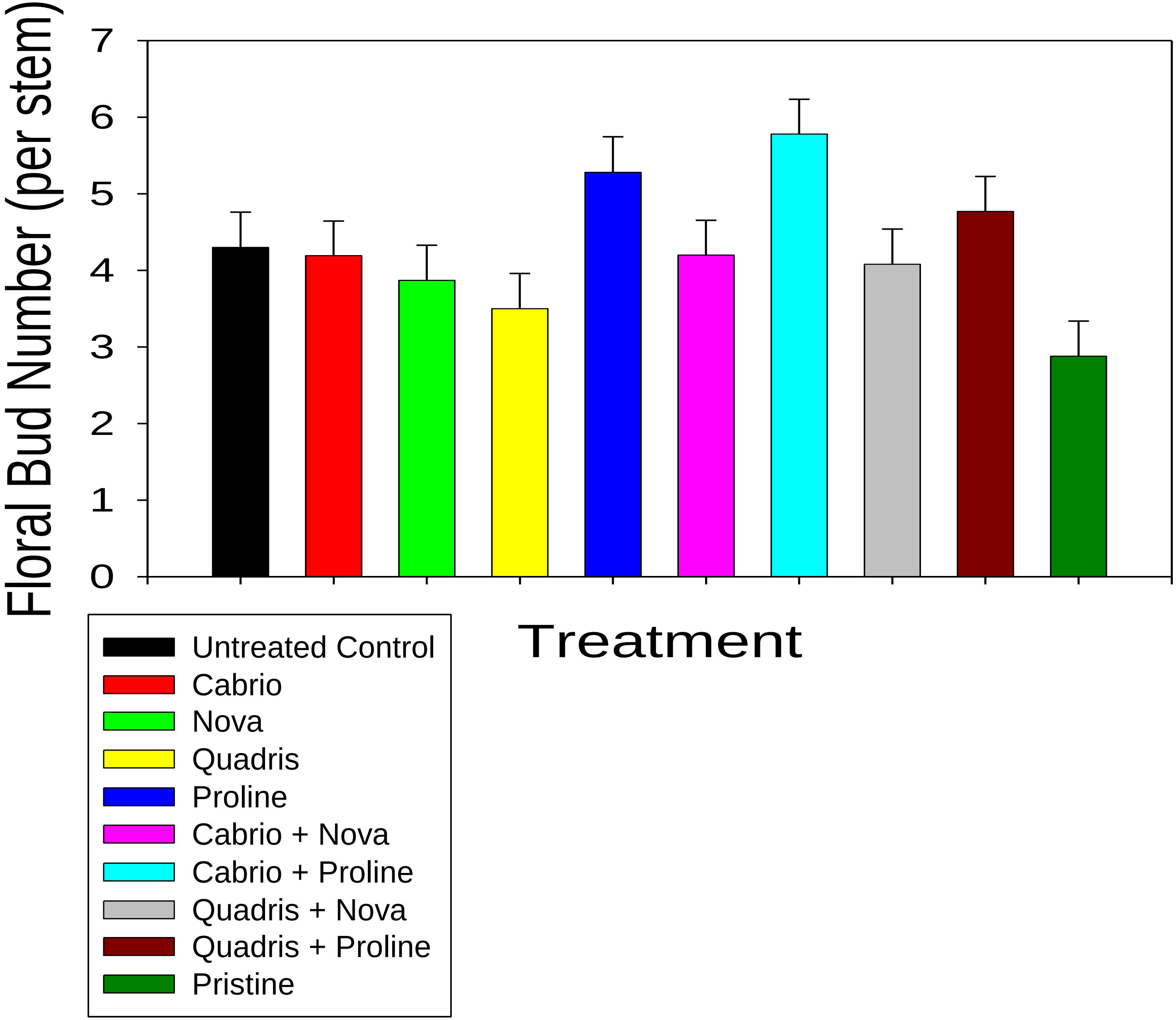
Incidence of *Valdensinia* – Sutherland's Lake



Stem Height – Sutherland's Lake



Floral Bud Number (Per Stem Basis) – Sutherland's Lake



Summary and Conclusions

- Results indicated that the active ingredients prothioconazole (Proline®), myclobutanil (Nova™) and to a lesser extent pyraclostrobin (Cabrio™) and axozystrobin (Quadris®) were very effective in suppressing *Monilinia* blight.
- Some benefits were attained with multiple active ingredient combinations
- Suppression was attained with one fungicide application
- Beneficial effects on yield potential (floral bud number) were attained at the Sutherlands Lake site.

Thanks to:

- Oxford Frozen Foods Ltd.
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- Wild Blueberry Producers Association of Nova Scotia
  - Al Tucker
- Atlantic Innovation Fund (ACOA)
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- Engage Agro/Valent BioSciences
- Bayer CropScience
- AgraQuest Inc.
- Advancing Canadian Agriculture and Agri-Food (ACAAF) program (AgriFutures Nova Scotia)
- Technology Development Program (NS Dept. Agr.)

Questions?

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Thank You!

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Mechanism of Binding of Prothioconazole to *Mycosphaerella graminicola* CYP51 Differs from That of Other Azole Antifungals[▽]

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Prothioconazole is one of the most important commercially available demethylase inhibitors (DMIs) used to treat *Mycosphaerella graminicola* infection of wheat, but specific information regarding its mode of action is not available in the scientific literature. Treatment of wild-type *M. graminicola* (strain IPO323) with 5 μg of epoxiconazole, tebuconazole, triadimenol, or prothioconazole ml^{-1} resulted in inhibition of *M. graminicola* CYP51 (MgCYP51), as evidenced by the accumulation of 14α-methylated sterol substrates (lanosterol and eburicol) and the depletion of ergosterol in azole-treated cells. Successful expression of MgCYP51 in *Escherichia coli* enabled us to conduct spectrophotometric assays using purified 62-kDa MgCYP51 protein. Antifungal-binding studies revealed that epoxiconazole, tebuconazole, and triadimenol all bound tightly to MgCYP51, producing strong type II difference spectra (peak at 423 to 429 nm and trough at 406 to 409 nm) indicative of the formation of classical low-spin sixth-ligand complexes. Interaction of prothioconazole with MgCYP51 exhibited a novel spectrum with a peak and trough observed at 410 nm and 428 nm, respectively, indicating a different mechanism of inhibition. Prothioconazole bound to MgCYP51 with 840-fold less affinity than epoxiconazole and, unlike epoxiconazole, tebuconazole, and triadimenol, which are noncompetitive inhibitors, prothioconazole was found to be a competitive inhibitor of substrate binding. This represents the first study to validate the effect of prothioconazole on the sterol composition of *M. graminicola* and the first on the successful heterologous expression of active MgCYP51 protein. The binding affinity studies documented here provide novel insights into the interaction of MgCYP51 with DMIs, especially for the new triazolinethione derivative prothioconazole.

Mycosphaerella graminicola (anamorph: *Septoria tritici*) is a plant-pathogenic fungus causing septoria leaf blotch that is responsible for significant yield losses (13). The most widely used fungicides for the control of this disease are demethylase inhibitors (DMIs), which bind to the target cytochrome P450 (CYP51, also called Erg11p in yeast) that mediates sterol 14α-demethylation during ergosterol biosynthesis. The original observation in fungi of inhibition of sterol 14α-demethylation by DMIs was in the plant pathogen *Ustilago maydis* (31) and is also seen for azole drugs when treating *Candida albicans* infections (28). The 14α-demethylation step of sterol biosynthesis had been proposed to be a cytochrome P450 mediated activity (1) and the protein was first purified from *Saccharomyces cerevisiae* microsomal fraction (2). Using yeast genetics the gene encoding this ancient activity of the cytochrome P450 superfamily was isolated in 1987 (17), and all CYP51 genes encoding this activity in sterol biosynthesis in different Kingdoms of Life are classified to this family (19).

DMIs are generally imidazole or triazole compounds. The N-2 of imidazole and N-3 of triazole compounds form a sixth ligand with the heme of the CYP51 that is reflected in a type II binding spectrum formed when the azoles become ligands of low-spin CYP51 (14). The selectivity of DMIs is defined by the interaction of the N-1 substituent groups of the azole and the CYP51 structure. Recently, such interactions have been investigated by X-ray crystallography using trypanosomal and human CYP51 enzymes (24, 35). DMIs result in the depletion of ergosterol and the concomitant increase in 14α-methylated sterols. In contrast to *S. cerevisiae* and *C. albicans*, *M. graminicola* does not accumulate the 14-methyl-3,6-diol observed in these yeasts under azole treatment (15, 20), but the depletion of ergosterol and accumulation of other 14α-methylated sterols are indicative of CYP51 inhibition.

Resistance to antifungal compounds has developed in *M. graminicola* populations through mutations resulting in an altered CYP51 enzyme (9, 10). Similar mutations in CYP51 have also been observed in the clinical setting, firstly with *C. albicans* (26, 32). The introduction of new antifungals has allowed control of *Septoria* wheat blotch to be maintained. The most recently introduced DMI for the treatment of *M. graminicola* is the triazolinethione derivative prothioconazole.

We are interested in the development of resistance and the mode of action and efficacy of this class of antifungal. The difference in chemical structure of prothioconazole compared to triazole compounds led us to probe the biochemical basis of DMI fungicide affinity to the target protein. This requires a mechanism for heterologous production, and we report here the first purification of CYP51 from this economically important pathogen. We also present data which confirm that the triazole compounds epoxiconazole, tebuconazole, and triadi-

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menol bind directly to the heme, as is observed with azole inhibitors of other CYP51s (14), and we have determined the affinities of these compounds for *M. graminicola* CYP51, which enables comparisons to be made with other species and compounds. Further investigation of the fungicide interaction with the target protein revealed that prothioconazole interacts with CYP51 in a novel way that is distinct from other azole fungicides. The mode of action of prothioconazole may therefore provide a new avenue of research for antifungals for the treatment of plant diseases and human infections such as candidiasis.

MATERIALS AND METHODS

Chemicals, media, and strains. Growth media, ampicillin, IPTG (isopropyl-β-D-thiogalactopyranoside), and 5-aminolevulenic acid were obtained from Foremedium, Ltd. (Hunstanton, United Kingdom). Eburicol was produced by David Nes. Enzymes for molecular biology were obtained from Promega (Madison, WI). All other chemicals were obtained from Sigma (Poole, United Kingdom). *Escherichia coli* DH5α (Stratagene, La Jolla, CA) was used for plasmid manipulation and protein expression.

Sterol composition of *M. graminicola*. *M. graminicola* IPO323 was grown in YPD broth (1% [wt/vol] yeast extract, 2% [wt/vol] peptone, and 2% [wt/vol] glucose) at 25°C for 4 days. Cultures were diluted to an optical density at 600 nm of 1.0, and 500 μl was used to inoculate 10 ml of YPD, followed by treatment with 5 μg of fungicide ml^{-1}. Azoles were diluted in dimethyl sulfoxide (adjusted to 1% [wt/vol] for azole solutions and the negative control). Cultures were grown for 48 h at 25°C, and the cells were harvested and washed twice with sterile water. Nonsaponifiable lipids were extracted as reported previously (18). Samples were dried in a vacuum centrifuge (Heto) and derivatized by the addition of 100 μl of 90% BSTFA–10% TMS (Sigma) and 50 μl of anhydrous pyridine (Sigma), followed by heating for 2 h at 80°C. TMS-derivatized sterols were analyzed and identified by using gas chromatography-mass spectrometry (GC-MS; Agilent 5975C Inert XL GC/MSD; Agilent Technologies, Ltd., Stockport, United Kingdom) with reference to retention times and fragmentation spectra for known standards. GC-MS data files were analyzed by using Agilent software (MSD Enhanced ChemStation) to determine the sterol profiles for all isolates and for integrated peak areas.

Heterologous expression of MgCYP51. The *M. graminicola CYP51* gene (*MgCYP51* [GenBank AAU43734]) was synthesized by GeneCust (Evry, France). The nucleotide sequence was optimized for expression in *E. coli* (codon adaptation index of 0.85 compared to 0.63 for the wild-type *MgCYP51* [34]) and engineered to contain 5′ NdeI and 3′ HindIII sites, a C-terminal hexahistidine tag, and the second residue, glycine, was replaced by alanine to aid overexpression (5). *MgCYP51* was cloned into pCWori^{+} (5) using the NdeI and HindIII sites, and transformants were selected by using ampicillin. pCWori^{+}::*MgCYP51* transformants were grown in Terrific broth containing ampicillin at 30°C and 160 rpm for 24 h prior to induction with 1 mM IPTG and expression at 20°C and 140 rpm for 48 h in the presence of 1 mM 5-aminolevulenic acid.

MgCYP51 protein was isolated as described previously (4) using modified sonication buffer containing 2% (wt/vol) sodium cholate and no Tween 20. Solubilized MgCYP51 protein was purified by affinity chromatography using Ni^{2+}-NTA agarose (Qiagen) and eluted using 1% (wt/vol) histidine in 0.1 M Tris-HCl (pH 8.1) containing 25% (wt/vol) glycerol. Purified protein was dialyzed against 4 liters of 0.1 M Tris-HCl (pH 8.1) overnight at 4°C using dialysis tubing with a 30-kDa molecular mass cutoff to remove histidine. Protein purity was assessed by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) (21).

Cytochrome P450 spectral determinations. Absolute spectra of the oxidized protein, the reduced protein (10 mM sodium dithionite), and the reduced carbon monoxide-P450 complex were determined between 300 and 700 nm by using 8 μM purified MgCYP51 in 0.1 M Tris-HCl (pH 8.1) and 25% (wt/vol) glycerol as previously described (8). Extinction coefficients of 125 mM^{-1} cm^{-1} for the oxidized heme Soret peak at 420 nm (12) and 91 mM^{-1} cm^{-1} at 445 nm (30) for the Soret peak of the red-shifted reduced carbon monoxide adduct were used. All UV-VIS spectrophotometry determinations were made by using a Hitachi U-3310 UV/VIS spectrophotometer (San Jose, CA) and quartz semi-micro cuvettes with a light path of 4.5 mm.

Azole-binding properties of MgCYP51. Binding of azole to MgCYP51 were performed as previously described (22, 23) except that dimethylformamide (DMF) was also added to the cytochrome P450-containing compartment of the reference cuvette. Stock solutions of 0.1 mg of epoxiconazole, tebuconazole, and triadimenol ml^{-1} and 1 and 10 mg of prothioconazole ml^{-1} were prepared in DMF. Azoles were progressively titrated against 4 μM MgCYP51 in 0.1 M Tris-HCl (pH 8.1) and 25% (wt/vol) glycerol, with the difference spectra between 500 and 350 nm determined after each addition; azole binding determinations were performed in triplicate for each compound. Binding saturation curves were constructed from $\Delta A_{\text{peak-trough}}$ versus the azole concentration. A rearrangement of the Morrison equation [$\Delta A = (\Delta A_{max} \times \{[E_t + [\text{azole}] + K_d] - [(E_t + [\text{azole}] + K_d)\hat{\ }2 - (4 \times E_t \times [\text{azole}])]\hat{\ }0.5\}/\{2 \times E_t\})$] (27, 29) (where E_t is the total amount of CYP51 available to bind azole) was used to determine the dissociation constant (K_d) values when ligand binding was "tight." Tight-binding is observed when the K_d for azole is similar or lower than the concentration of CYP51 present (11). The Michaelis-Menten equation $\Delta A = (\Delta A_{max} \times [\text{azole}])/(K_d + [\text{azole}])$ was used when the ligand binding was not tight.

Substrate binding studies. Lanosterol and eburicol (0.5 mg) were each dissolved in 0.1 ml of chloroform, to which 1 ml of acetone and 0.05 ml of Tween 80 were added. The solution was evaporated to dryness under nitrogen with constant vortexing. Sterol and Tween 80 residues were then dissolved in 1 ml of water to give 0.05% (vol/vol) stock sterol solutions. Lanosterol and eburicol were progressively titrated against 8 μM MgCYP51 in the sample cuvette with equivalent amounts of 5% (vol/vol) Tween 80 added to the reference cuvette also containing 8 μM MgCYP51. The absorbance difference spectrum between 500 and 350 nm was determined after each incremental addition of sterol up to 34 μM, and sterol saturation curves were constructed from the $\Delta A_{385-422}$ value. Eburicol binding determinations were performed in triplicate. The substrate binding constant (K_s) was determined by nonlinear regression (Levenberg-Marquardt algorithm) using the Michaelis-Menten equation: $\Delta A = (\Delta A_{max} \times [\text{sterol}])/(K_s + [\text{sterol}])$.

Substrate binding studies were also performed with lanosterol and eburicol (3 to 80 μM) in the presence or absence of 0.35 mM prothioconazole or 6 μM epoxiconazole. Control determinations were made in the presence of 1.25% (vol/vol) DMF. Determinations were performed in triplicate and Lineweaver-Burk plots were constructed from resultant substrate binding spectra. To determine the modality of these two inhibitors the inhibitor constant (K_{ei}) for the formation of the enzyme-prothioconazole complex was calculated by using the equation $K_{s.app} = K_s \times (1 + [I]/K_{ei})$ for pure competitive inhibition.

Data analysis. Curve-fitting substrate and azole binding data were performed using the computer program ProFit 5.0.1 (QuantumSoft, Zurich, Switzerland). Protein targeting signal peptide prediction was performed using the Predotar (http://urgi.versailles.inra.fr/predotar/predotar.html), SignalP3.0 (http://www.cbs.dtu.dk/services/SignalP/), and TargetP1.1 (http://www.cbs.dtu.dk/services/TargetP/) programs.

RESULTS

Sterol composition of azole-treated *M. graminicola*. The novel chemistry of prothioconazole led us to question whether the mode of action of inhibition of *M. graminicola* was through the inhibition of CYP51 activity. To investigate this initially, we first analyzed the sterol profiles of *M. graminicola* cultures treated with prothioconazole compared to those treated with epoxiconazole, tebuconazole, and triadimenol. It was expected that an increase in the CYP51 substrate, together with a depletion of ergosterol, would be observed upon treatment with azoles as seen previously. Table 1 shows the percentages of 14α-methylated sterols (eburicol and lanosterol) and 14α-demethylated sterols (ergosterol, ergosta-5,8,22-trienol, and ergosta-7,22-dienol) present in the treated samples. As expected, *M. graminicola* accumulated eburicol predominantly when treated with epoxiconazole, tebuconazole, and triadimenol in agreement with this being the main CYP51 substrate. Importantly, treatment with prothioconazole also resulted in an accumulation of eburicol and a depletion of the major 14α-demethylated sterols ergosterol and ergosta-5,8,22-trienol, confirming that prothioconazole does inhibit the activity of MgCYP51. In our previous work we had identified an ergosterol isomer as being detectable in *M. graminicola*, and we

TABLE 1. Sterol profiles of azole-treated *M. graminicola* cultures[a]

Treatment	Mean % content ± SD				
	Ergosta-5,8,22-trienol	Ergosterol	Ergosta-7,22-dienol	Lanosterol	Eburicol
Untreated	4.5 ± 0.6	85.3 ± 0.5	6.4 ± 0.3	ND	3.0 ± 0.1
Epoxiconazole	ND	ND	ND	19.3 ± 0.2	80.7 ± 0.2
Tebuconazole	ND	ND	ND	17.5 ± 0.4	82.4 ± 0.4
Triadimenol	ND	ND	ND	17.5 ± 0.5	82.5 ± 0.4
Prothioconazole	ND	ND	ND	21.4 ± 1.8	78.6 ± 1.8

[a] The percentage of different sterols in total sterol extracts of *M. graminicola* IPO323 treated with 5 μg of epoxiconazole, tebuconazole, triadimenol, or prothioconazole ml^{-1}. ND, not detected.

were able to confirm here that the isomer was ergosta-5,8,22-trienol present at lower levels in prior studies (6, 15).

Characterization of MgCYP51. MgCYP51 was predicted to be a membrane bound protein localized in the endoplasmic reticulum (Predotar, SignalP3.0, and TargetP1.1), as is expected for eukaryotic CYPs, and sodium cholate was necessary to solubilize MgCYP51, confirming this prediction. Overexpression of MgCYP51 in *E. coli* yielded ~300 nmol of MgCYP51 per liter of culture, as determined from the reduced carbon monoxide difference spectra. Purification by Ni^{2+}-NTA agarose chromatography resulted in >90% purity when assessed by SDS-PAGE and an apparent molecular mass in agreement with the expected 62.177 kDa (Fig. 1B).

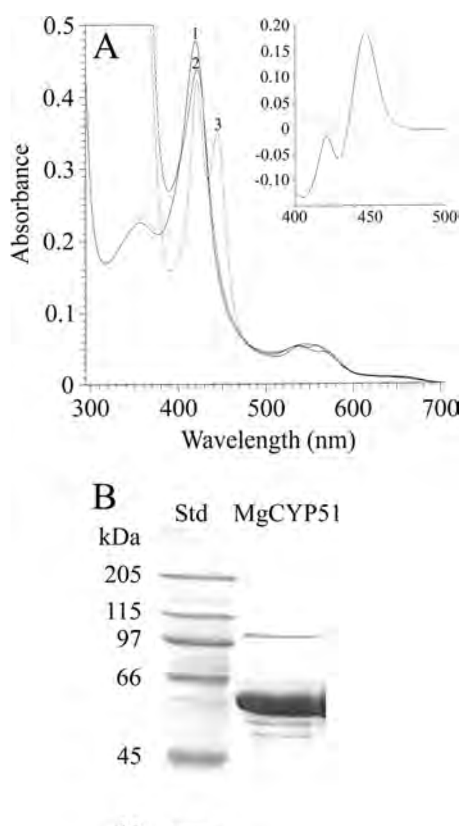

FIG. 1. Properties of purified MgCYP51. (A) Absolute spectra of 8 μM purified MgCYP51 were determined under oxidative conditions (line 1), indicating that MgCYP51 was isolated predominantly in the ferric low-spin state. Lines 2 and 3 show dithionite-reduced MgCYP51 and dithionite-reduced MgCYP51 in the presence of carbon monoxide, respectively. The reduced-CO difference spectrum (inset) was derived by subtracting line 3 from line 2 and confirmed that the protein was expressed in its active form. (B) SDS-PAGE was performed with 20 μg of purified protein. Std, standard.

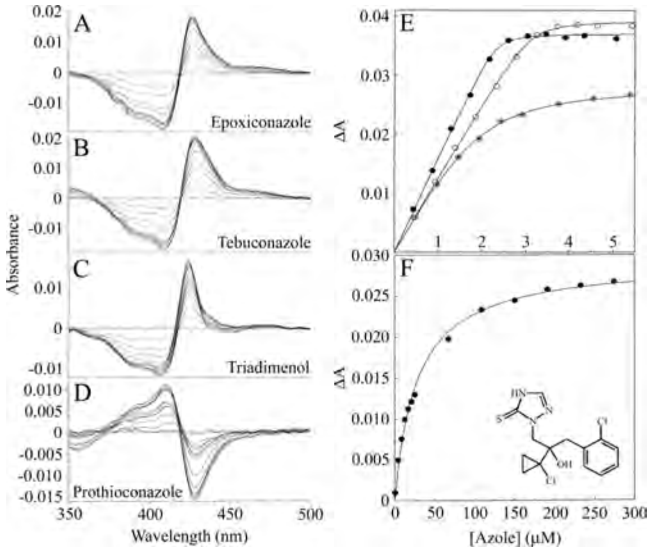

FIG. 2. Binding properties of azole fungicides to MgCYP51. Epoxiconazole (A), tebuconazole (B), triadimenol (C), and prothioconazole (D) bound to 4 μM MgCYP51. Each line represents the successive addition of antifungal, resulting in a progressive increase in absorbance at 423 to 429 nm and a decrease in absorbance at 406 to 409 nm with epoxiconazole, tebuconazole, and triadimenol and a progressive increase in absorbance at 410 nm and decrease in absorbance at 428 nm with prothioconazole, until saturation is reached. (E) The concentration of azole added to MgCYP51 and the resulting change in absorbance ($\Delta A_{peak-trough}$) were plotted to produce binding saturation profiles for epoxiconazole (●), tebuconazole (○), and triadimenol (⊙) using the Morrison equation. (F) A prothioconazole saturation profile was constructed by using the Michaelis-Menten equation. The data for one of three replicates are shown. The chemical structure of prothioconazole is also shown in panel F.

The absolute spectra (Fig. 1A) and reduced carbon monoxide difference spectra (Fig. 1A, inset) of MgCYP51 were characteristic of a cytochrome P450 enzyme (8, 14), confirming that the protein was expressed in its active form. MgCYP51 was isolated predominantly in the ferric low-spin state with a heme Soret (γ) peak at 420 nm in addition to α, β, and δ peaks at 569, 537, and 356 nm, respectively. Dithionite one-electron reduction caused a small red-shift of the Soret peak to 422 nm with binding of carbon monoxide to the reduced ferrous form, resulting in a characteristic red-shift of the Soret peak from 420 to 445 nm. These studies confirmed the successful production of pure MgCYP51 for the first time and the ability to utilize this for *in vitro* investigation of inhibitors.

Fungicide binding studies to MgCYP51. Binding of azole compounds to CYP51 enzymes has been investigated previously especially in the clinical setting (7). Purified MgCYP51 was used in spectrophotometric assessment of the interaction with epoxiconazole, tebuconazole, triadimenol, and prothioconazole. Epoxiconazole, tebuconazole, and triadimenol bound tightly to MgCYP51 (Fig. 2), producing strong type II difference spectra indicative of an azole-bound low-spin

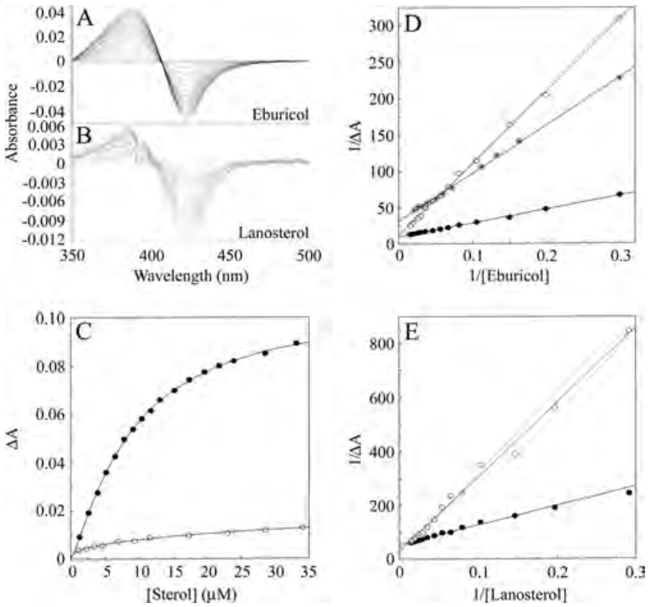

FIG. 3. Substrate binding properties of MgCYP51. Eburicol (A) and lanosterol (B) bound to 8 μM purified MgCYP51. Each line represents the successive addition of substrate and results in a progressive increase in absorbance at 385 nm and a decrease in absorbance at 422 nm, until saturation is reached. (C) The concentration of azole added to MgCYP51 and the resulting change in absorbance ($\Delta A_{\text{peak-trough}}$) were plotted to produce binding saturation profiles for eburicol (●) and lanosterol (○) using the Michaelis-Menten equation. The substrate binding affinities were determined to be 10.85 ± 0.92 and 13.4 μM, respectively. Lineweaver-Burk plots of eburicol (D) and lanosterol (E) binding to 8 μM purified MgCYP51 in the absence (●) or presence of 0.35 mM prothioconazole (○) or in the presence of 6 μM epoxiconazole (⊙ [eburicol only]) were constructed to determine the modality of inhibitor action on substrate binding.

CYP51 complex (Fig. 2A, B, and C) with a peak at 423 to 429 nm and a trough at 406 to 409 nm. The Morrison equation was used to fit the saturation curve data (Fig. 2E) and that of the other two replicates for each azole. Mean K_d values of 0.0166, 0.0266, and 0.299 μM were obtained for epoxiconazole, tebuconazole, and triadimenol, respectively, with standard errors between replicates of <10%. In contrast, prothioconazole produced a novel spectrum on interaction with MgCYP51 with a peak at 410 nm and a trough at 428 nm (Fig. 2D). Azole-induced type II difference spectra reflect the direct coordination of an azole nitrogen atom to the heme as the sixth ligand, and the prothioconazole-induced spectrum indicated a difference in the mode of binding. The Michaelis-Menten equation was used to fit the prothioconazole-induced spectral changes to a saturation curve (Fig. 2F). Together with two replicates, this allowed a mean K_d of 14 ± 0.16 μM to be calculated, an affinity substantially less than for the other azole compounds.

Fungicide interference with substrate binding. To gain further information on the MgCYP51 protein and mode of action, a comparison of the binding of two CYP51 substrates to MgCYP51 was undertaken, and then the ability of all four fungicides to interfere with these was measured. Progressive titration of MgCYP51 with lanosterol and eburicol gave type I binding spectra (Fig. 3A and B) with peaks at 385 nm and troughs at 422 nm. This showed that the binding of sterol substrate caused a change in spin state from a low to a high spin by displacing the water molecule coordinated as the sixth ligand to the low-spin heme prosthetic group, causing the heme to adopt the high-spin pentacoordinated conformation (14). The type I binding spectrum obtained with eburicol was 9-fold more intense than that obtained with lanosterol, indicating that eburicol was more effective at displacing the water molecule coordinated as the sixth ligand to the heme than lanosterol. However, at saturating concentrations of eburicol, <10% of the MgCYP51 molecules changed spin state from low to high spin. This relatively low degree of spin state conversion induced by substrate binding has also been observed with other CYP51 enzymes (3, 7, 16, 25), with spin state changes usually not exceeding 10%.

The Michaelis-Menten equation best fit for the sterol saturation curves (Fig. 3C) yielded K_s values of 10.85 μM (with standard errors between replicates of <10%) for eburicol and 13.4 μM (error of curve fit ± 2.0) for lanosterol, signifying that MgCYP51 bound both substrates with similar affinities. The presence of 0.35 mM prothioconazole inhibited the binding of both eburicol and lanosterol to MgCYP51 (Fig. 3D and E). The converging lines of the Lineweaver-Burk plots at the $1/\Delta A$ axis are indicative of competitive inhibition, where the ΔA_{max} value remains constant and the apparent K_s value increases in response to the presence of inhibitor (33). In contrast, the presence of 6 μM epoxiconazole inhibited eburicol binding noncompetitively, as observed in the Lineweaver-Burk plot (Fig. 3D), where the epoxiconazole and control data sets converge to intersect on the 1/[eburicol] axis, indicating the apparent K_s remained unchanged, while the ΔA_{max} decreased. Due to the reduced quality of the lanosterol-induced spectra, the data obtained with this substrate were not included since reliable analysis was not possible.

DISCUSSION

There are no previous reports in the scientific literature of the effect of prothioconazole on sterols of treated fungi, and we demonstrated here that it behaves as an active inhibitor of sterol 14 α-demethylation and reduces ergosterol in *M. graminicola* cells. It is active against growing *M. graminicola* at concentrations equivalent to those of the azole fungicides epoxiconazole, tebuconazole, and triadimenol. The sterol profile of treated cultures showed a similar accumulation of eburicol and, to a lesser extent, lanosterol, which is consistent with the normal metabolic route suggested for filamentous fungi (eburicol rather than lanosterol being the CYP51 substrate). Since no other enzyme in fungi can fulfill the essential function of CYP51, the accumulation of 14 α-methyl sterols and the depletion of ergosterol confirms that CYP51 is the target of the prothioconazole-mediated growth inhibition of *M. graminicola*. The confirmation here that the ergosterol isomer observed in *M. graminicola* previously (6, 15) is ergosta-5,8,22-trienol suggests that C8 isomerization may be less efficient in *M. graminicola* than in other fungal species.

Successful heterologous expression of MgCYP51 was achieved with *E. coli*, and this allowed the interaction of DMIs, including prothioconazole, to be studied for the first time. The interaction of epoxiconazole, tebuconazole, and triadimenol indicated typical type II spectral interaction with high affinity for

MgCYP51, confirming the formation of a low-spin complex with the compounds bound as a sixth ligand of the heme. Prothioconazole did not bind in this way, as reflected by the novel spectrum observed and the absence of type II spectral interaction. The binding affinity of MgCYP51 for prothioconazole was 840-fold less than for epoxiconazole. Epoxiconazole bound with greatest affinity to MgCYP51, followed closely by tebuconazole, and triadimenol bound with 18-fold less affinity than epoxiconazole. The ability to compare the affinities of different azole compounds for MgCYP51, as well as comparison to MgCYP51 strains harboring mutations implicated in resistance to azoles and with other CYP51s, may be of use in aiding the further understanding of the resistance to azoles and may aid in drug development.

The nature of the spectrum observed for prothioconazole is not currently clear and does not conform to inhibitor or substrate effects observed previously. The perturbation of prothioconazole on binding to MgCYP51 might be caused by a weak interaction between the electronegative sulfur atom on the azole ring of prothioconazole (Fig. 2F) and the ferric ion of the heme prosthetic group.

To compare the interaction of prothioconazole with MgCYP51 more closely, the interference with 14α-methyl substrate interaction was investigated. The presence of 0.35 mM prothioconazole caused 4.6- and 7.5-fold increases in the apparent K_s values for eburicol and lanosterol, respectively, resulting in estimates of the K_{ei} for prothioconazole of 51 to 104 μM. This suggested that prothioconazole "competes" for the substrate binding site on MgCYP51. It is not surprising that epoxiconazole was a noncompetitive inhibitor of MgCYP51 since azole antifungal agents bind to the CYP51 molecule through direct coordination with the heme prosthetic group and not through interactions with the substrate binding site (8).

The treatment of whole cells revealed that prothioconazole has an efficacy comparable to that of epoxiconazole, tebuconazole, and triadimenol. However, the competitive inhibition observed with prothioconazole and the high K_d value for prothioconazole would not alone account for the effectiveness of prothioconazole *in vivo* as a CYP51 inhibitor if it were binding directly as a sixth ligand of the heme. Prothioconazole may therefore inhibit MgCYP51 activity in an additional capacity that does not result in the perturbation of the heme environment (and hence cannot be directly measured spectrophotometrically).

The possibility exists that *in vivo* metabolism of prothioconazole to the desthio metabolite (a triazole) in wheat may be important for the efficacy of this compound in the field, but our results show inhibition of sterol biosynthesis in *M. graminicola* cells grown in broth cultures and therefore indicate that the antifungal activity does not rely on *in planta* metabolism. Alternatively, it is possible that the *in vivo* metabolism of prothioconazole occurs in fungal cells and that this is necessary for the antifungal activity of the compound. Further work on prothioconazole-treated *M. graminicola* cultures will elucidate how prothioconazole itself is inhibiting CYP51 and whether biotransformation resulting in the desthio triazole compound contributes to CYP51 inhibition. In either case, prothioconazole presents a novel antifungal agent. The findings described here suggest an inhibition of CYP51 activity by binding to the enzyme in a manner other than direct coordination to the heme. Additionally, an eventual metabolism to the desthio triazole compound within the fungus would lead to an active antifungal. This mode of antifungal action therefore presents a possible basis for the development of new compounds both for agriculturally important pathogenic species and for the causative agents of human diseases, and we are currently examining other CYP51s of such pathogens for their interaction with this new fungicide.

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IR-4 Ornamental Horticulture Program
Fusarium Efficacy: A Literature Review

Fusarium avenaceum
Fusarium communi
Fusarium oxysporum
Fusarium solani

Authors: Ely Vea and Cristi Palmer
Date: June 27, 2012

Acknowledgements
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Abstract

From 2001 to 2011, numerous products representing 24 active ingredients were evaluated in greenhouse and field trials as soil drench, foliar, in-furrow, drip irrigation or tuber soak applications against several *Fusarium* species causing rots (crown, stem and tuber rots) and wilt on ornamentals, and wilt and root rot on vegetables. *Fusarium* species tested included: *F. avenaceum, F. communi, F. oxysporum* and *F. solani*. Most trials were conducted on *F. oxysporum* on larkspur, lisianthus and watermelon. Although there were insufficient data for definitive conclusions, several relatively new products showed promising, though inconsistent, efficacy comparable to the standards. These include acibenzolar, Heritage (azoxystrobin), Compass (trifloxystrobin), Hurricane (fludioxonil+mefenoxam), Insignia (pyraclostrobin), SP2169, Tourney (metconazole) and Trinity (triticonazole). BW240, (*Trichoderma harzianum & T. virens*), CG100 (organic acid), Pageant (boscalid+pyraclostrobin) and Palladium (cyprodinil+fludioxonil) provided no to mediocre efficacy. Proline (prothioconazole) provided consistently good control of *F. oxysporum* in watermelon trials. The established standards 3336 and Medallion generally provided inconsistent efficacy while Terraguard was effective in one trial

Introduction

In 2010, IR-4 initiated a high priority project to determine efficacy of several fungicides on *Fusarium* species and obtain data supporting current and future registrations on ornamentals. There are many different species of *Fusarium* causing ornamental diseases and an extensive project may be required to generate sufficient efficacy data. We reviewed available ornamental and vegetable trials published in Biological and Cultural Tests, Fungicide & Nematicide Tests and Plant Disease Management Reports to check efficacy of experimental and registered fungicides on *Fusarium* species. This report is a brief summary of available data from 4 ornamental and 10 vegetable trial reports. The source of report is included under each data table.Three trials from the IR-4 project are included in this report. Additional data will be added when received from researchers.

Materials and Methods

From 2001 to 2011, numerous products representing 24 active ingredients were evaluated in greenhouse and field trials as soil drench, foliar, in-furrow, drip irrigation or tuber soak applications against several *Fusarium* species causing rots (crown, stem and tuber rots) and wilt on ornamentals, and wilt and root rot on vegetables. *Fusarium* species tested included: *F. avenaceum, F. communi, F. oxysporum* and *F. solani*. Most trials were conducted on *F. oxysporum* on larkspur, lisianthus and watermelon. In greenhouse studies, treatments were generally applied as soil drench either a few days before *Fusarium* inoculation or immediately after inoculation and reapplied biweekly. In field trials, treatments were applied as soil drench immediately after transplanting, through drip irrigation several times during the growing season, in-furrow at planting or tuber soak application for control of natural *Fusarium* infestations. Researchers used a minimum of four replications. Disease severity and incidence were recorded at various intervals after initial application. Phytotoxicity or lack of it was generally noted in the reports. Seven researchers were involved in the testing (Appendix 1).

Products were supplied by their respective manufacturers.

For IR-4 testing, the following protocols were used: 10-016 and 11-010. Please visit http://ir4.rutgers.edu/ornamental/OrnamentalDrafts.cfm to view and download these protocols.

For all research data tables, product names have been updated where manufacturers have established trade names, and tables have been rearranged by product alphanumeric order. Where both inoculated and non-inoculated checks were included in the experiment, the inoculated check appears last in the table with the non-inoculated check immediately preceding it.

Table 1. List of Products and Rates Tested on Ornamentals from 2001 to 2011.

Active Ingredient(s)	Trade Name(s)		Manufacturer	Rate(s) Tested		# Trials
	Ornamental Horticulture	Food				
Acibenzolar	Acibenzolar	Actigard	Syngenta	Drench	0.125 oz per 100 gal 0.25 oz per 100 gal	5
Azoxystrobin	Heritage	Abound, Amistar, Quadris	Syngenta	Drench	0.9 oz per 100 ga1 1.8 oz per 100 gal 4 oz per 100 gal 8.7 oz per 100 gal 16 oz per 100 gal	6
				Sprench	4 oz per 100 gal	1
Boscalid + Pyraclostrobin	Pageant	Pristine	BASF	Drench	8 oz per 100 gal 12 oz per 100 gal	3
Copper sulfate pentahydrate	Phyton 27		Phyton	Drench	25 oz per 100 gal	1
Chlorothalonil + Thiophanate-methyl	Spectro		Cleary	Drench	12 oz per 100 gal 24 oz per 100 gal	2
Cyprodinil + fludioxonil	Palladium	Switch	Syngenta	Drench	6 oz per 100 gal 4 oz per 100 gal	3
				Sprench	4 oz per 100 gal	1
Fluazinam	Fluazinam	Omega	Syngenta	Drench	6.4 fl oz per 100 gal	1
Fludioxonil	Medallion	Cannonball, Scholar	Syngenta	Drench	2 oz per 100 gal	6
				Sprench	2 oz per 100 gal	1
Fludioxonil + Mefenoxam	Hurricane		Syngenta	Drench	0.75 oz per 100 gal 1.5 oz per 100 gal 12 oz per 100 gal	4
				Spray	1.5 oz per 100 gal	1
Hydrogen peroxide, peroxyacetic & octanoic acids	X-3		Phyton	Drench	1:500 dilution	1
Metconazole	Tourney	Caramba, Quash, V-10116	BASF, Valent	Drench	1 oz per 100 gal 2 oz per 100 gal	4
				Sprench	1 oz per 100 gal 2 oz per 100 gal	1
Organic acid	CG100	CG100	Summerdale	Drench	9.6 fl oz per 100 gal 0.6 pt per 100 gal 0.8 pt per 100 gal	4
				Sprench	0.6 pt per 100 gal	1
Propiconazole	Banner Maxx	Orbit, Tilt	Syngenta	Drench	5 fl oz per 100 gal	1
Pyraclostrobin	Insignia	Cabrio, Headline	BASF	Drench	3.1 fl oz per 100 gal 6.1 fl oz per 100 gal	1

Active Ingredient(s)	Trade Name(s): Ornamental Horticulture	Trade Name(s): Food	Manufacturer	Rate(s) Tested		# Trials
SP2169	SP2169		SePro	Drench	12.3 fl oz per 100 gal	2
Tebuconazole	Torque	Folicur	Bayer, Cleary	Drench	6 fl oz per 100 gal	1
Triflumizole	Terraguard	Procure	Chemtura	Drench	6 oz per 100 gal	1
Thiophanate methyl	3336	Topsin	UPI, Cleary	Drench	16 oz per 100 gal 24 oz per 100 gal	5
				Sprench	12 fl oz per 100 gal	1
Trichoderma harziamum & T. virens	RootShield Plus (BW240)		BioWorks	Drench	3 oz per 100 gal 6 oz per 100 gal 8 oz per 100 gal	4
				Sprench	6 oz per 100 gal	1
Trifloxystrobin	Compass O	Flint, Gem	Bayer	Drench	0.5 oz per 100 gal 1 oz per 100 gal 4 oz per 100 gal	4
				Sprench	2 oz per 100 gal	1
Triticonazole	Trinity	Charter	BASF	Drench	6 fl oz per 100 gal 8 fl oz per 100 gal	4
				Sprench	6 fl oz per 100 gal 8 fl oz per 100 gal	1

Table 2. List of Products and Rates Tested on Vegetables from 2001 to 2009.

Active Ingredient(s)	Trade Name(s): Food Use	Trade Name(s): Ornamental Horticulture	Manufacturer	Rate(s) Tested		# Trials
Acibenzolar	Actigard	Acibenzolar	Syngenta	Drench	0.33 oz per acre 0.25 oz per 100 gal 0.75 oz per 100 gal	8
				Drip	0.25 oz per 100 gal	2
				Foliar	0.75 oz per acre	1
Azoxystrobin	Abound, Amistar, Quadris	Heritage	Syngenta	Drench	15.4 fl oz per 100 gal	6
				In-furrow	0.8 pt per 1000 ft	1
				Foliar	15.4 fl oz per acre	1
Chlorothalonil	Bravo	Daconil	Syngenta	In-furrow	1.5 pt per 1000 ft	1
Fludioxonil	Cannonball, Scholar	Medallion	Syngenta	Drench	0.5 lb per acre 16 oz per 100 gal	5
Hymexazol	Tachigaren	Hymexazol	Sankyo, Cleary	Drench	3 ml per sq m 6 ml per sq m	2
Metconazole	Caramba, Quash, V-10116	Tourney	BASF, Valent	Drench	4 oz per 100 gal 8 oz per 100 gal	5
				Foliar	1 oz per acre	1
					2 oz per acre	1
Prothioconazole	Proline	--	Bayer	Drench	5.7 fl oz per 100 gal	6
				Drip	5.7 fl oz per 100 gal	2
				Foliar	1 oz per acre	1
Pyraclostrobin	Cabrio, Headline	Insignia	BASF	Drench	16 oz per 100 gal	3
				In-furrow	0.77 pt per 1000 ft	1
Thiophanate	Topsin	3336	UPI, Cleary	Drench	10 fl oz per 100 gal	8

Active Ingredient(s)	Trade Name(s)		Manufacturer	Rate(s) Tested		# Trials
	Food Use	Ornamental Horticulture				
methyl				Drip	10 fl oz per 100 gal	2
				Foliar	10 fl oz per acre	1
Tiadinil	Tiadinil	--	Nichino	Drench	5.3 fl oz per 100 gal 51.1 fl oz per 100 gal	3
Trifloxystrobin	Flint, Gem	Compass	Bayer	In-furrow	0.8 pt per 1000 ft	1
Triticonazole	Charter	Trinity	BASF	Drench	9.5 fl oz per 100 gal 76.7 fl oz per 100 gal	3

Results

Comparative Efficacy on Fusarium avenaceum

In 2001, McGovern conducted a trial to determine efficacy of several fungicides for control of Fusarium crown and stem rot (*F. avenaceum*) on lisianthus (*Eustoma grandiflorum).* All products were applied as a soil drench 24-hr prior to inoculation, and reapplied biweekly, except for Medallion which was reapplied after 1 month. Heritage, 3336 WP, Banner Maxx and a reduced-rate combination of Heritage and Medallion significantly reduced a severe Fusarium crown and stem rot incidence and plant mortality, with Heritage and Heritage + Medallion being the most effective (Table 3). Medallion and Fluazinam were less effective, and Systhane was ineffective. No phytotoxicity was observed from any treatment.

Table 3. * Efficacy on Fusarium Crown and Stem Rot (*Fusarium avenaceum*) on Lisianthus (*Eustoma grandiflorum*) 'Maurine Blue', McGovern, FL, 2001.

Treatment	Rate Per 100 Gal	Final Disease Incidence (%)^x	Final Mortality (%)	AUDPC^y	AUMPC^z
3336 50WP (thiophanate methyl)	16 oz	58.5 b	29.2 bc	522 cd	96 a
Banner Maxx 1.3MEC (propiconazole)	5 fl oz	66.0 b	33.5 b	1972 ab	965 a
Fluazinam 4.17F (fluazinam)	6.4 fl oz	70.8 ab	37.5 b	1425 bc	728 a
Heritage 50WG (azoxystrobin)	8.7 oz	20.8 c	0.0 c	314 d	0 a
Heritage + Medallion	4.35 + 1 oz	21.0 c	0.0 c	244 d	0 a
Medallion 50WP (fludioxonil)	2 oz	66.5 ab	29.2 bc	921 cd	2139 a
Systhane 40WSP (myclobutanil)	4 oz	91.8 ab	54.5 a	1978 a	1002 a
Untreated inoculated	-	100 a	87.5 a	2844 a	1457 a

* Not an IR-4 Experiment: F&N Tests Vol 57: OT16.
^{x} Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.01).
^{y} AUDPC = area under the disease incidence progress curve.
^{z} AUMPC = area under the mortality progress curve.

Comparative Efficacy on Fusarium communi

During 2010 and 2011, Chastagner conducted three greenhouse trials to test the efficacy of several fungicides applied mainly as drench for control of damping off and root rot caused by *F. communi* (Isolates 34, 39, 53, 101, MBL12015) on Douglas fir (*Pseudotsuga menziesii*). In 2010, all products were applied 5 days after disease inoculation of potting mix (15 Dec), except BW240 which was applied on 12 Dec. Plants were seeded on 22 Dec. Treatments were applied one to three times on 1 to 4-week intervals for various products. In 2011, all treatments, with the exception of BW240, foliar Pageant, and the initial application of Acibenzolar were applied as drenches. On November 3, 2011 all treatments were planted with 10 seeds per pot. The initial application of Acibenzolar was applied directly to the seeds at this time. This was done by soaking the seeds in the Acibenzolar solution for 10 minutes prior to planting. The initial foliar application of Pageant was applied on November 21, 2011, which was 4-7 days after germination. See Table 5 and Table 6 for application details. Data on symptom development was collected once per week for 4 weeks beginning 14-15 days after seeding. Notes on symptoms were taken and the number of "healthy" seedlings was recorded. Symptoms included damping off, which occurred shortly after emergence of the cotyledon, to root rot which killed the seedlings during the experiment. Disease pressure was high in all trials. In 2010, only the drench applications of Tourney at 1 or 2 oz/100 gallons had significantly higher numbers of healthy seedlings per pot (Table 4). Promising activity was observed for Compass, Pageant and Trinity as they were comparable to the non-inoculated check. In 2011, the drench applications of Torque, Pageant, 3336, CG100, Insignia at the high rate and Tourney had significantly higher numbers of healthy seedlings (Table 5). BW240 was ineffective (Table 6). No phytotoxicity was observed from any treatment except SP2169 in which some plants appeared to be stunted with malformed needles.

Table 4. Efficacy on Damping-off and Root Rot Caused by *Fusarium communi* on Douglas Fir (*Pseudotsuga menziesii*), Chastagner WA, 2010.

Treatment	Rate Per 100 Gal	Application Dates[z]	Application Interval	No. of Healthy Seedlings[x,y]
Acibenzolar	0.125 oz	2, 4	21 Days	2.2 b
	0.25 oz	2, 4	21 Days	2.4 b
CG100 (organic acid)	0.6 pt	2, 5	28 Days	3.0 b
Compass (trifloxystrobin)	0.5 oz	2, 5	28 Days	4.0 ab
Heritage (azoxystrobin)	1.8 oz	2, 5	28 Days	4.0 ab
	4 oz	2, 5	28 Days	2.2 b
Hurricane (fludioxonil+mefenoxam)	0.75 oz	2	1 application	3.0 b
Medallion (fludioxonil)	2 oz	2, 4	21 Days	2.6 b
Pageant 38WG (boscalid+pyraclostrobin)	12 oz	2, 3, 5	14 Days	4.4 ab
Palladium (cyprodinil+fludioxonil)	6 oz	2, 3, 5	14 Days	1.8 b
RootShield Plus (*Trichoderma harziamum & T. virens)*	6 oz	1	1 application	1.6 b
Tourney (metconazole)	1 oz	2, 4	21 Days	8.2 a
	2 oz	2, 4	21 Days	8.2 a
Trinity (triticonazole)	6 fl oz	2, 3, 5	14 Days	5.2 ab
	8 fl oz	2, 3, 5	14 Days	5.0 ab
Untreated non-inoculated	-	-	-	5.7 ab
Untreated inoculated	-	-	-	1.9 b

[x] Means followed by the same letter do not differ significantly based on Tukey's HSD Test, (P=0.001).
[y] Data collected 35 days after seeding (January 26, 2011).
[z] Dates: 1 = 12/12/10, 2 = 12/20/10, 3 = 1/3/11, 4 = 1/10/11, 5 = 1/18/11.

Table 5. Efficacy on Damping-off and Root Rot Caused by *Fusarium communi* on Douglas Fir (*Pseudotsuga menziesii*), Chastagner WA, 2011, Trial 1.

Treatment	Rate Per 100 Gal	Application Method	Applic. Dates[y]	Applic. Interval	Emergence Out of 10 Seeds[x]	No. of Healthy Seedlings	No. of Plants W/ Phyto Symptoms
3336 F (thiophanate-methyl)	16 fl oz	Drench	1, 2, 5	14 Days	8.8 abc	7.0 abc	0.0 b
Acibenzolar-s-methyl	0.25 oz	Seed soak & Drench	2, 4	21 Days	6.2 bc	0.2 f	0.0 b
CG100 (organic acid)	0.6 pints	Drench	1, 5	28 Days	8.6 abc	5.0 bcd	0.0 b
Compass 50WDG (trifloxystrobin)	0.5 oz	Drench	1, 4	21 Days	8.8 abc	4.0cde	0.0 b
Heritage 50WG (azoxystrobin)	1.8 oz	Drench	1, 5	28 Days	7.4 abc	1.6 def	0.0 b
Hurricane (fludioxonil+mefenoxam)	0.75 oz	Drench	1	1 application	7.4 abc	1.6 def	0.0 b
Insignia SC (pyraclostrobin)	3.1 fl oz	Drench	1, 3, 5	14 Days	8.4 abc	2.4 def	0.0 b
	6.1 fl oz	Drench	1, 3, 5	14 Days	8.8 abc	4.8 bcd	0.0 b
Medallion (fludioxonil)	2 oz	Drench	1, 4	21 Days	7.8 abc	2.0 def	0.0 b
Pageant 38WG (boscalid+pyrclostrobin)	8 oz	Foliar	4	14 Days	7.2 abc	0.6 f	0.0 b
	12 oz	Drench	1, 3, 5	14 Days	9.4 a	7.2 abc	0.0 b
Palladium 62.5WG (cyprodinil+fludioxonil)	4 oz	Drench	1, 3, 5	14 Days	8.2 abc	2.4 def	0.0 b
SP2169	12.3 fl oz	Drench	1, 3, 5	14 Days	9.0 ab	4.4 cde	4.2 a
Torque (tebuconazole)	6 fl oz	Drench	1, 3, 5	14 Days	9.2 a	8.2 ab	0.0 b
Tourney 50 WDG (metconazole)	1 oz	Drench	1, 4	21 Days	8.8 abc	7.4 abc	0.0 b
	2 oz	Drench	1, 4	21 Days	9.8 a	9.0 a	0.0 b
Trinity 2 SC (triticonazole)	6 oz	Drench	1, 3, 5	14 Days	9.0 ab	2.4 def	0.0 b
	8 oz	Drench	1, 3, 5	14 Days	9.4 a	3.2 def	0.6 b
Untreated non-inoculated	-	-	-	-	8.8 abc	8.8 a	0.0 b
Untreated inoculated	-	-	-	-	6.0 c	1.2 ef	0.0 b

[x] Means followed by the same letter do not differ significantly based on Tukey's HSD Test, (P=0.001).
[y] Dates: 1 = 11/1/11, 2 = 11/3/11, 3 = 11/16/11, 4 = 11/21/11, 5 = 11/29/11.
Emergence data collected 28 days after seeding; no. of healthy seedlings and phytotoxicity collected 35 days after seeding (11/3/11).

Table 6. Efficacy on Damping-off and Root Rot Caused by *Fusarium communi* on Douglas Fir (*Pseudotsuga menziesii*), Chastagner WA, 2011, Trial 2.

Treatment	Rate Per 100 Gal	Application Method[y]	Emergence Out of 10 Seeds[x]	No. of Healthy Seedlings
RootShield Plus (*Trichoderma harziamum & T. virens)*	8 oz	Soil incorp. and seed trt	0.0 b	0.0 b
Untreated non-inoculated	-	-	8.6 a	7.4 a
Untreated inoculated	-	-	7.6 a	0.4 b

[x] Means followed by the same letter do not differ significantly based on Tukey's HSD Test, (P=0.001).
[y] BW240 applied to soil 3 days before inoculation and to seeds before seeding 5 days after inoculation.
Emergence data collected 28 days after seeding; no. of healthy seedlings and phytotoxicity collected 35 days after seeding (11/3/11).

Comparative Efficacy on Fusarium oxysporum

In 2001, McGovern conducted two trials to determine efficacy of several fungicides for control of Fusarium wilt (*F. oxysporum*) on lisianthus (*Eustoma grandiflorum)*. Treatments were applied as a soil drench 24 hr prior to inoculation with *F. oxysporum*, and reapplied at 2-3 wk intervals. In the first trial, severe final disease incidence was significantly reduced by Medallion and Hurricane (Table 7). Final plant mortality was significantly reduced by all treatments, with Medallion, and Hurricane the most effective in increasing plant survival. Plant height was significantly increased by Medallion, Hurricane and Compass. In the second trial, Medallion, Terraguard, Heritage, Systhane and 3336 WP significantly reduced a severe disease incidence and plant mortality, with Medallion and Terraguard being the most effective (Table 8). Spectro 90WDG was ineffective. No phytotoxicity was observed from any treatment.

Table 7. * Efficacy on Fusarium Wilt (*Fusarium oxysporum*) on Lisianthus (*Eustoma grandiflorum)* 'Maurine Blue', McGovern, FL, 2001.

Treatment	Rate Per 100 Gal	Final Disease Incidence (%)[x]	Final Mortality (%)	AUDPC[y]	AUMPC[z]	Plant Height (cm)
Compass 50WDG (trifloxystrobin)	1 oz	88.9 a	39.4 bc	1698.0 b	508.5 b	18.2 c
Heritage 50WG (azoxystrobin)	0.9 oz	97.2 a	25.0 c	2085.7 b	295.0 bc	11.6 de
Hurricane 48WP (fludioxonil + mefenoxam)	1.5 oz	41.7 b	0.0 d	263.3 c	0.0 c	27.1 b
Medallion 50WP (fludioxonil)	2 oz	36.1 b	0.0 d	144.0 c	0.0 c	34.3 a
Untreated inoculated	-	100 a	69.4 a	3394.2 a	1220.2 a	10.5 de

* Not an IR-4 Experiment: F&N Tests Vol 57: OT17. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.01).
[y] AUDPC = area under the disease incidence progress curve.
[z] AUMPC = area under the mortality progress curve.

Table 8. * Efficacy on Fusarium Wilt (*Fusarium oxysporum*) on Lisianthus (*Eustoma grandiflorum)* 'Maurine Blue', McGovern, FL, 2001.

Treatment	Rate Per 100 Gal	Final Disease Incidence (%)[x]	Final Mortality (%)	AUDPC[y]	AUMPC[z]
3336 50WP (thiophanate methyl)	16 oz	75.0 b	33.3 b	502 b	161 b
Heritage 50WG (azoxystrobin)	8.7 oz	44.4 c	25.0 bc	326 bc	102 b
Medallion 50WP (fludioxonil)	2 oz	8.3 d	5.5 c	82 c	62 b
Spectro 90WDG (chlorothalonil + thiophanate methyl)	12 oz	88.8 ab	72.2 a	1560 a	948 a
Systhane 40WSP (myclobutanil)	4 oz	43.8 c	27.8 b	408 bc	304 b
Terraguard 50W (triflumizole)	6 oz	13.9 d	5.5 c	104 c	54 b
Untreated inoculated	-	94.4 a	77.8 a	1456 a	1055 a

* Not an IR-4 Experiment: F&N Tests Vol 57: OT18.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.01).
[y] AUDPC = area under the disease incidence progress curve.
[z] AUMPC = area under the mortality progress curve.

In 2010, Kirk conducted a greenhouse trial to test the efficacy of several fungicides for control of root rot caused by *F. oxysporum* on larkspur (*Delphinium sp.*). All treatments were applied as drench, except BW240 which was applied to plant roots as an immersion in solution for 30 seconds prior to transplanting. Initial treatments were applied 4 days after transplanting, except Acibenzolar applied 14 days before, CG100 applied at transplanting and Trinity applied 21 days after transplanting. Plants were inoculated immediately after the application of fungicides on 20 Sep. Fusarium necrosis and root rot developed in the trial and about 150 days after transplanting, the inoculated check plants developed severe leaf necrosis and root necrosis. All treatments except Tourney significantly reduced the foliar and root necrosis in comparison to the non-treated inoculated control (Table 9). It is possible that plants treated with Tourney were excessively inoculated. The treatments with the greatest efficacy included the standards 3336, and Medallion, with Hurricane almost comparable; Acibenzolar at the lower rate also looked promising. All treatments caused transient leaf phytotoxicity.

Table 9. Efficacy on Fusarium Root Rot (*Fusarium oxysporum*) on Larkspur (*Delphinium sp.*), Kirk, MI, 2010.

Treatment	Rate Per 100 Gal	Application Dates[u]	Phytotoxicity[x, t] 74 DAP[v]	No. Leaves Per Plant 104 DAP	Plant Height (cm) 104 DAP	Leaf Necrosis[w] 148 DAP	RAUDPC[y] 148 DAP	Root Necrosis[z] 148 DAP
Acibenzolar	0.125 oz	A	1.1 ab	9.4 de	30.3 de	39.0 ef	9.2 e	3.9 e
	0.25 oz	A	1.4 a	9.0 def	35.2 cd	47.5 d	10.3 d	4.6 cd
3336 80WG (thiophanate methyl)	4 lb	D	0.9 bc	11.2 bc	42.5 bc	28.5 h	8.8 e	2.6 f
BW240 WP (*Trichoderma harziamum & T. virens)*	6 oz, 3 oz	B, H	1.1 ab	7.5 fgh	25.5 de	56.0 c	11.9 c	4.4 cde
CG100 20SC (organic acid)	0.8 pt	C	0.9 bc	8.7 d-g	23.7 e	55.8 c	12.1 c	5.5 b
Hurricane (fludioxonil + mefenoxam)	12 oz	D	1.4 a	12.6 ab	51.3 ab	35.1 fg	9.2 e	2.6 f
Medallion (fludioxonil)	2 oz	D	1.0 bc	13.6 a	54.4 a	31.3 gh	9.3 e	2.7 f
Pageant 38WG (boscalid+pyraclostrobin)	12 oz	D, E	0.5 d	7.3 gh	28.0 de	46.3 d	11.1 cd	4.2 de
Tourney (metconazole)	2 oz	D	1.0 bc	3.0 i	41.6 bc	78.5 a	14.5 b	7.6 a
Trinity (triticonazole)	6 fl oz	F, G	0.7 cd	10.0 cd	35.3 cd	43.8 de	10.6 d	5.0 bc
Untreated non-inoculated	-	-	0.0 e	8.0 efg	34.2 cd	16.4 i	2.4 f	2.3 f
Untreated inoculated	-	-	0.0 e	6.2 h	23.5 e	65.0 b	17.6 a	7.7 a

[x] Means followed by the same letter do not differ significantly based on Fisher's LSD (P=0.05).
[t] Phytotoxicity scale from 0 – 5; 0= no phytotoxicity; 1= ≈1mm of entire leaf margin yellow of at least one leaf; 2= 1-5% of entire leaf margin yellow of at least one leaf; 3= 1-5% of entire leaf margin yellow of all leaves; 4= 5-10% of entire leaf margin yellow of all leaves; 5= >10% of entire leaf margin yellow of all leaves.
[w] Leaf necrosis percentage over whole plant.
[y] RAUDPC, relative area under the disease progress curve calculated from day of appearance of initial symptoms.
[z] Root necrosis scale from 0 – 10; 0= no necrosis; 1= 0-5%; 2= 6-10%; 3= 11-15%; 4= 16-20%; 5= 20-30%; 6= 30-40%; 7= 40-50%; 8= 50-60%; 9= 60-75%; 10= 75-100% of root mass necrotic.
[v] Days after planting
[u] Application dates: A= 2 Sep (2 weeks prior to inoculation); B= 16 Sep (root dip before planting); C= 16 Sep (soil drench at planting); D= 16 Sep; E= 30 Sep; F= 7 Oct; G= 21 Oct; H= 25 Nov

In 2011, Chase conducted a greenhouse trial to test the efficacy of several fungicides applied as drench/sprench for control of Fusarium wilt caused by *F. oxysporum* on lisianthus (*Eustoma grandiflora)*. Plugs were planted on 21 March and all treatments applied as drench/sprench on 28 March. Plants were inoculated on 11 April. Additional treatments were applied at different intervals for various products on 4, 18 April, 2, 9, 16 and 23 May. Three weeks after test initiation, stunting due to either Fusarium or phytotoxicity had become apparent. The worst damage was seen with both rates of Tourney which caused severe stunting (Table 10). Only plants treated with acibenozolar at the low rate were as tall as the noninoculated control. After three weeks, top grade was lowest for plants treated with Tourney. After about four weeks, severity of Fusarium wilt was low for all treatments except for the inoculated control, BW240 and Phyton 27 alone. After six weeks, only the higher rate of acibenzolar, SP2169 and Tourney at the 1 oz rate showed significantly lower disease severity.

Table 10. Efficacy on Fusarium wilt (*F. oxysporum*) on Lisianthus (*Eustoma grandiflora*), Chase, CA, 2011.

Treatment	Rate per 100 Gal	Applic. Interval (Days)	Height (cm) 5-4-11	Top Grade 5-4-11	Disease Severity[y]		
					5-9-11	5-16-11	5-23-11
Acibenzolar	0.125 oz	21	13.2 d	3.2 f	1.0 a	1.0 a	1.3 ab
	0.25 oz	21	10.9 bcd	3.0 def	1.0 a	1.1 a	1.0 a
3336 80WG (thiophanate methyl)	16 oz	14	9.8 bc	2.9 cdef	1.2 a	1.1 a	1.7 abc
BW240 WP (*Trichoderma harziamum & T. virens)*	6 oz, then 3 oz		8.0 bc	2.7 bcd	1.9 ab	2.4 d	2.2 abc
CG100 20SC (organic acid)	9.6 fl oz	14	9.4 bc	2.8 bcdef	1.2 a	1.5 abcd	2.4 abc
Palladium (cyprodinil + fludioxonil)	6 oz	14	10.6 bcd	2.9 cdef	1.1 a	1.2 ab	1.4 ab
Phyton 27 (copper sulfate pentahydrate)	25 oz	14	9.7 bc	2.8 bcde	2.1 b	2.4 cd	2.9 c
Phyton 27 + X3	25 oz + 1:500	14	10.1 bcd	3.0 cdef	1.1 a	1.7 abcd	1.9 ab
SP-2169	12.3 fl oz	14	8.3 bc	2.8 bcdef	1.0 a	1.0 a	1.0 a
Tourney (metconazole)	1 oz	14	3.9 a	2.5 ab	1.2 a	1.2 abc	1.0 a
	2 oz	14	3.4 a	2.3 a	1.1 a	1.3 abcd	1.3 ab
Trinity (triticonazole)	6 fl oz	14	8.2 bc	2.9 cdef	1.1 a	1.3 abcd	1.6 abc
	8 fl oz	14	7.4 b	2.7 bcd	1.0 a	1.0 a	1.3 ab
X3 (hydrogen peroxide, peroxyacetic & octanoic acids)	1:500	14	8.2 bc	2.6 bc	1.3 a	1.5 abcd	2.1 abc
Untreated noninoculated			11.5 cd	3.1 ef	1.0 a	1.0 a	1.0 a
Untreated inoculated			9.6 bc	2.9 cdef	1.6 ab	2.3 bcd	2.7 bc

[x] Means followed by the same letter do not differ significantly (P=0.05).
[y] Disease severity was recorded using the following scale: 1 – no disease, 2 – slight, 3 – moderate, 4 – severe to 5 – plant dead.

From 2007 to 2008, five greenhouse studies were conducted to determine efficacy of several fungicides for control of Fusarium wilt (*F. oxysporum* f. sp. *niveum*) on watermelon (*Citrullus lanatus*). Treatments were applied as soil drench 72 hr prior to soil drench inoculation with *F. oxysporum*. In two trials conducted by Egel in 2007, Topsin provided the best control of Fusarium wilt, with Actigard and Tachigaren at the higher rate less effective (Table 11). Cannonball and Tachigaren at the lower rate provided significant control in one of two trials. No phytotoxicity was observed from treatments except Actigard which reduced seedling growth. In a 2008 experiment by Egel, Topsin, V-10116, Proline and Tiadinil provided 100 % control of a severe Fusarium wilt pressure, similar to uninoculated control (Table 12). Quadris was essentially as effective as these products, Charter and Cabrio were less effective and Actigard and Cannonball virtually ineffective. No phytotoxicity was observed from any treatment in this trial.

Table 11. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus lanatus*) 'Black Diamond', Egel, IN, 2007.

Treatment	Rate Per Acre[w]	Test 1 Feb 2007		Test 2 March 2007	
		AUDPC[x,y]	Plant Size (cm^2)[z] 3/12/07	AUDPC	Plant Size (cm^2) 4/6/07
Actigard 50WG (acibenzolar)	0.33 oz	220.90 c	118.8 c	140.42 c	350.4 c
Cannonball 50WP (fludioxonil)	0.5 lb	607.62 a	310.2 a	353.51 b	756.8 a
Tachigaren 30L (hymexazol)	3 ml/sq m	365.37 b	311.7 a	563.76 a	712.4 a
Tachigaren 30L	6 ml/sq m	252.13 c	307.5 a	348.22 b	653.8 ab
Topsin 4.5FL (thiophanate methyl)	10 fl oz	15.35 d	213.1 b	0.00 d	637.3 ab
Untreated non-inoculated	-	0.00 d	237.2 ab	0.00 d	501.8 bc
Untreated inoculated	-	679.89 a	-	531.10 a	-

* Not an IR-4 Experiment: IR-4 Food Crops Website (online).
[x] Means followed by same letter do not differ significantly (P=0.05, LSD).
[w] Rate per acre was calculated on the assumption of 1,400 plants per acre.
[y] AUDPC = area under the disease incidence progress curve.
[z] The height and the maximum width of the leaves were measured in cm and the result multiplied to give an area.

Table 12. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus lanatus*) 'Black Diamond', Egel, IN, 2008.

Treatment	Rate Per 100 Gal	AUDPC[x,y]	Incidence[z]
Actigard 50WG (acibenzolar)	0.75 oz	32 b	0.74 ab
Cabrio EG (pyraclostrobin)	16 oz	91 b	0.25 de
Cannonball 50WP (fludioxonil)	16 oz	659 a	0.66 bc
Charter 25FS (triticonazole)	76.7 fl oz	45 b	0.16 de
Proline 480SC (prothioconazole)	5.7 fl oz	0 b	0 e
Quadris 2.08SC (azoxystrobin)	15.4 fl oz	6 b	0.08 e
Tiadinil (tiadinil)	51.1 fl oz	0 b	0 e
Topsin 4.5FL (thiophanate methyl)	10 fl oz	0 b	0 e
V-10116 (metconazole)	8 oz	0 b	0 e
Untreated non-inoculated	-	0 b	0 e
Untreated inoculated	-	646 a	1.00 a

* Not an IR-4 Experiment: IR-4 Food Crops Website (online). Not all products tested included in table.
[x] Means followed by same letter do not differ significantly (P=0.01, LSD).
[y] AUDPC = area under the disease incidence progress curve.
[z] 1.00 = 100 % disease incidence.

In a greenhouse trial conducted by Langston in 2008, Actigard, V-10116, Quadris, Proline and Topsin significantly reduced a very high Fusarium wilt pressure (Table 13). Significant stunting and phytotoxicity were observed in all treatments except Proline, with V-10116 treatments showing the most severe phytotoxcity. These data indicate that Proline, Actigard, Quadris and Topsin may have potential in watermelon production as at-planting applications for suppressing losses to Fusarium wilt. A greenhouse study conducted by Everts in 2008 showed that Quadris, Actigard at either high and low rate, Topsin, Proline and Metconazole were highly effective in reducing a very high Fusarium wilt pressure (Table 14). No phytotoxicity was observed for all treatments except Actigard and Metconazole. Actigard caused necrotic lesions, leaf yellowing, and slow plant growth although the symptoms were less with the low rate. Metconazole caused stunted plants with dark green leaves.

Table 13. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus lanatus*) 'Black Diamond', Langston, GA, 2008.

Treatment	Rate Per 100 Gal	Disease Severity[x,y] 5/12/08	AUDPC[z]
Actigard 50WG (acibenzolar)	0.75 oz	3.2 c	34.2 e
Cabrio 20EG (pyraclostrobin)	16 oz	9.7 a	100.3 a-d
Cannonball 50WP (fludioxonil)	16 oz	9.8 a	105.2 a-c
Proline 4SC (prothioconazole)	5.7 fl oz	5.9 b	50.3 e
Quadris 2.08SC (azoxystrobin)	15.4 fl oz	5.5 b	46.6 e
Tiadinil 30% SC (tiadinil)	51.1 fl oz	9.9 a	112.8 a
Topsin 4.5F (thiophanate methyl)	10 fl oz	8.5 a	79.5 d
Trinity 1.69SC (triticonazole)	9.5 fl oz	9.9 a	109.0 a-c
V-10116 50WG (metconazole)	4 oz	5.2 bc	40.8 e
Untreated inoculated	-	9.8 a	108.3 a-c

* Not an IR-4 Experiment: PDM Reports Vol 3: V155. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.05).
[y] 0-10 scale where 0= no foliar wilt symptoms, 5.0=50% of the foliage wilted, and 10.0= a dead plant.
[z]. AUDPC = area under the disease progress curve calculated from severity ratings taken on May 1, 5, 8, 12 and 15.

Table 14. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus lanatus*) 'Sugar Baby', Everts, MD, 2008.

Treatment	Rate Per 100 Gal	Wilt Incidence (%)[x]	Final Wilt Severity	AUWSPC (%.days)[y]
Actigard 50WG (acibenzolar)	0.25 oz	8 bc	1 cd	6 e
Actigard	0.75 oz	0 c	0 d	0 e
Cabrio 20EG (pyraclostrobin)	16 oz	58 a	68 ab	635 cd
Cannonball 50WP (fludioxonil)	16 oz	75 a	62 ab	707 bcd
Metconazole 50WG (metconazole)	4 oz	17 b	6 cd	16 e
Proline 480SC (prothioconazole)	5.7 fl oz	17 b	2 cd	12 e
Quadris 2.08SC (azoxystrobin)	15.4 fl oz	0 c	0 d	0 e
Tiadinil 30% SC (tiadinil)	5.3 fl oz	100 a	67 ab	977 bc
Topsin 4.5FL (thiophanate methyl)	10 fl oz	17 b	1 cd	1 e
Trinity 1.69SC (triticonazole)	9.5 fl oz	83 a	49 b	438 d
Untreated inoculated	-	100 a	99 a	1510 a

* Not an IR-4 Experiment: PDM Reports Vol 3: V092. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.05).
[y]. AUWSPC = area under wilt severity progress curve.

Four field experiments were conducted from 2008 to 2009 to determine efficacy of several fungicides for control of natural populations of Fusarium wilt (*F. oxysporum* f. sp. *niveum*) on watermelon (*Citrullus lanatus*). Everts conducted two trials where treatments were drenched to the soil around each plant immediately after transplanting. In the first trial planted 10 June, Actigard, Proline and Topsin significantly reduced wilt at 2½ weeks after transplanting (Table 15). The same three treatments that reduced wilt had the highest numerical vine length, although there were no significant differences among treatments. No phytotoxicity was observed for all treatments except Metconazole causing stunting and dark green leaves early in the season. In a second trial planted 3 June, all treatments, except Quadris, were effective in reducing wilt incidence at both 4 and 5 weeks after transplanting (Table 16). Watermelons treated with Actigard, Proline, Topsin and Quadris had longer vines than the untreated control. No phytotoxicity was observed for any treatment except Metconazole causing a significant reduction in growth of plants, and dark green leaves during the early growing season. In 2009, Everts determined the efficacy of Actigard, Proline and Topsin applied through drip irrigation immediately after transplanting on 16 June, and again at 2 and 4 weeks after transplanting. Proline was the only product that significantly reduced a severe Fusarium wilt incidence where untreated plots had 78 % of plants with wilt symptoms by 1 Aug. (Table 17). Plot vigor and yield were numerically highest in plots where Proline was applied alone or in combination with other fungicides, although not significantly higher than in some treatments. No phytotoxicity was observed in any treatment.

Table 15. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus lanatus*) 'Sugar Baby', Everts, DE, 2008.

Treatment	Rate Per 100 Gal	Wilt Incidence (%)[x] at		Vine Length (in) 7/11/08	Plant Vigor (%) 7/22/08	Marketable Fruit	
		2 ½ wk	4 ½ wk			T/A	No./A
Actigard 50WG (acibenzolar)	0.25 oz	5 b	5	43	94	9.8	3449
Metconazole 50WG (metconazole)	4 oz	18 ab	15	30	76	7.0	2723
Proline 480SC (prothioconazole)	5.7 fl oz	5 b	10	44	92	7.5	3086
Quadris F (azoxystrobin)	15.4 fl oz	18 ab	20	33	72	6.6	2783
Topsin 4.5FL (thiophanate methyl)	10 fl oz	8 b	8	37	90	7.4	2602
Untreated	-	25 a	23	34	79	6.5	3086
P Values		0.0498	0.2893	0.0551	0.0516	0.4536	0.3631

* Not an IR-4 Experiment: PDM Reports Vol 3: V097. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.05).

Table 16. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus* lanatus) 'Sugar Baby', Everts, MD, 2008.

Treatment	Rate Per 100 Gal	Wilt Incidence (%)[x] at			AUWIPC (% days)[y]	Wilt Severity (%)[z]	Vine Length (in) 6/27/08	Marketable Fruit 7/29/08)	
		4 wk	5 wk	6 wk				T/A	No./A
Actigard 50WG (acibenzolar)	0.25 oz	0 b	2 b	25	734	61	72 ab	8.6	2133
Metconazole 50WG (metconazole)	4 oz	0 b	8 b	35	915	71	49 d	9.1	2042
Proline 480SC (prothioconazole)	5.7 fl oz	2 b	8 b	37	909	66	72 ab	8.7	2224
Quadris F (azoxystrobin)	15.4 fl oz	4 ab	15 ab	42	1057	60	70 ab	6.5	1679
Topsin 4.5FL (thiophanate methyl)	10 fl oz	2 b	6 b	33	875	63	73 a	8.5	2269
Untreated	-	8 a	29 a	58	1494	77	64 c	5.9	1588
P Values		0.0460	0.0212	0.2089	0.1267	0.2019	<0.0001	0.2956	0.4318

* Not an IR-4 Experiment: PDM Reports Vol 3: V093. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.05).
[y] The area under wilt incidence progress curve (AUWIPC) was calculated from wilt incidence data made at 3 through 8 weeks after transplanting.
[z] Final wilt severity was rated at fruit harvest using the Horsfall-Barratt scale.

Table 17. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus* lanatus) 'Sugar Baby', Everts, MD, 2009.

Treatment	Rate Per 100 Gal	Wilt Count Per Plot[x]		Plant Vigor (%) 8/7/09	Fruit Wt (Lb/Plot) 8/12/09
		7/17/09	8/1/09		
Actigard 50WG (acibenzolar)	0.25 oz	13 a	12.3 a	35.5 bcd	36.5 e
Actigard + Proline	0.25 oz + 5.7 fl oz	7.0 cd	8.5 b	38.0 bc	100.3 abc
Actigard + Topsin	0.25 oz + 10 fl oz	9.8 bc	12.3 a	26.0 cde	75.4 bcd
Proline 480SC (prothioconazole)	5.7 fl oz	5.0 d	6.3 b	45.0 b	105.7 a
Proline + Topsin	5.7 fl oz + 10 fl oz	7.3 cd	7.8 b	47.5 ab	102.8 ab
Topsin 4.5FL (thiophanate methyl)	10 fl oz	10.8 ab	14.0 a	19.0 e	73.4 cd
Untreated	-	10.0 abc	14.0 a	19.0 e	80.8 a-d

* Not an IR-4 Experiment: PDM Reports Vol 4: V065. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.05).

In 2009, Engel conducted a field trial to determine efficacy of Actigard, Proline and Topsin applied through trickle irrigation. All products were equally effective against Fusarium wilt (Table 18). No phytotoxicity was observed in any treatment.

Table 18. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus* lanatus) 'Imagination', Egel, IN, 2009.

Treatment[w]	Rate Per Acre	AUDPC[x,y]	Fruit Weight (Lb/A)[z]
Actigard 50WG (acibenzolar)	0.25 oz	257.4 c	32,125 a
Proline 480SC (prothioconazole)	5.7 fl oz	233.6 c	32,307 a
Topsin 4.5FL (thiophanate methyl)	10 fl oz	352.3 bc	31,581 a
Untreated Control	-	691.2 a	27,388 a

* Not an IR-4 Experiment: IR-4 Food Crops Website (online). Not all products tested included in table.
[w] Applied 12, 26 May and 10 June.
[x] Means followed by same letter do not differ significantly (P=0.05,LSD).
[y] AUDPC = area under the disease incidence progress curve.
[z] Fruit was harvested 20, 27 July, 3 and 10 August.

In 2010, Langston conducted a field trial to determine efficacy of Actigard, Proline, Quadris, Topsin and V-10116 applied as drench at transplanting (4/7) followed by foliar spray 4 weeks later (5/5). All products significantly reduced Fusarium wilt incidence, with Actigard, Proline and V-10116 at the high rate providing superior control (Table 19). Significant phytotoxicity was observed with Actigard, Proline and V-10116, with V-10116 causing severe stunting. There was no difference in yields between treatments (data not shown).

Table 19. * Efficacy on Fusarium Wilt (*Fusarium oxysporum* f. sp. *niveum*) on Watermelon (*Citrullus* lanatus) 'Black Diamond', Langston, GA, 2010.

Treatment[w]	Rate[y]	Plant Vigor[z] 4/21	% Wilt Incidence[x]	
			4/21	5/10
Actigard 50WG (acibenzolar)	0.75 oz	7.3 b	0.0 b	11.2 cd
Proline 4SC (prothioconazole)	5.7 fl oz	6.3 c	0.0 b	5.7 d
Quadris 2.08SC (azoxystrobin)	15.4 fl oz	8.7 a	0.0 b	33.2 bc
Topsin 4.5F (thiophanate methyl)	10 fl oz	8.8 a	0.0 b	55.7 b
V-10116 50WG (metconazole)	1 oz	4.7 d	2.7 b	30.7 c
	2 oz	3.3 e	0.0 b	5.5 d
Untreated inoculated	-	8.7 a	33.3 a	94.3 a

* Not an IR-4 Experiment: PDM Reports Vol 5: V156. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD (P=0.05). % wilt incidence was rated by counting the number of plants in each plant that showed signs of wilting and dividing that number by the total number of plants in each plot x100.
[w] Products were applied on 4/7 as transplant drench; 5/5 as foliar spray.
[y] Rates are in per 100 gal as transplant drench and per acre as foliar spray.
[z] Plant Vigor was rated on 1-10 scale where 1= a dead or dying plant, 5 = moderately stunted plant and 10 = a healthy non-stunted plant.

Comparative Efficacy on Fusarium solani

In 2001, McGovern conducted a trial to determine efficacy of several fungicides for control of Fusarium tuber rot (*F. solani*) on caladium (*Caladium* x *hortulanum*). Tubers were soaked overnight (~16 hr) at ambient temperature in each of the fungicides on 16 May 2000, 3 days prior to planting. Tubers to be sprayed at planting with Hurricane initially were soaked overnight in water alone. Hurricane was applied at planting on 19 May 2000 with a hand-powered hydraulic sprayer and an approximate volume of the diluted fungicide of 1500 gal/A. Plant emergence was significantly increased compared to the water control by preplant soak application of Spectro and Heritage and by Hurricane applied at planting (Table 20). Spectro significantly increased the number of marketable tubers per plot. Spectro, Heritage at 16 oz, or Hurricane applied as tuber soaks, and spray application of Hurricane at planting significantly increased total tuber weight per plot. Hurricane applied as a tuber soak or as a spray at planting was the only product that significantly reduced the severity of Fusarium tuber rot. No phytotoxicity was observed from any treatment.

Table 20. * Efficacy on Fusarium Tuber Rot (*Fusarium solani*) on Caladium (*Caladium x hortulanum*) 'Florida Cardinal', McGovern, FL, 2001.

Treatment[y]	Rate Per 100 Gal	% Emergence[x] 6/29/00	No Marketable Tubers 4/9/01	Tuber Weight (Lb/Plot) 4/9/01	Disease Severity[z] 3/27/01
3336 50WP (thiophanate methyl)	24 oz	67.7 ab	71.8 e	8.0 d	8.8 abcd
Compass 50WDG (trifloxystrobin)	4 oz	72.5 bc	78.2 bcde	8.8 bcd	7.5 bcd
Heritage 50WG (azoxystrobin)	4 oz	63.6 a	76.0 cde	8.8 bcd	10.6 a
Heritage	8 oz	77.7 cde	82.2 abcde	8.6 bcd	9.0 abc
Heritage	16 oz	74.2 bcd	90.6 ab	9.6 ab	9.3 abc
Hurricane 48WP (fludioxonil + mefenoxam)	1.5 oz	76.0 cd	87.5 abcd	10.1 a	6.3 d
Hurricane spray at planting	1.5 oz	85.7 f	83.4 abcde	9.7 ab	7.0 cd
Spectro 90WDG (chlorothalonil +thiophanate methyl)	24 oz	83.3 ef	92.6 a	9.8 ab	9.5 abc
Untreated	-	71.0 bc	77.8 bcde	8.2 cd	9.6 ab

* Not an IR-4 Experiment: F&N Tests Vol 57: OT05. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Fisher's Protected LSD.
[y] All fungicides were applied as tuber soaks unless otherwise indicated.
[z] Tuber rot severity was measured using a 1-5 rating scale where 1 = 0%, 2 = 1-10%, 3 = 11-25%, 4 = 26-50%, and 5 = 51-100% internal discoloration.

In 2011, Palmateer conducted a greenhouse trial to test the efficacy of several fungicides for control of stem rot caused by *F. solani* (isolate # 0110111067) on *Dracaena deremensis* (Table 21). Disease inoculation occurred after the first application, with the exception of Acibenzolar where inoculation occurred after the second application. Disease ratings were obtained weekly from 9/21 to 12/19, and plant marketability rating obtained with the help of a local grower on 12/19. Disease severity was moderate to severe throughout the trial. Disease levels for all fungicide treatments were statistically lower than the inoculated control. Though not statistically different from the other fungicide treatments, disease severity (stem rot) ratings for Heritage and 3336 were lowest and 100% of the canes treated with these products were in marketable condition. Also, disease severity from BW 240, CG100, Medallion, Palladium, and the higher rates of Tourney and Trinity were comparable to that from the non-inoculated check. No phytotoxicity was observed for any treatment.

In 2002, Kirk conducted a field trial to determine efficacy of BAS 500, Bravo Zn, Gem and Quadris for control of root rot caused by *Fusarium solani* f. sp. *phaseoli* on snap bean (*Phaseolus vulgaris*). All plots were inoculated and in-furrow applications of fungicides were made over the seed at planting. No treatments were significantly different from each other as measured by root rot index at the first harvest (32 DAP) but at the second harvest (72 DAP) all treatments had a significantly lower root rot index value than the untreated control (Table 22). No treatments were significantly different from each other in plant emergence and marketable yield. No phytotoxicity was observed from any treatment.

Table 21. Efficacy on Stem Root Rot Caused by *Fusarium solani* on *Dracaena deremensis* 'Janet Craig', Palmateer FL, 2011.

Treatment	Rate Per 100 Gal	Application Method	Applic. Dates[y]	Applic. Interval	% Disease Severity[x]	Plant Marketability[z]
3336 F (thiophanate-methyl)	12 fl oz	Sprench	1, 4	21 Days	5 d	5
Acibenzolar-s-methyl	0.125	Drench	1, 4	21 Days	37 b	2
	0.25 oz	Drench	1, 4	21 Days	37 b	2
BW240 WP (*Trichoderma harziamum & T. virens)*	6 oz	Sprench	2, 4	14 Days	12 cd	4
CG100 (organic acid)	0.6 pints	Sprench	1, 3, 5, 6	14 Days	25 bc	3
Compass 50WDG (trifloxystrobin)	2 oz	Sprench	1, 3, 5, 6	14 Days	36 b	2
Heritage 50WG (azoxystrobin)	4 oz	Sprench	1, 5	28 Days	3 d	5
Medallion (fludioxonil)	2 oz	Sprench	1, 4	21 Days	23 bc	3
Palladium 62.5WG (cyprodinil+fludioxonil)	4 oz	Sprench	1, 3, 5, 6	14 Days	17 cd	4
Tourney 50 WDG (metconazole)	1 oz	Sprench	1, 3, 5, 6	14 Days	18 cd	4
	2 oz	Sprench	1, 3, 5, 6	14 Days	28 bc	3
Trinity 2 SC (triticonazole)	6 oz	Sprench	1, 3, 5, 6	14 Days	18 cd	4
	8 oz	Sprench	1, 3, 5, 6	14 Days	26 bc	3
Untreated non-inoculated	-	-	-	-	13 cd	4
Untreated inoculated	-	-	-	-	69 a	0

[x] Means followed by the same letter do not differ significantly based on based on Student Newman Keuls Test, (P=0.05).
[y] Dates: 1 = 9/1/11, 2 = 9/6/11, 3 = 9/15/11, 4 = 9/20/11, 5 = 9/29/11, 6 = 10/13/11.
[z] Rating of 0-5 where 0= not marketable, 5 = best marketability.

Table 22. * Efficacy on Fusarium Root Rot (Fusarium solani f. sp. phaseoli) on Snap Bean (Phaseolus vulgaris) 'Hi-Style', Kirk, MI, 2002.

Treatment[y]	Rate Per 1000 ft	% Emergence[x]	Root Rot Index[y]		Marketable Yield (Lb/A)
			35 DAT	72 DAT	
BAS 500 2.09EC (pyraclostrobin)	0.77 pt	98.8 a	13.8 a	48.8 bcde	1104 a
Bravo ZN 6SC (chlorothalonil)	1.5 pt	96.3 a	21.3 a	55.0 bc	981 a
Gem 4EC (trifloxystrobin)	0.8 pt	96.3 a	16.9 a	52.5 bcde	1023 a
Quadris 2SC (azoxystrobin)	0.8 pt	98.8 a	16.9 a	51.3 bcde	1056 a
Untreated inoculated	-	96.9 a	30.0 a	78.8 a	1008 a

* Not an IR-4 Experiment: F&N Tests Vol 58: ST007. Not all products tested included in table.
[x] Means followed by same letter do not differ significantly based on Tukey Multiple Comparison (P = 0.05).
[y] Root rot index calculated by counting the number of roots from a sample of 10 plants falling onto class 0 = no visible root rot; 1 = 1 - 10% girdling of tap root; 2 = 11 - 20% girdling of tap root; 3 = 21 - 50% girdling of tap root; 4 = 51 - 100% girdling of tap root. The number in each class is multiplied by the class number and summed. The sum is multiplied by a constant to express as a percentage. Indices of 0 - 50 cover the range 0 - 20% girdling; 51 - 75 cover the range 21 - 50% girdling and > 75 cover the range 50 - 100% girdling..

Efficacy Summary by Product/Active Ingredient

A brief efficacy summary for select products is given below, with a reminder that there are very limited data available to draw definitive conclusions for each product/pest species. Products were selected based on interest in these products for testing in 2010 and 2011 Fusarium efficacy projects.

Acibenzolar. In greenhouse trials, Acibenzolar applied as drench provided good efficacy against Fusarium wilt (*F. oxysporum*) on lisianthus, promising efficacy against Fusarium root rot (*F. oxysporum*) on larkspur, and mediocre efficacy on stem root rot (*F. solani*) on *Dracaena deremensis*. On Douglas fir, drench or a combination of seed soak and drench applications provided no efficacy against damping-off and root rot (*Fusarium communi)*. On vegetables, Actigard applied as drench provided poor to excellent efficacy against *Fusarium oxysporum* f. sp. *niveum* on watermelon in 5 greenhouse trials. In 4 field trials, Actigard provided good control when applied as drench to the soil immediately after transplanting, but variable control when applied through drip irrigation.

Azoxystrobin. Heritage applied as drench provided excellent efficacy against Fusarium crown and stem rot (*F. avenaceum*) on lisianthus, and on stem root rot (*F. solani*) on *Dracaena deremensis* in 2 greenhouse trials; however efficacy against severe Fusarium wilt (*F. oxysporum*) pressure was poor in two other trials. A trial on Douglas fir showed drench application providing no efficacy against damping-off and root rot (*Fusarium communi)*. Used as a tuber soak, it did not significantly reduce disease severity of Fusarium tuber rot (*F. solani*) on caladium in one field trial. Quadris applied as drench provided good to excellent control of *Fusarium oxysporum* f. sp. *niveum* on watermelon in three greenhouse trials; however it did not significantly reduce disease incidence in 2 field trials.

Boscalid+Pyraclostrobin. In a greenhouse trial, Pageant applied as drench provided mediocre efficacy against Fusarium root rot (*F. oxysporum*) on larkspur. It provided and promising and good efficacy against damping-off and root rot (*Fusarium communi)* applied as drench, and no efficacy as foliar, in 2 trials on Douglas fir.

Cyprodinil+Fludioxonil. In greenhouse trials, Palladium applied as drench provided good efficacy against stem root rot (*F. solani*) on *Dracaena deremensis*, mediocre efficacy against Fusarium wilt (*F. oxysporum*) on lisianthus, and no efficacy against damping-off and root rot (*Fusarium communi)* on Douglas fir.

Fludioxonil. Medallion applied as drench provided excellent efficacy against severe Fusarium wilt (*F. oxysporum*) pressure on lisianthus in two greenhouse trials; however, efficacy against Fusarium crown and stem rot (*F. avenaceum*) was poor in another trial. Promising efficacy on stem root rot (*F. solani*) was obtained in *Dracaena deremensis*. On larkspur, it provided good efficacy against Fusarium root rot (*F. oxysporum*), but no efficacy against damping-off and root rot (*Fusarium communi*) on Douglas fir in 3 trials. Cannonball applied as drench provided no to poor efficacy against *Fusarium oxysporum* f. sp. *niveum* on watermelon in 5 greenhouse trials.

Fludioxonil+Mefenoxam. Hurricane applied as drench provided excellent efficacy against a severe Fusarium wilt (*F. oxysporum*) pressure on lisianthus in a greenhouse trial. In 3 trials, it provided good efficacy against Fusarium root rot (*F. oxysporum*) on larkspur, but no efficacy against damping-off and root rot (*Fusarium communi*) on Douglas fir. When applied as a tuber soak or as a spray at planting, it significantly reduced the severity of Fusarium tuber rot rot (*F. solani*) on caladium in a field trial.

Metconazole. In greenhouse trials, Tourney applied as drench provided good to excellent efficacy against damping-off and root rot (*Fusarium communi)* on Douglas fir, good efficacy against Fusarium wilt (*F. oxysporum*) on lisianthus, and against stem root rot (*F. solani*) on *Dracaena deremensis*, but poor efficacy against Fusarium root rot (*F. oxysporum*) on larkspur. V-10116 or Metconazole applied as drench provided good to excellent control of *Fusarium oxysporum* f. sp. *niveum* on watermelon in 3 greenhouse trials; however poor efficacy was observed in 2 field trials.

Organic Acid. In greenhouse trials, CG100 applied as drench provided promising efficacy against stem root rot (*F. solani*) on *Dracaena deremensis*, poor efficacy against Fusarium root rot (*F. oxysporum*) on larkspur and against Fusarium wilt (*F. oxysporum*) on lisianthus, and no to poor efficacy against damping-off and root rot (*Fusarium communi)* on Douglas fir.

Prothioconazole. Proline applied as drench provided good to excellentefficacy against *Fusarium oxysporum* f. sp. *niveum* on watermelon in 3 greenhouse trials. It also provided good control in 4 field trials either applied as drench to the soil immediately after transplanting or through drip irrigation.

Pyraclostrobin. In a greenhouse trial, Insignia provided no to poor efficacy against damping-off and root rot (Fusarium communi) on Douglas fir. Cabrio applied as drench provided good efficacy against *Fusarium oxysporum* f. sp. *niveum* on watermelon in one trial but no efficacy in 2 other greenhouse trials. BAS 500 applied in-furrow significantly reduced Fusarium root rot caused by *Fusarium solani* f. sp. *phaseoli* on snap bean in one field trial.

SP2169. In greenhouse trials, SP2169 provided good efficacy against Fusarium wilt (Fusarium oxysporum) on lisianthus but no efficacy against damping-off and root rot (F. communi) on Douglas fir.

Thiophanate methyl. In greenhouse trials, 3336 applied as drench provided excellent efficacy against stem root rot (*F. solani*) on *Dracaena deremensis*, and good efficacy against damping-off and root rot (*Fusarium communi)* on Douglas fir and against Fusarium root rot (*F. oxysporum*) on larkspur. It provided poor efficacy against Fusarium crown and stem rot (*F. avenaceum*) and poor to mediocre efficacy against Fusarium wilt (*F. oxysporum*) on lisianthus in 3 greenhouse trials. Used as a tuber soak, it did not significantly reduce disease severity of Fusarium tuber rot (*F. solani*) on caladium in one field trial. On vegetables, Topsin applied as drench provided excellent efficacy against *Fusarium oxysporum* f. sp. *niveum* on watermelon in 4 of 5 greenhouse trials. In 4 field trials, Topsin provided good control when applied as drench to the soil immediately after transplanting, but variable control when applied through drip irrigation.

Trichoderma harzianum & T. virens. In greenhouse trials, BW240 applied as drench provided good efficacy against stem root rot (*F. solani*) on *Dracaena deremensis*, poor efficacy against Fusarium root rot (*F. oxysporum*) on larkspur, and no efficacy against damping-off and root rot (*Fusarium communi)* on Douglas fir, and against Fusarium wilt (*F. oxysporum*) on lisianthus.

Trifloxystrobin. In greenhouse trials, Compass applied as drench provided mediocre efficacy on stem root rot (*F. solani*) on *Dracaena deremensis*, no and promising activity against damping-off and root rot (*Fusarium communi*) on Douglas fir, and poor efficacy against a severe Fusarium wilt (*F. oxysporum*) pressure on lisianthus. Used as a tuber soak, it did not significantly reduce disease severity of Fusarium tuber rot (*F. solani*) on caladium in one field trial. Gem applied in-furrow significantly reduced Fusarium root rot caused by *Fusarium solani* f. sp. *phaseoli* on snap bean in one field trial.

Triflumizole. Terraguard applied as drench provided excellent efficacy against a severe Fusarium wilt (*F. oxysporum*) pressure on lisianthus in a greenhouse trial.

Triticonazole. In greenhouse trials, Trinity applied as drench provided good efficacy against stem root rot (*F. solani*) on *Dracaena deremensis*, but no and promising efficacy against damping-off and root rot

(*Fusarium communi)* on Douglas fir. Efficacy was promising against Fusarium wilt (*F. oxysporum*) on lisianthus, but poor against Fusarium root rot (*F. oxysporum*) on larkspur in other trials. This active ingredient applied as drench provided good control of *Fusarium oxysporum* f. sp. *niveum* on watermelon in one greenhouse trial but no control in 2 other trials.

Phytotoxicity

No phytotoxicity was observed with the products listed above with the exception of acibenzolar on watermelon (stunting, leaf yellowing) and metconazole on watermelon (stunting, dark green leaves) in some trials. Significant stunting was also observed with metconazole on lisianthus and SP2169 on Douglas fir.

Table 23. Summary of product efficacy by pathogen and crop.

Note: Table entries are sorted by product, pathogen Latin name, and then by crop Latin name. Only those IR-4 trials received by 5/15/2012 are included in the table below.

PR#	Product (Active Ingredients)	Target	Crop	Production Site	Researcher	Trial Year	Application Type	Results	File Name
30475	3336 F (Thiophanate-methyl)	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Drench	Excellent control at 4 lb per 100 gal applied once; almost comparable to non-inoculated check; very minor, transient leaf phytotoxicity.	20110427a.pdf
29745	Acibenzolar-S-methyl (Acibenzolar-S-methyl)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	No control of a high disease pressure with 0.125 and 0.25 oz per 100 gal.	20110328e.pdf
30468	Acibenzolar-S-methyl (Acibenzolar-S-methyl)	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Drench	Significantly reduced leaf and root necrosis at 0.25 oz per 100 gal applied once; inferior to Medallion; very minor, transient leaf phytotoxicity.	20110427a.pdf
30191	Acibenzolar-S-methyl (Acibenzolar-S-methyl)	Fusarium sp. (Fusarium sp.)	Lisanthus (Lisianthus sp.) Eustoma grandiflora	Greenhouse	Chase	2011	Drench	Significantly reduced F. oxysporum severity with 0.125 and 0.25 oz per 100 gal applied every 21 days; comparable to non-inoculated check.	20110713a.pdf
29744	BW240 (BW240)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	No control of a high disease pressure with 6 oz per 100 gal.	20110328e.pdf
30469	BW240 (BW240)	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Root dip, Drench	Significantly reduced leaf and root necrosis at 6, then 3 oz per 100 gal; inferior to Medallion; very minor, transient leaf phytotoxicity.	20110427a.pdf
30192	BW240 (BW240)	Fusarium sp. (Fusarium sp.)	Lisanthus (Lisianthus sp.) Eustoma grandiflora	Greenhouse	Chase	2011	Drench	Did not significantly reduce F. oxysporum severity with 6 oz, then 3 oz per 100 gal.	20110713a.pdf
29747	CG100 (CG100 (organic acid))	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	No control of a high disease pressure with 0.6 pt per 100 gal.	20110328e.pdf

PR#	Product (Active Ingredients)	Target	Crop	Production Site	Researcher	Trial Year	Application Type	Results	File Name
30470	CG100 (CG100 (organic acid))	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Drench	Significantly reduced leaf and root necrosis at 0.8 pt per 100 gal applied once; inferior to Medallion; very minor, transient leaf phytotoxicity.	20110427a.pdf
30193	CG100 (CG100 (organic acid))	Fusarium sp. (Fusarium sp.)	Lisanthus (Lisianthus sp.) Eustoma grandiflora	Greenhouse	Chase	2011	Drench	Did not significantly reduce F. oxysporum severity with 0.6 pt per 100 gal applied every 14 days.	20110713a.pdf
30000	Compass 0 50WDG (Trifloxystrobin)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	Poor control of a high disease pressure with 0.5 oz per 100 gal.	20110328e.pdf
29753	Heritage (Azoxystrobin)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Directed spray	No control of a high disease pressure with 4 oz per 100 gal.	20110328e.pdf
29753	Heritage (Azoxystrobin)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	Poor control of a high disease pressure with 1.8 oz per 100 gal.	20110328e.pdf
30001	Hurricane (fludioxonil + mefonaxam)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	No control of a high disease pressure with 0.75 oz per 100 gal.	20110328e.pdf
29755	Medallion (Fludioxonil)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	No control of a high disease pressure with 2 oz per 100 gal.	20110328e.pdf
30474	Medallion (Fludioxonil)	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Drench	Excellent control at 2 fl oz per 100 gal applied once; almost comparable to non-inoculated check; very minor, transient leaf phytotoxicity.	20110427a.pdf
29749	Pageant 38WG (Boscalid + Pyraclostrobin)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	Poor control of a high disease pressure with 12 oz per 100 gal.	20110328e.pdf

PR#	Product (Active Ingredients)	Target	Crop	Production Site	Researcher	Trial Year	Application Type	Results	File Name
30476	Pageant 38WG (Boscalid + Pyraclostrobin)	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Drench	Significantly reduced leaf and root necrosis at 12 oz per 100 gal applied twice; inferior to Medallion; very minor, transient leaf phytotoxicity.	20110427a.pdf
29750	Palladium (Cyprodinil + fludioxanil)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	No control of a high disease pressure with 6 oz per 100 gal.	20110328e.pdf
30194	Palladium (Cyprodinil + fludioxanil)	Fusarium sp. (Fusarium sp.)	Lisanthus (Lisianthus sp.) Eustoma grandiflora	Greenhouse	Chase	2011	Drench	Did not significantly reduce F. oxysporum severity with 6 oz per 100 gal applied every 14 days.	20110713a.pdf
30195	SP2169 (SP2169)	Fusarium sp. (Fusarium sp.)	Lisanthus (Lisianthus sp.) Eustoma grandiflora	Greenhouse	Chase	2011	Drench	Significantly reduced F. oxysporum severity with 12.3 oz per 100 gal applied every 14 days; comparable to non-inoculated check.	20110713a.pdf
29751	Tourney 50WDG (Metconazole)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	Excellent control of a high disease pressure with 1 and 2 oz per 100 gal; best treatment.	20110328e.pdf
30471	Tourney 50WDG (Metconazole)	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Drench	Did not significantly reduce leaf and root necrosis at 2 fl oz per 100 gal applied once; very minor, transient leaf phytotoxicity.	20110427a.pdf
30196	Tourney 50WDG (Metconazole)	Fusarium sp. (Fusarium sp.)	Lisanthus (Lisianthus sp.) Eustoma grandiflora	Greenhouse	Chase	2011	Drench	Did not significantly reduce F. oxysporum severity with 1 and 2 oz per 100 gal applied every 14 days; severe stunting.	20110713a.pdf
29752	Trinity 2SC (Triticonazole)	Fusarium commune (Fusarium commune)	Fir, Douglas (Pseudotsuga menziesii)	Seedbed	Chastagner	2010	Drench	Poor control of a high disease pressure with 6 and 8 fl oz per 100 gal.	20110328e.pdf
30472	Trinity 2SC (Triticonazole)	Fusarium oxysporum (Fusarium oxysporum)	Larkspur (Delphinium sp.)	Greenhouse	Kirk	2010	Drench	Significantly reduced leaf and root necrosis at 11.8 oz per 100 gal applied as curative twice; inferior to Medallion; very minor, transient leaf phytotoxicity.	20110427a.pdf

PR#	Product (Active Ingredients)	Target	Crop	Production Site	Researcher	Trial Year	Application Type	Results	File Name
30197	Trinity 2SC (Triticonazole)	Fusarium sp. (Fusarium sp.)	Lisanthus (Lisianthus sp.) Eustoma grandiflora	Greenhouse	Chase	2011	Drench	Did not significantly reduce F. oxysporum severity with 6 and 8 oz per 100 gal applied every 14 days; significant stunting at the higher rate.	20110713a.pdf

Appendix 1: Contributing Researchers

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Dr. Aaron Palmateer	University of Florida Tropical Research & Education Center 18905 SW 280 Street Homestead, FL 33031

Appendix 2: Submitted Data Reports

The IR-4 reports in this Appendix cover multiple PR numbers and are arranged alphabetically by the researchers' last names. Only those reports received by 5/15/2012 are included.

These reports can also be found at www.rutgers.ir4.edu by searching under the Fusarium Efficacy project.

FRAC
FUNGICIDE RESISTANCE ACTION COMMITTEE

FRAC recommendations for fungicide mixtures designed to delay resistance evolution.

INTRODUCTION

Designing a disease control programme to include effective measures to combat the development of resistance to the fungicide(s) used is a complex subject. However, within all resistance management programmes there are certain common practices relating to how the fungicide(s) is used. These practices frequently involve advice on appropriate fungicide dose rates, limitations on how often the fungicide should be used in a spray programme and programmes designed around the use of two or more fungicides which have different modes of action in controlling the same pathogen.

When considering how best to use fungicides with different modes of action in a resistance management programme there are two basic alternatives: the fungicides can be applied in alternation or they can be applied together in a mixture. Alternation programmes can also include mixtures. Such programmes can include simple alternation where fungicide A is applied followed by fungicide B, then A, then B etc or products can be arranged in different sequences to include, for instance, a block of A sprays followed by a single spray or a block of B sprays. It may even be appropriate to include a third fungicide in the sequence. Where blocks are used, it is common practice to limit the number of applications of a fungicide in a block. For mixtures, the two or more active ingredients are applied together. The mixture may have been designed and produced by the manufacturer as a ‘co-formulation’ in which the active ingredients are combined in the same formulation or the mixture may be prepared by the user by physically mixing the mixture components in the spray tank; the latter are commonly referred to as tank mixes. In certain cases the manufacturer may provide the components of a tank mixture as individual containers in a common product package; these are usually referred to as ‘twin packs’ or ‘combi-packs’. For both alternation and mixture programmes, considerations based on dose rates and limitations on the number of applications used for a specific fungicide still apply.

There is no clear evidence to suggest that either strategy, alternation or mixtures, is the better for resistance management and the choice of which to adopt must be made according to the pathogen to be controlled, the crop variety to be protected, and the availability of suitable fungicides. In crops with a high number of applications per cropping cycle and in which only a limited number of different modes of action are available, alternation rather than combination of fungicides may be a more effective way to reduce selection pressure in commercial spray programs.

The advantage of a co-formulation is that the manufacturer has already selected the ingredients, the precise ratio and the dose rates best suited for the job. Tank mixes may provide some extra flexibility but need more expert knowledge to design the ideal combination of ingredients and the dose rates within the regulatory frame work.
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Whatever strategy is adopted, alternations or mixtures, the objective should be to minimise the risk of resistance developing to any of the fungicides used in the programme.

The purpose of this document is to give general advice on the composition of fungicide mixtures designed to delay the onset of or manage resistance in plant pathogen populations, with special reference to the risks of resistance development.

WHY USE MIXTURES?

Fungicides are often combined as co-formulations or tank mixes for several reasons. These can be conveniently divided into three categories:

1. Improved disease control. Mixtures can be used to broaden the spectrum of disease control of a product, to combine the specific characteristics of the components of the mixture to increase the effectiveness of the product (for example curative plus protectant activity, or systemic plus non-systemic), or to take advantage of additive or synergistic interactions leading to more potent disease control and greater flexibility. Even if the mixture does not in itself provide resistance management such mixtures can be used successfully within disease control programmes that require such management providing suitable strategies are included.
2. Disease control security when resistance is present. Resistance to fungicides can develop rapidly in plant pathogen populations and it is possible that the fungicide user may not be aware of the resistance status of the population to be controlled. It could be argued that the use of a mixture in these cases is better than an alternation strategy as the application programme would be more robust in terms of disease control.
3. Resistance management. When used for resistance management it is necessary for at least two components of the mixture to have activity against the field populations of the target pathogen when used alone. In addition the activity profiles of these components should be combined in such a way that effective disease management is achieved.

A key requirement for any mixture product applied to manage resistance is that the components of the mixture must not be cross-resistant and the dose rates of each component used in the mixture should provide sufficient control of sensitive isolates when used alone. The most common mixtures consist of single-site fungicides (with moderate or high resistance risk) mixed with multisite fungicides (with low resistance risk) either as tank mixes or as a co-formulation. However, since more regulatory restrictions are being imposed on multi-site fungicides and highly effective single site fungicides with different modes of action are available in most crops, mixtures between single-site fungicides are appearing in the market and it is clear that more care regarding the resistance status in pathogen populations needs to be taken when recommending them.

DEFINITION OF RISK

Care must be taken in how to interpret the term ‘risk’. “Resistance risk” is defined as a combination of the inherent risk determined by the chemical class or compound concerned, its interaction with the target sites of the pathogen, the pathogen itself and several risk modifying factors (see FRAC Monograph 2).

The major modifying factor is called the ‘Agronomic Risk’ and is determined by the geographical area in which the crop is grown, the crop variety, the expected severity of disease in that area and the disease control practices used, for example, application number and timing. The disease control practices are particularly important because these factors can be modified by growers and advisors and are also influenced by precautionary statements on fungicide labels.

‘Resistance risk’ is thus determined by how a particular fungicide is being used to control a particular pathogen under certain conditions. For convenience, ‘Resistance risk’ is divided into three categories: Low, High and Medium. The ‘Low’ and ‘High’ risk categories tend to be easily determined. The ‘Medium’ category is more difficult. In some cases, e.g. the multi-site compounds such as the dithiocarbamates, the term ‘low risk’ is attached to the chemical irrespective of which pathogen it is used to control. This is because the nature of the chemistry and its mode of action precludes resistance development and the biology of the target pathogen is not important. However, in the majority of cases, particularly with modern single site inhibitors, the classification of risk is based on a consideration of all the above factors. It is thus quite possible that one fungicide – pathogen combination will be classified as ‘high risk`, while another combination of the same fungicide with a different pathogen or in locations with generally low disease pressure could be classified as ‘low risk’. By utilising all available mitigation measures (agronomic risk factors), the resistance risk of a particular combination may be reduced.

It is important to realise that for new chemistry (new mode of action), the risk associated with the chemistry will not be known and decisions may have to be made based on experiences with the target pathogens. In such circumstances a precautionary approach may be wise.

Definition of low risk

To qualify as a ‘low risk’ use, the fungicide or the fungicide-pathogen use combination must have a confirmed history of a lack of or very rare instance of resistance development. As indicated above, several low risk fungicides have a multi-site mode of action (e.g. dithiocarbamates), but this is not a general requirement.

Definition of high risk

A fungicide – pathogen combination can be classed as ‘high risk’ based on the expectation of resistance developing quickly if no resistance management is practiced or the actual development of resistance during product use.

Criteria for a high resistance risk include:

- Resistance based mainly on single target site mutations, highly conserved within all affected pathogens, monogenic resistance (known or suspected): e.g. QoIs: G143A; MBCs: E198A/G/K, F200Y; Dicarboximides: I365S. Such mutations are usually associated with high levels of resistance.
- Resistant isolates are still virulent after several generations without selection pressure and without significant fitness costs.
- Appearance of resistance in field populations a few years (2-5) after product launch.
- Rapid increase of resistance frequency over time and area.
- Significant decrease of disease control under commercial field conditions when the fungicide is used as a solo product and/or at low rates according to the product label. This may include complaints of insufficient disease control.
- Product failure associated with confirmed presence of resistant isolates in field populations of the pathogen.

Phenylamide, QoI, MBC, and Dicarboximides are considered as high risk fungicides and a ‘high risk’ category is justified for most pathogens. All are single-site inhibitors.

Definition of medium risk
The normally accepted definition of ‘medium risk’ is applied to situations where the fungicide or its intended use cannot be categorised as presenting a low risk, yet the risk posed is not sufficient that resistance would be expected to develop to the solo product as rapidly as to an accepted high risk situation. Criteria can be similar to those described in the definition for “high risk” but are usually less severe, e.g. mutants can be created but confer reduced fitness, resistance is polygenic, i.e. significant sensitivity shifts in field populations are only observed with stepwise selection of multiple gene mutations; or inheritance of resistance is recessive. Modifying factors like limited spread of resistance can apply. At appropriate dosages, the fungicides will continue to provide good control of the pathogens.

Many single-site fungicides can be considered to bear a medium resistance risk, e.g. DMIs (polygenic resistance, good field performance at appropriate rate), APs (limited spread of resistance), CAA fungicides (recessive inheritance of resistance, limited spread of resistance).

MIXTURE OPTIONS AND THEIR RISK POTENTIAL

There are various combinations of individual fungicides that can be placed together in a ‘mixture’. When discussing fungicide mixtures designed to manage resistance, it is convenient to consider the mixture to be made up of (usually two) components; each being a particular fungicide targeted at the same pathogen. Each component will present its own ‘Resistance risk’. It is thus necessary to consider how different components with the same or different risk levels can be used together in a mixture and whether a particular mixture is a valid resistance management option in the presence or absence of resistance. In all cases, the relative component dose rates used in the mixture must be carefully balanced based on the individual properties of each mixing partner (e.g. lasting effect, dose response curve, etc.) to ensure that, for instance, the concentration of one component in or on the plant does not decrease below an acceptable level much faster than the other component and so leave an ‘at risk’ component without any protection.

It must also be remembered that no mixture is likely to completely prevent the eventual development of resistance to a mixture component. Used wisely, however, mixtures can significantly delay the process and lead to a longer fungicide life.

The various options are considered below.

1. **Mixing two low risk fungicides.**
This poses no change of risk to the use of either component used solo.

2. Mixing a high or medium risk single site fungicide with a low risk multisite.

No resistance to high or medium risk component present: This has been, and still is, a firm favourite for managing resistance development to the high or medium risk fungicide. In many cases, reduced rates (compared to recommended solo use rates) of both the high or medium risk and the low risk components are used. The critical requirement for such a mixture is that the dose rates used for the individual components must be capable of providing good disease control if used solo. This is governed by the dose response curve for the individual component but usually needs dose rates of no less than 50% of the recommended rate of the solo product. For some components and particularly for the multisite component, dose rates of 75% of the solo rate may be more appropriate in order to achieve long lasting protection for the at risk component.

Resistance to high or medium risk component present: In situations where resistance to the high or medium risk fungicide in the mixture is already present, the use of a mixture with a low risk component will ensure disease management and can slow down the build up in frequency of resistant isolates. It is often recommended to impose limitations on spray numbers in a season and placement of such a mixture in the spray programme; these are determined according to the crop – pathogen system being considered.

There are notable cases where such mixtures can be expected to be particularly valuable:

1. In cases where the frequency of isolates resistant to the high or medium risk fungicide in field populations is low, mixtures with a low risk fungicide have been shown to delay the build up of resistance.
2. In situations where the fungal population resistant to the high or medium risk fungicide declines between seasons such that it is at a minimum at the start of the spray cycle. In these cases, use of the mixture may provide better control of the pathogen in early season than either mixture product alone. However, experience usually shows that resistance rapidly builds up to the at risk component with each subsequent spray application. The number of spray applications must thus be limited depending on the host-pathogen system.
3. In situations where it is proven that the current impact of resistance to the high or medium risk component is low in terms of disease control i.e. resistance can be detected but it is not causing great harm and the biological profile of the

target pathogen indicates that resistance development would be a slow process. Such situations could occur with control of, for example:

a. monocyclic diseases.
b. diseases of infrequent occurrence.
c. pathogens where the rate of development of resistance has been shown to be restricted, for instance where genetic studies show that the inheritance of resistance is by recessive genes, as for the CAA fungicides and *Plasmopara viticola*.

Mixing a low risk fungicide with a high or medium risk component could thus delay further the development of resistance. It would, however, be wise to limit the number of applications in such circumstances and the situation would require careful monitoring.

3. **Mixing single-site (high risk or medium risk) fungicides with different modes of action:**

No resistance present to either component

If no resistance has yet been found to either mixture component the use of a mixture can delay the development of resistance to the components. The extent of the delay cannot be predicted but should allow both components to remain effective for longer than if either had been used as a solo product. Reductions in dose rate of the mixture components to below an effective rate should be avoided. The number of applications needs to be restricted (i.e. a disease control programme should not be based on continuous and sole use of the mixture) but depending upon the pathogen it may be possible to recommend more applications of the mixture product than either component used solo. With such combinations disease management can be improved and thereby, resistance management in general is strengthened. Such cases must be considered on their individual merits.

Resistance present to one or both components

If resistance in field populations against one high or medium risk component has already evolved to an extent that this component used as a solo product does not provide sufficient disease control, the addition of a second fungicide bearing a moderate or a high resistance risk may place undue selection pressure upon the second mixture component which, if a recognised high risk one, could favour rapid development of resistance just as if it was being used as a solo product.

For these reasons two high risk components, a high plus a medium risk component or two medium risk components should not be recommended as a strategy to delay resistance evolution where resistance already occurs in current pathogen populations to either one or both component such that inadequate disease control would result if that component was used solo.

Examples would be a mixture between QoI and Phenylamide fungicides in *Plasmopara viticola* or between QoI and MBC fungicides in *Venturia inaequalis*. Note that such mixtures may still have a valid use for spectrum extension purposes. In this case other resistance management techniques should be included in the disease control programme e.g. alternating with a third component, a 3-way mixture combination etc.

4. Mixtures between low risk single site fungicides and a moderate or high risk component.

In these circumstances, the same considerations apply as if the low risk component was a multisite fungicide, although during the time of early product introduction it would be wise to monitor the performance of both components and not assume that resistance to the single site, low risk component could not happen. An example of a single site low risk category could be the use of DMI fungicides to control *Puccinia* spp. on cereals. Despite over 30 years of exposure, no resistance has occurred.

SPECIAL NOTE: Mixture products used to control two or more pathogens on the same crop.

Where the same mixture product is used to control two or more pathogens on the same crop and there are different resistance risks associated with each pathogen, the decision making process of how best to use the product is clearly more complex. Alongside a consideration of the various risk factors associated with the exposure of the individual pathogens to the mixture product, a consideration of the economic impact of the selected pattern of use of the mixture product becomes important. In some cases it has to be accepted that, for economic reasons, the priority will be to provide effective control of the most damaging pathogen, even if this means exposing a lower threat pathogen to a higher risk of resistance development. Such situations can only be analysed on a case by case basis.

CONCLUSION

Resistance Management is an important and crucial objective of any disease control programme and the incorporation of mixture products into the programme is an excellent means of achieving this objective. Mixtures can be designed and used to delay the onset of resistance to any fungicide or, if resistance has appeared, to manage the effects of such resistance. The result is to prolong the active life of a particular fungicide to the benefit of the grower and producer. This document has given practical general advice on how this can be achieved.

FURTHER INFORMATION

Further information on resistance risk and resistance management can be found on the FRAC webpage at www.frac.info

Management of Ascochyta blight of chickpea

Last update:
March 2, 2012

Causal pathogen: *Ascochyta rabiei*

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- The pathogen is introduced through infected seed and via airborne inoculum. Note that infected seeds are often symptomless.
- Timing of disease onset depends on inoculum arrival, but disease symptoms often appear at early bloom.
- Infections result in tan to brown lesions on leaves, stems, and pods.
- Within lesions, concentric rings of small gray to brown specks can generally be found. Each of these specks is a pycnidium, a tiny flask-shaped fruiting structure containing thousands of spores of the causal pathogen.
- Diseased pods often fail to produce seed or may produce shriveled, discolored seeds.
- Ascochyta blight can reach epidemic levels very quickly.
- Even low levels of foliar disease during the bloom period can lead to high levels of pod infections during the pod-fill period. Because many infected pods do not set seed, management of pod infections is critical for preserving yield potential.
- Disease risk is always highest during periods of rainfall and/or heavy dews.

FOLIAR AND POD LESIONS:

STEM LESIONS:

Management of Ascochyta blight of chickpea

Causal pathogen: *Ascochyta rabiei*

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1. **Select a moderately resistant variety.**

- B-90 (also known as Amit) is a small-seeded Kabuli chickpea with moderate resistance to Ascochyta blight.
- CDC Frontier is a medium-seeded Kabuli chickpea with moderate resistance to Ascochyta blight.
- CDC Luna is a large-seeded Kabuli chickpea with fair resistance to Ascochyta blight.

2. **Use seed that has been tested for Ascochyta.**

- Ascochyta is seed-borne, and the disease is readily transmitted from infested seeds to seedlings.
- Diseased seeds are not always discolored. Make sure your seed has been tested for Ascochyta; the plant disease diagnostic labs at NDSU and MSU conduct this test. It is best to only use seed that tests completely negative for Ascochyta. Never use seed with Ascochyta incidence greater than 0.3%.

3. **Treat your seed with the fungicide thiabendazole (Mertect 340-F).**

- Treat your seed with thiabendazole even if your seed test indicates an incidence of Ascochyta infection of 0%. Seed testing is done on only a few seeds, and virtually no seed lot is completely free of Ascochyta-infected seeds.
- Other commonly used seed treatments (eg Apron Maxx) are not very effective against Ascochyta. Likewise, thiabendazole is not very effective against Phytophthora root rot and other seed and seedling diseases of chickpea. Treat with a mix of thiabendazole and other products if you need protection against seed and seedling diseases.

3. **Do not plant chickpeas in a field or adjacent to a field where chickpeas were grown the previous 3 years.**

- A minimum 3-year rotation out of chickpeas is recommended.
- This crop rotation recommendation should be extended to adjacent fields. Ascochyta will be readily transmitted from residues in an immediately adjacent field; planting chickpeas immediately adjacent to a field where chickpeas were recently grown will place your crop at high risk of disease.

4. **Use foliar fungicides.**

This disease can reach epidemic levels very quickly, and fungicide applications must be made in a timely manner.

- A preventative approach to managing this disease is generally recommended. If no disease has been detected 7 to 10 days before bloom initiation (if there have been frequent rain events and/or heavy dew) or at bloom initiation (if it is dry), a preventative application of chlorothalonil (Bravo WS, Echo 720, etc) is advised. Seven to ten days after applying chlorothalonil, applications of systemic fungicides (Proline, Endura, Priaxor, etc.) should begin on a 10 to 14 day schedule.
- If you prefer to start fungicide applications as soon as disease occurs, scout your fields very carefully. Beginning in the late vegetative stages (approx. 2 weeks prior to bloom initiation) walk in a zig-zag pattern through the field, stopping at multiple points to examine the bottom third of the canopy for Ascochyta lesions. As soon as trace levels of Ascochyta blight are found, applications of systemic fungicides should begin. Sequential applications should be made 10 to 14 days apart during the critical bloom and pod-fill period.
- Even if disease is at low levels at the end of bloom, a fungicide application may be warranted during the pod-fill stage. Even when foliar disease is at low levels, the incidence of pod infection can be quite high. When pods become infected, they often do not produce seeds.

5. **Guidelines for fungicide use on chickpeas.**

- **ROTATING FUNGICIDE CHEMISTRIES IS CRITICAL**.
  - Inadequate rotation of fungicide chemistries caused a loss of efficacy of QoI (strobilurin/FRAC 11) fungicides (Headline and Quadris).
- **ROTATE BETWEEN DMI** (FRAC 3) **AND CARBOXAMIDE** (FRAC 7) **FUNGICIDES**.
  - DMI FUNGICIDES: **Proline** (prothioconazole) is registered (5.0 and 5.7 fl oz/ac)
  - CARBOXAMIDE FUNGICIDES: **Endura** (boscalid) is registered (6.0 oz/ac); **Priaxor** (fluxapyroxad + pyraclostrobin) and **Vertisan** (penthiopyrad) should be registered for the 2012 growing season. Because pyraclostrobin is no longer effective against Ascochyta blight of chickpea, you can assume that disease control conferred by Priaxor is due to the carboxamide ingredient, fluxapyroxad.
- **CONSIDER TANK-MIXING DMI or CARBOXAMIDE FUNGICIDES WITH CHLOROTHALONIL** (Bravo WS, Echo 720, etc.), especially if the chickpea canopy is still open.
- **DO NOT USE STROBILURIN** (QoI/FRAC 11) **FUNGICIDES such as Headline and Quadris:** *Ascochyta rabiei* has developed resistance to these fungicides, and they no longer work.
- **ProPulse, a new product from Bayer that may be registered as early as 2012, should be used cautiously**. ProPulse is a premix of a DMI fungicide (prothioconazole, the active ingredient in Proline) and a carboxamide fungicide (fluopyram). If you apply ProPulse and then Priaxor, Endura, or Vertisan, you will not be rotating fungicide chemistries. Carboxamide (FRAC 7) chemistries are high-risk for the development of pathogen resistance, and you need to make sure that you do not make sequential (back-to-back) applications of carboxamide chemistries.

Fungicide usage for management of Ascochyta blight of chickpea

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CHOOSING A CARBOXAMIDE CHEMISTRY TO ROTATE WITH PROLINE:

1. Endura: *Endura (6 oz/ac) performed the same as Proline in one field trial and performed worse than Proline in two field trials.*

Treatment	CARRINGTON (2011) Disease Progress over Time (0 to 100)		MINOT (2011) Disease Progress over Time (0 to 100)	
Proline 5.0 fl oz/ac (A,B,C,D)	50	a	21	a
Endura 6.0 oz/ac (A,B,C,D)	55	ab	51	b
Endura 5.5 oz/ac (A,B,C,D)	55	ab	58	bc
Endura 5.0 oz/ac (A,B,C,D)	60	abc	48	b
Endura 4.5 oz/ac (A,B,C,D)	52	ab	53	bc
Endura 4.0 oz/ac (A,B,C,D)	64	bcd	54	bc
Endura 3.5 oz/ac (A,B,C,D)	59	abc	51	b
Endura 3.0 oz/ac (A,B,C,D)	61	abc	52	b
Endura 2.5 oz/ac (A,B,C,D)	64	bcd	54	bc
Endura 2.0 oz/ac (A,B,C,D)	68	cd	56	bc
Endura 1.5 oz/ac (A,B,C,D)	70	cd	Not tested	
Non-treated check	76	d	64	c
CV:	8.17		3.37	

Treatment	CARRINGTON (2009) Disease Severity Aug. 31 (percent)		Yield (lbs / acre)	
Proline 5.0 fl oz/ac (A,B,C)	16	a	2989	a
Endura 6.0 oz/ac (A,B,C)	56	b	114	b
Endura 5.5 oz/ac (A,B,C)	Not tested		Not tested	
Endura 5.0 oz/ac (A,B,C)	Not tested		Not tested	
Endura 4.5 oz/ac (A,B,C)	Not tested		Not tested	
Endura 4.0 oz/ac (A,B,C)	Not tested		Not tested	
Endura 3.5 oz/ac (A,B,C)	Not tested		Not tested	
Endura 3.0 oz/ac (A,B,C)	Not tested		Not tested	
Endura 2.5 oz/ac (A,B,C)	Not tested		Not tested	
Endura 2.0 oz/ac (A,B,C)	Not tested		Not tested	
Endura 1.5 oz/ac (A,B,C)	Not tested		Not tested	
Non-treated check	99	c	0	b
CV:	37.2		24.2	

CARRINGTON 2011:
Chickpea cultivar: CDC Xena
Planting date: May 25
Fungicide applications:
A = June 23, B = July 6, C = July 18, D = July 29

MINOT 2011:
Chickpea cultivar: CDC Xena
Planting date: May 19
Fungicide applications:
A = July 2, B = July 15, C = July 29, D = Aug. 12

CARRINGTON 2009:
Chickpea cultivar: Sierra
Planting date: May 22
Fungicide applications:
A = June 30, B = July 13, C = July 28

Within-column means followed by different letters are significantly different (*P* < 0.05)

2. Vertisan: *Vertisan (20 fl oz/ac) performed equivalently to Proline or a Proline-Endura rotation in both trials in which it was tested.*

Treatment	CARRINGTON (2011) Disease Severity July 13 (percent)		WILLISTON (2011) Disease Severity Aug. 6 (percent)		Diseased Pods Aug. 6 (percent)		Yield (lbs / acre)	
Proline 5.0 fl oz/ac (A,B,C)	14	a	Not tested		Not tested		Not tested	
Proline 5.0 oz/ac (A,C) / **Endura** 6 oz/ac (B)	19	a	3	a	30	a	945	a
Vertisan 20 fl oz/ac (A,B,C)	18	a	3	a	33	a	913	a
Non-treated check	77	b	40	b	90	b	381	b
CV:	15.43		15.02		24.86		21.74	

CARRINGTON 2011:
Cultivar: CDC Xena, **Planting date:** May 25
Fungicide applications:
A = June 23, B = July 6, C = July 18

WILLISTON 2011:
Cultivar: Dylan, **Planting date:** May 26
Fungicide applications:
A = June 28, B = July 7, C = July 21

Within-column means followed by different letters are significantly different (*P* < 0.05)

3. Priaxor: *Priaxor (4 and 6 fl oz/ac) provided much better disease control than Proline (5 fl oz/ac) in a field trial conducted in Carrington in 2011.* Priaxor is a premix of fluxapyroxad (FRAC 7) and pyraclostrobin (FRAC 11), disease control is conferred by fluxapyroxad.

Treatment	CARRINGTON (2011) Disease Severity July 14 (percent necrosis)		Disease Severity July 28 (percent necrosis)		Disease Severity Aug. 9 (percent necrosis)		Disease Severity Aug. 20 (percent necrosis)		Disease Progress over Time (0 to 100)	
Priaxor 6 fl oz/ac (A,B,C,D,E)	13	a	11	a	48	a	66	a	23	a
Priaxor 4 fl oz/ac (A,B,C,D,E)	21	a	26	a	65	a	78	a	33	ab
Confidential (A,B,C,D,E)	19	a	36	ab	95	b	100	b	43	abc
Proline 5 fl oz/ac (A,C,E) / **Endura** 6 oz/ac (B,D)	42	ab	64	abc	98	b	98	b	56	bcd
Proline 5 fl oz/ac (A,B,C,D,E)	56	abc	83	bcd	97	b	98	b	65	cde
Headline 6 fl oz/ac (A,B,C,D,E)	85	bcd	98	cd	100	b	100	b	77	de
Quadris 6.2 fl oz/ac (A,B,C,D,E)	85	cd	96	d	100	b	100	b	77	e
Non-treated check	90	d	99	d	100	b	100	b	79	e
CV:	28.07		21.98		10.40		5.72		14.09	

CARRINGTON 2011:
Cultivar: CDC Xena, **Planting date:** May 25
Fungicide applications:
A = June 23, B = July 6, C = July 18, D = July 29, E = Aug. 10

Within-column means followed by different letters are significantly different (*P* < 0.05)

YIELD DATA FOR THE 2011 TRIALS:
CARRINGTON and MINOT --The combination of (1) using a highly susceptible chickpea cultivar, (2) recurrent, torrential rains, and (3) inoculating the trials in Carrington led to severe levels of Ascochyta blight in the chickpea fungicide trials. Yields were zero or nearly zero in all treatments in Carrington and below 300 lbs/ac in all treatments in Minot.