US Environmental Protection Agency
Office of Pesticide Programs

Boscalid Reduced Risk Pesticide Application for Extension of Exclusive Use of Data Under FIFRA 3c(1)(f)(ii) - Part 1 of 2

August 2, 2007

BASF

The Chemical Company

Agricultural Products

August 2, 2007

U.S. Environmental Protection Agency
Document Processing Desk - **APPL**
Office of Pesticide Programs (7505C)
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460-0001

ATTENTION: Cynthia Giles-Parker – Branch Chief, Fungicide Branch

Dear Ms. Giles-Parker:

SUBJECT: Boscalid (EPA Reg. No. 7969-198) [Reduced Risk Pesticide]

REFERENCE: Application for Extension of Exclusive Use of Data under FIFRA Section 3c(1)(F)(ii).

This letter conveys an application by BASF Corporation for a 3-year Extension of Exclusive Use of Data for the active ingredient, Boscalid (EPA Reg. No. 7969-198) under the provisions in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Section 3c(1)(F)(ii), {As Amended Through P.L. 108–199, January 23, 2004]. The approval of this application by EPA will extend the exclusive use period of 10 years for the data used to register boscalid as a "reduced risk" pesticide from the current effective date of July 2013 to a new effective date of July 2016. The application for the Extension of Exclusive Use is based primarily on the registrations of Boscalid (EPA Reg. No. 7969-198), Pristine® fungicide (EPA Reg. No. 7969-199), and Endura® fungicide (EPA Reg. No. 7969-197). However, it is also intended to cover all the data supporting the registrations for the following products containing boscalid:

BAS 516 ST® seed treatment fungicide (EPA Reg. No. 7969-248)
Emerald® fungicide (EPA Reg. No. 7969-196)
Honor® fungicide (EPA Reg. No. 7969-255)

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

"The period of exclusive data use provided under clause (i) shall be extended 1 additional year for each 3 minor uses registered after August 3, 1996, 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;

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

The registration of a pesticide for a minor use on a crop grouping established by the Administrator shall be considered for purposes of this clause 1 minor use for each representative crop for which data are provided in the crop grouping".

This application for the 3-year Extension of Exclusive Use of Data for Boscalid is based primarily on **(III)** above that boscalid "**will play a significant part in managing pest resistance**" and to some extent on **(I)** above that "**there are insufficient efficacious alternative registered pesticides available for the use**" for some of the minor crops. Boscalid's unique mode of action against a broad spectrum of target pathogens provides a valuable resistance management tool to protect other fungicide classes that possess a single site mode of action, such as strobilurins (QoI) and triazoles (DMI). For example, use of Pristine® Fungicide (EPA Reg. No. 7969-199), a pre-mix of boscalid and pyraclostrobin, reduces the risk of development of fungicide resistance in key at-risk pathogens, such as powdery mildews, *Alternaria* spp., *Botrytis* spp. *Cercospora* spp., and *Monilinia* spp.

The justification for the 3-year extension is based on tolerances obtained for the following minor crops: **blueberry, cantaloupe, carrot, cherry, cucumber, hops, dry bulb onion, green onion, peach, pistachio, plum, raspberry, strawberry, and summer squash minor crops**. All of the residue data supporting these tolerances was generated by BASF. In addition to these crops, tolerances for boscalid were also obtained for other minor crops including cabbage, broccoli, mustard greens, bell pepper, non-bell pepper, leaf lettuce, head lettuce, pecan, and pear for a total of 23 minor crops on which residue studies have been conducted. This is enough crops to justify the full 3-year extension of the exclusive use period from July 2013 to July 2016.

The following document is enclosed in support of the application for the Extension of Exclusive Use of Data for Boscalid:

- **Boscalid (BAS 510F): Application for Extension of Exclusive Use Period (Data Protection)**

If you have any questions or need further information or clarification, I can be reached directly by phone at 919-547-2976, or via e-mail at khalid.akkari@basf.com.

Sincerely,

K.H. Akkari

Khalid H. Akkari, Ph.D.
NAFTA Registration Manager

CC: Tony Kish, EPA PM 22
Dan Kunkel – IR-4, Associate Director, Regulatory Affairs

TRANSMITTAL DOCUMENT

Boscalid (BAS 510F)
(3-pyridinecarboxamide,2-chloro-N-(4'chloro(1,1'-biphenyl)-2-yl))

Submitter: BASF Corporation
Agricultural Products
26 Davis Drive
Research Triangle Park, NC 27709

Regulatory Action in support of which this package is submitted:

Application for Extension of Exclusive Use Period (Data Protection).
Active Ingredient: Boscalid Technical (7969-198), Endura® Fungicide (7969-197), Pristine® Fungicide (7969-199),

Transmittal Date: August 6, 2007

List of submitted studies: The Study Submitted with this application is shown on the next page.

Submitted by: K. H. Akkari

Khalid Akkari, Ph.D.
NAFTA Registration Manager
Regulatory Affairs
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Subdivision: None

OPPTS No.	EPA GLN	Study Reference	MRID No.
None	None	Bardinelli, Ted and Akkari, Khalid. **Boscalid (BAS 510F): Application for Extension of Exclusive Use Period (Data Protection.** BASF Corporation.Reg. Doc. # 2007/7007824, AAugust 2,2007. 50 pages.	

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Agricultural Products
P.O. Box 13528
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Report Title

Boscalid (BAS 510F): Application for Extension of Exclusive Use Period (Data Protection)

EPA Guideline Number

None

Author

Ted Bardinelli
Khalid Akkari

Completion Date

August 2, 2007

BASF Registration Document No.

2007/7007824.

This report consists of 50 pages

Page 1 of 50

STATEMENT OF NO DATA CONFIDENTIALITY CLAIMS

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

Company: BASF Corporation, Agricultural Products
P.O. Box 13528
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Company Agent: Khalid Akkari, Ph.D. Date: August 2, 2007

NAFTA Registration Manager
Title

K.H. Akkari
Signature

GOOD LABORATORY PRACTICES STATEMENT

This study was not conducted in accordance with the rules and regulations set forth under the EPA Code of Federal Regulations Title 40 Part 160 and differs in the following ways:

This study is not required to meet the standards of good laboratory practices since it does not meet the definition of a study contained in part 160.3 as there is no test material or experimentation.

STUDY DIRECTOR: As this study does not meet the definition of a study as defined in part 160.3 there is no study director of record.

SPONSOR AND SUBMITTER: K. H. Akkari

Khalid Akkari, Ph.D.
BASF Corporation, Agricultural Products
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BASF Corporation

Boscalid (EPA Reg. No. 7969-198):
Application for 3-year Extension of Exclusive Use Period (Data Protection)

Products : Pristine® fungicide (EPA Reg. No. 7969-199)
Endura® fungicide(EPA Reg. No. 7969-199)

Minor crops included in this justification are blueberry, cantaloupe, carrot, cherry, cucumber, hops, dry bulb onion, green onion, peach, pistachio, plum, raspberry, strawberry, and summer squash.

Overview/ General Statement

Boscalid (3-pyridinecarboxamide or 2-chloro-N-(4'-chlororobiphenyl-2-yl) nicotinamide) [EPA Reg. No. 7969-198] was registered by the EPA in July 2003 as a "Reduced Risk" pesticide. Boscalid (Code No. BAS 510F) is a unique fungicide chemically belonging to the class of oxathiin fungicides, also known as carboxamide, carboxin or (carbox)anilidee fungicides. Boscalid inhibits mitochondrial respiration and subsequent production of ATP by binding to the succinate-ubiquinone oxidoreductase system in Complex II of the mitochondrial electron transfer chain. Of all fungicides used in North America, it only shares this mode of action with carboxin and flutolanil. In food crops, carboxin is labeled only for seed treatments in cereals, corn, rice, beans, and soybeans, and flutolanil is labeled for control of sheath blight in rice. Boscalid's mode of action is therefore unique in all minor crops and most other crops on which its use is registered. Boscalid effectively controls numerous fungal pathogens belonging to the classes of plant pathogenic fungi including Ascomycetes (powdery mildews, *Sclerotinia* spp, *Monilinia* spp., etc.) and Deuteromycetes (*Alternaria* spp, *Botrytis* spp., etc.). Boscalid has excellent preventative and curative properties. It inhibits spore germination, germ tube elongation, mycelial growth, and sporulation (all major stages of fungal growth and reproduction necessary for disease development). Despite boscalid's systemic transport and curative activities against the various stages of fungal growth, the use of boscalid is recommended as preventative applications as one of the strategies for resistance management.

The tradenames for products containing boscalid are Endura® fungicide (EPA Reg. No. 7969-197) and Pristine® fungicide (EPA Reg. No. 7969-199). Endura is a 70% WG containing boscalid as the sole fungicidal active ingredient. Pristine (38% WG) contains boscalid and pyraclostrobin fungicidal active ingredients in a 2:1 ratio. Pristine provides broad-spectrum efficacy against diseases that is unmatched by other fungicides available in blueberry, cantaloupe, carrot, cherry, cucumber, hops, dry bulb onion, green onion, peach, pistachio, plum, raspberry, strawberry, and summer squash markets. In addition to its broad-spectrum activity, Pristine also reduces the risk of development of fungicide resistance in key at-risk pathogens, such as powdery mildews, *Alternaria* spp., *Botrytis* spp. *Cercospora* spp., and *Monilinia* spp. Pristine has also been used to effectively manage resistance that has developed to strobilurin fungicides, such as gummy stem blight in cucurbits and some powdery mildews. Furthermore, the combination of boscalid and pyraclostrobin provides a true synergistic control of a variety of fungal diseases, well beyond the additive activity of either component alone. This effect has been demonstrated on diseases such as anthracnose, Botrytis, gummy stem blight, and powdery mildews.

Submissions for the first registration petitions for boscalid were made to EPA in the spring of 2001. These submissions included the use of boscalid to control diseases in small berries, dry and succulent bean, bulb vegetables, canola, carrots, fruiting vegetables, lettuce, peanut, pistachio, potato, tree nuts, stonefruits and strawberries. The first Section 3 resgistrations for boscalid, Endura, and Pristine were granted by the EPA in July 2003. Additional tolerances have

since been obtained on brassicas, cucurbits, hops, peas, pome fruits, root and tuber vegetables, soybean and sunflower.

Minor Crops Registrations

The current application for extension of data protection includes justifications based on boscalid tolerances obtained for **blueberry, cantaloupe, carrot, cherry, cucumber, hops, dry bulb onion, green onion, peach, pistachio, plum, raspberry, strawberry, and summer squash minor crops**. Each of these crops will be discussed individually in subsequent sections. In addition to these crops, tolerances for boscalid were also obtained for other minor crops including cabbage, broccoli, mustard greens, bell pepper, non-bell pepper, leaf lettuce, head lettuce, pecan, and pear for a total of 23 minor crops on which residue studies have been conducted.

Status of resistance to boscalid and other anilidee fungicides

No resistant field isolates of the intended target pathogens for boscalid have so far been found. There is, however, published information on the putative mechanism of resistance in some fungal pathogens to carboxin. It is currently thought that mutations that lead to amino acid substitutions in the iron-sulfur protein subunit of succinate dehydrogenase confer resistance to carboxin in *Ustilago maydis* (Keon et al., 1991) and *Mycosphaerella graminicola* (*Septoria tritici*) (Skinner et al., 1998). There is no evidence of field resistance to boscalid in any of the target pathogens. Reports of naturally occurring field resistance to carboxanilidees are restricted to *Ustilago nuda* (Leroux and Berthier, 1988; Newcombe and Thomas, 1991) and *Puccinia horiana* (Grouet et al., 1981), the latter being reported as being non-persistent in nature. There is no indication of cross-resistance between boscalid and the other carboxanilidee fungicides. Such cross-resistance is not likely because boscalid's spectrum of diseases controlled does not overlap that of carboxin and flutolanil.

Fungicide resistance management

Recent documentation of the development of resistance to fungicides of different chemistries including the strobilurins and the sterol inhibitors indicates the need for fungicides with novel modes of action that can be alternated or mixed with current fungicides to preserve their efficacy. Boscalid's mode of action is unique on the target pathogens listed on the label. However, boscalid is an anilidee fungicide with a single known mode of action. This implies that there is a risk of development of resistance in the target pathogen population. In particular, foliar pathogens with a high multiplication rate, such as powdery mildew fungi and Botrytis, are prone to develop resistance to fungicides. Pristine, the premix of boscalid and pyraclostrobin, the latter a broad-spectrum strobilurin fungicide with high intrinsic activity, provides an important tool for use in IPM and resistance management programs. Each active ingredient helps protect the other against resistance development in key target pathogens. Further protection against resistance development can be achieved by rotations with fungicides of different chemistries and limiting the number of applications per season.

The recommended program of applications for Pristine is consistent with FRAC (Fungicide Resistance Action Committee) guidelines. These guidelines are recommended for fungicides applied either solo or in combination with fungicides of different modes of action. One of these strategies for resistance management is to limit the aggregate seasonal applications on registered crops to approximately 33% to 50% of the grower's total number of fungicide applications, depending on product, crop and disease.

Boscalid's unique mode of action against the target pathogens provides a valuable resistance management tool to protect other fungicide classes that possess a single site mode of action, such as strobilurins (QoI) and triazoles (DMI).

References

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Kulka, M. and Schmeling, B. von. (1995). Carboxin fungicides and related compounds. In: Lyr, H. (Ed.). Modern Selective Fungicides. Gustav Fischer Verlag, pp. 133-147.

Leroux, P. and Berthier, G. (1988). Resistance to carboxin and fenfuram in *Ustilago nuda* (Jens.) Rostr., the causal agent of barley loose smut. Crop Protection 7: 16-19.

Newcombe, G. and Thomas, P.L. (2000). Inheritance of carboxin resistance in a European field isolate of *Ustilago nuda*. Phytopathology 90: 179-182.

Skinner, W., Bailey, A., Renwick A., Keon, J., Gurr, S. and Hargreaves, J. (1998). A single amino-acid substitution in the iron-sulphur protein subunit of succinate dehydrogenase determines resistance to carboxin in *Mycosphaerella graminicola*. Current Genetics 34: 393-398.

DISCUSSION OF PRISTINE® FUNGICIDE IMPORTANCE BY MINOR CROP TO SATISFY CRITERIA FOR EXTENSION OF DATA PROTECTION

The following arguments are focused primarily on Pristine® fungicide (premix of boscalid + pyraclostrobin). Pristine offers a critical resistance management tool for most of the key diseases in many of the minor crops presented in this document. In some cases, however, Endura® fungicide is also an excellent tool for resistance management by tank mixing or alternating with fungicides having a different mode of action, especially those with single site activity. Both products play integral roles in Integrated Pest Management programs especially where multiple products and fungicide applications are needed for disease control throughout the season. Since their introduction, Pristine and Endura have replaced a significant amount of older fungicides such as Bravo and Captan. Each crop will be discussed individually, however in a few cases similar arguments apply for closely related but distinct minor crops.

Crop

1.) **Blueberry**

2.) **Cantaloupe**

3.) **Carrot**

4.) **Cherry**

5.) **Cucumber**

6.) **Hops**

7.) **Dry bulb onion**

8.) **Green onion**

9.) **Peach**

10.) **Pistachio**

11.) **Plum**

12.) **Raspberry**

13.) **Strawberry**

14.) **Summer squash**

1. BLUEBERRY

Blueberries are harvested from approximately 120,000 acres in the United States. This includes both those planted and those growing in the wild. The primary growing regions are Maine with 60,000 acres and Michigan with 19,000 acres. The remainder of the production acres are scattered throughout the Northeast, Mid Atlantic, South, and Northwest United States.

Important diseases:

The most important blueberry diseases are Botrytis blossom blight and fruit rot (*Botrytis cinerea*), mummyberry (*Monilinia vacinii corymbosi*), Phomopsis twig blight and fruit rot (*Phomopsis vacinii*), anthracnose (*Colletotrichum gloeosporioides*), and Alternaria leaf spot and fruit rot (*Alternaria tenuissima*). Other diseases including spur blights (*Phoma* spp., *Didymella* spp.), *Mycosphaerella* leafspot and blotch (Mycosphaerella spp.), Septoria leaf spot (*Septoria* spp.) and rust (*Pucciniastrum vacinii*) are prevalent along the east coast and can cause sporadic outbreaks. Powdery mildew can be found on most blueberries however it only causes severe damage in isolated instances.

Botrytis blight is caused by the fungus, *Botrytis cinerea*. It causes significant crop losses under cool wet conditions. It infects the blossom clusters causing a blight killing the blossoms and new shoots. Blossom fungicide applications are required to prevent early infections. Early berry infections may remain latent until maturity when they can cause considerable losses during shipping and storage.

Mummyberry, caused by the fungus *Monilinia vacinii-corymbosi,* is the most well known blueberry disease. The first symptom is a shoot blight that appears soon after bud break resulting from early infections of emerging leaves. As flower blossoms emerge they are also infected from conidiospores. These infections remain inconspicuous until the fruit begin to ripen and can cause significant losses during shipping and storage. Infected berries shrivel or mummify. Fungicides must be applied prebloom and during bloom to contol this disease.

Phomopsis twig blight and fruit rot is caused by the fungus *Phomopsis vaccinii.* This disease primarily affects the stems causing cankers, followed by wilting and death during the summer months. This disease is more severe on frost damaged bushes. Infections occur all season long during rainy periods. The use of season long fungicide applications are necessary to control Phomopsis twig blight.

Anthracnose, caused by *Colletotrichum gloeosporioides*, can cause berry losses up to 20%. The first symptoms are shoot blighting and a blackening of blossom clusters if conditions are warm and humid in the spring. As the fruit begin to ripen, the blossom end of the fruit will rot and spread to other ripening berries. The ripening berries are most susceptible and can cause major losses during shipping and storage. Fungicides must be applied to protect the emerging shoots and clusters and developing berries.

Alternaria leaf spot and fruit rot are caused by *Alternaria tenuissima*. The most important symptom is a fruit rot within a few weeks of harvest leading to major crop losses. This disease can also cause losses during shipping and storage. Infected fruit bear large numbers of dark green spores. Fungicides must be applied to protect maturing fruit.

Pristine® fungicide advantages over current control options:

The key fungicides currently used in blueberries are Abound, Bravo, Cabrio EG, Captan, Indar, Pristine and Switch. Of these, only Pristine and Switch contain 2 active ingredients with 2 different modes of action. Products with multiple modes of action provide an effective means of resistance management for those fungal pathogens where each active ingredient has sufficient biological activity.

Pristine® fungicide (boscalid + pyraclostrobin) has a very broad spectrum of activity, greater than any other blueberry fungicide. It is registered for the control of Alternaria leafspot and fruit rot, anthracnose, Botrytis blights and rots, leafspot and blotch caused by *Mycosphaerella* and *Septoria*, Monilinia blight and mummyberry, Phomopsis leafspot, twig blight, and fruit rot, powdery mildews, rusts, and spur blights (*Didymella* and *Phoma* spp.). Pristine provides effective resistance management of Alternaria leafspot and fruit rot, Botrytis blights and rots, leafspot and blotch caused by *Mycosphaerella* and *Septoria*, Monilinia blight and mummyberry, powdery mildews, rusts, and spur blights (*Didymella* and *Phoma* spp.).

In contrast, Switch (cyprodinil + fludioxanil is labeled only for the control of mummyberry, anthracnose, Alternaria fruit rot, Phomopsis, and Botrytis fruit rot. It lacks control of Mycosphaerella, Septoria, Didymella, Phoma, powdery mildew, and rust.

Indar (fenbuconazole) is a triazole fungicide (DMI) that was recently approved for use in blueberry. It is labeled for the control of *Alternaria*, anthracnose, *Mycosphaerella,* Septoria, mummyberry, *Phomopsi*, powdery mildew, and rusts. It lacks control of *Botrytis, Didymella,* and *Phoma*.

Cabrio EG (pyraclostrobin) and Abound (azoxystrobin) are strobilurin fungicides with the same mode of action but differ in spectrum of activity. Abound is only labeled for anthracnose, Botryosphaeria, powdery mildew, mummyberry, and Phomopsis stem canker. Cabrio EG has a broader spectrum controlling Alternaria leafspot and fruit rot, anthracnose, leafspot and blotch caused by *Mycosphaerella* and *Septoria*, Phomopsis leafspot, twig blight, and fruit rot, powdery mildews, and spur blights (*Didymella* and *Phoma* spp.). Cabrio EG also suppresses Botrytis gray mold, Monilinia blight (mummyberry) and rusts. Since both have the same single site mode of action, they should be used as tank mix and alternation partners with other fungicides with different modes of action within an integrated pest management program.

Bravo and Captan are older fungicide products. Captan is labeled only for Botrytis fruit rot and mummy berry. Bravo has very weak activity and is only labeled for suppression of anthracnose and mummyberry. Pristine and Cabrio EG have replaced much of the Bravo and Captan uses in blueberries.

Resistance Management

Management of pathogen resistance development to commercial fungicides requires the use of multiple modes of action and effective rates of application within the spray program. The two modes of action, disease control performance, and broad-spectrum of activity of Pristine make it the best choice as an alternation partner for other chemistries to reduce the potential for resistance development.

Summary

1. There are insufficient efficacious fungicide alternatives to Pristine (boscalid + pyraclostrobin) registered for blueberry disease control. The only other available fungicide that has a similar spectrum of activity is Cabrio EG (pyraclostrobin). Cabrio EG, however, provides only one mode of action and is not as effective as Pristine for two of the key diseases, Botrytis gray mold and Monilinia blight. Pristine controls 11 blueberry pathogens. The other alternative fungicides only control 2-5 diseases and even with tank mixtures of these, they cannot match the spectrum of control afforded by Pristine.

2. Boscalid plays a key role in managing resistance development. The boscalid component of Pristine provides excellent control of 8 blueberry diseases that are in common with the activity spectrum of pyraclostrobin. This dual mode of action provides greater resistance management

than other fungicides with only a single site mode of action and those with a limited spectrum of diseases controlled.

3. Pristine® fungicide plays a significant part in Integrated Pest Management programs for blueberries. It is the most broad-spectrum fungicide for use on blueberries reducing the overall fungicide usage. Pristine is the best fungicide for the control of Botrytis. It provides excellent control of the various fruit infecting fungi resulting in reduced losses during shipping and storage. As a result, 49% of all berry production acres were treated with Pristine in 2005.

2. CANTELOUPE

Canteloupes are grown on approximately 130, 000 acres in the United States. The primary growing regions are the California, Arizona, Texas, and Georgia.

Important diseases:

The most important foliar diseases of canteloupes are powdery mildew, Alternaria blight, downy mildew, gummy stem blight and anthracnose. All of these diseases, except powdery mildew, require wet weather conditions for infection.

Powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*) is prevalent in all regions of the US including the arid growing regions of California and Arizona. Loss of foliage causes exposure of the fruit to sunscald reducing their quality and quantity. Resistance of *S. fuliginea* to benzimidazoles, DMI-fungicides, and QoI fungicides has been reported in the United States.

Alternaria blight (*Alternaria cucumerina*) can infect most cucurbit crops, however, it is most devastating on cantaloupes and watermelons. It is prevalent in areas with high temperatures and rainfall. Infected leaves are rapidly killed resulting in crop failure. Fruit may fail to mature completely. Late season epidemics cause exposure of the fruit to sunscald reducing their quality and quantity.

Downy mildew (*Pseudoperonospora cubensis*) prevails in the temperate-tropical regions of the US where adequate free moisture is available, especially dew. It is one of the most important cucurbit diseases. Downy mildew primarily affects the foliage leading to severe blighting and subsequent yield loss. Resistance of *Pseudoperonospora cubensis* to mefenoxam and QoI fungicides has been reported, although resistance to QoI fungicides has not been confirmed in the United States to date.

Gummy stem blight (*Didymella bryoniae*) affects fruit, stems and leaves of cantaloupes. It occurs primarily in the Southern and Eastern regions of the US. It affects foliage, stems and fruit leading to loss in fruit number and quality. Complete yield loss may occur. Resistance to QoI fungicides (azoxystrobin) was first detected in 2001 in several counties in Maryland, Delaware and Georgia. In laboratory tests with *Didymella bryoniae*, this mutation has conferred resistance to all QoI fungicides, including azoxystrobin, trifloxystrobin, kresoxim-methyl and pyraclostrobin.

Anthracnose (*Colletotrichum* spp.) is also very common on the fruits and foliage of canteloupes. This disease also thrives in warm and moist environments that often occur in the East and Southeast US.

Pristine® fungicide and Endura® fungicide advantages over current control options:

The main fungicides currently available for foliar use in canteloupes are Amistar, Bravo, Cabrio EG, Dithane, Endura, Flint, **Gavel**, Maneb, Nova, **Pristine**, Procure, Quadris, **Quadris Opti**, Rally, **Ridomil Gold MZ**, **Ridomil Gold Bravo**, **Tanos,** Topsin M, and sulfur. Those fungicides shown in **bold** (above) are premixes containing 2 active ingredients, however, there are key differences in spectrum of activity and resistance management.

Pristine (boscalid + pyraclostobin) is the most active broad-spectrum cantaloupe fungicide. It controls all of the key cantaloupe diseases occurring aboveground:

Downy Mildew (*Pseudoperonospora cubensis*)
Powdery Mildew (*Sphaerotheca fuligena, Erysiphe chichoracearum*)
Anthracnose (*Colletotrichum orbiculare*)
Alternaria Blight (*Alternaria cucumerina*)
Gummy Stem Blight (*Didymella bryoniae*)

Microdochium Blight (*Microdochium tabicinum*)
Cercospora Leaf Spot (*Cercospora citrulina*)
Target Leaf Spot (*Corynespora cassiicola*)

The combination of boscalid and pyraclostrobin provides vital resistance management against powdery mildew, Alternaria, Microdochium, Cercospora, and target leaf spot. Although the gummy stem blight pathogen has developed resistance to the QoI fungicides in some areas, Pristine continues to provide excellent control of these resistant strains. The high level of control demonstrates synergy between the boscalid and pyraclostrobin components.

Endura® fungicide (boscalid) is presently labeled for the control of Alternaria blight, gummy stem blight and suppression of powdery mildew however it also has significant activity against Microdochium, Cercospora, and target leaf spot. This activity provides an important tool for resistance management of these diseases when used as a tank mixing or alternation partner with complementary fungicides including strobilurins and traizoles. Recent data has shown that when Endura is combined with penetrating adjuvants, it provides excellent control of powdery mildew.

Cabrio® EG fungicide, Amistar, Quadris and Flint are strobilurin (QoI) fungicides with a single site mode of action. They must be used in alternation or tank mixed with non-strobilurin fungicides with different modes of action for effective resistance management. Although the strobilurin fungicides are similar in chemistry and posess the same mode of action, they differ in their spectrum of activity.

Cabrio EG (pyraclostrobin) is a broad-spectrum strobilurin fungicide with activity against all of the key above ground cantaloupe diseases. Cabrio EG is labeled for the control of downy mildew, powdery mildew, anthracnose, Alternaria blight, gummy stem blight (no longer effective on gummy stem blight in many areas due to resistance), Microdochium blight, Cercospora leaf spot, and target spot.

Amistar and Quadris (azoxystrobin) are QoI or strobilurin fungicides with activity against many of the key melon diseases. They are labeled for the control of anthracnose, belly rot, downy mildew, gummy stem blight (no longer effective on gummy stem blight in many areas due to resistance), Alternaria, Cercospora leaf spot, Microthecium and powdery mildew. Their activity on powdery mildew, downy mildew and anthracnose is fairly weak.

Flint (trifloxystrobin) is a strobilurin fungicide with a narrow spectrum of activity. It is only labeled for powdery mildew control and suppression of downy mildew.

Although the Ridomil combination products (Ridomil Gold MZ and Ridomil Gold Bravo) have 2 active ingredients, the mefanoxam component is only active against downy mildew and Pythium. Resistance to mefanoxam is fairly widespread in downy mildew and has limited its use to premixes with Bravo and mancozeb, that are chiefly responsible for the disease control.

Bravo (chlorothalonil) is a commonly used fungicide because it is relatively inexpensive and fairly broad-spectrum. There are no known instances of resistance to chlorothalonil from any of the cucurbit pathogens making it a useful alternation fungicide for resistance management within a commercial program. Its importance has recently increased in cucurbit production following the detection of resistance in D. bryoniae (gummy stem blight) to QoI fungicides, one of the few other fungicide classes with efficacy against this pathogen. Chlorothalonil's weaknesses are many including lack of powdery mildew control, high application rates, short reapplication intervals, visible residues, crop injury potential, and tank mix incompatibilities.

Dithane (mancozeb), Maneb (maneb) and other EBDC fungicides have a fairly broad-spectrum of activity and a low potential for resistance. It has no activity on powdery mildew or Alternaria blight and is only moderately effective on downy mildew, anthracnose and gummy stem blight. Other weaknesses are the need for high rates and visible residues.

Rally/Nova (myclobutanil) and Procure (triflumizole) are triazole (DMI) fungicides that have a narrow spectrum of activity with activity only against powdery mildew. Resistance of powdery mildew to another member of the DMI-family, triadimefon (Bayleton), was reported in previous years and has contributed to withdrawal of this product from the cucurbit market. Due to cross-resistance between the different DMI-fungicides, there are also concerns about reduced sensitivity in powdery mildew populations to myclobutanil and triflumizole and subsequent reduction in efficacy.

Tanos (femoxadone + cymoxanil) is primarily targeted against downy mildew. The 2 active ingredients confer some resistance management against this disease. It is also labeled for the control of Alternaria and anthracnose.

Gavel (mancozeb + zoxamide) includes Alternaria leaf spot, Cercospora leaf spot, downy mildew and fruit and stem rot on the label however the main target is downy mildew. The mancozeb in the premix provides some control of the other diseases but is primarily used for downy mildew resistance management.

Quadris Opti (azoxystrobin + clorothalonil) is a fairly broad-spectrum fungicide listing diseases that can be controlled by either active ingredient. See discussion above for azoxystrobin and clorothalonil regarding resistance, crop safety, and tank mix compatibility. It has only moderate activity against powdery mildew, a key disease affecting most canteloupes.

Sulfur fungicides are widely used on cantaloupes primarily to assist in the control of powdery mildew.

A comparison of biologiocal activity for pristine and key competitive fungicides is presented in Table 1. Pristine offers the most effective and broad-spectrum control of the most important cucurbit diseases.

Table 1. Comparison of Use Patterns and Biological Activity for Endura, Pristine and Competitive Cucurbit Fungicides

Product	Rate (lb ai/A)	PHI (days)	Spray Interval (days)	Biological Activity				
				Downy Mildew	Powdery Mildew	Anthra cnose	Alternaria	Gummy Stem Blight
Pristine	0.25-0.45	0	7-14	+++	++++	+++	+++	+++ (if QoI-resistant: +++)
Cabrio EG	0.1-0.2	0	7-14	+++	+++	+++	+++	+++ (if QoI-resistant: -)
Endura	0.2-0.3	0	7-14	+	++	+	+++	+++ (if QoI-resistant: +++)
Quadris	0.18-0.25	1	5-7 (DM, PM) 7-14 (others)	++	++	++	+++	++ (if QoI-resistant: -)
Bravo	1.1-2.5	0	5-7	++	+	++	++	++
Mancozeb	1.5-2.25	5	7-10	++	-	++	-	+
Tanos	0.25	3	5-7	+++	-	+	+	-
Gavel	1.13-1.5	5	7-10	++	-	++	++	+
Rally, Nova,	0.06-0.12	0	7-10	-	++++	+	-	-

Resistance Management

Management of pathogen resistance development to commercial fungicides requires the use of multiple modes of action and effective rates of application within the spray program. The use of weaker products (e.g. azoxystrobin) allow for greater survival and potentially greater probability for these survivors to develop resistance. The disease control performance and broad-spectrum of activity of Pristine® fungicide make it the best choice as an alternation partner for other chemistries to reduce the potential for resistance development and to manage existing resistance in gummy stem blight and powdery mildew populations.

Summary

1. Although there are numerous fungicide products available for use in cantaloupe production, there are insufficient alternatives that can match the spectrum and level of activity afforded by Pristine. It provides excellent control of all major foliar diseases of cantaloupe. The boscalid component provides efficacy against gummy stem blight resistant to solo QoI-fungicides such as azoxystrobin and Cabrio EG. Pristine and Endura are major components within commercial disease control programs for gummy stem blight control as alternation partners with Bravo.

2. Boscalid plays a critical role in managing pest resistance. The combination of boscalid and pyraclostrobin within Pristine provides vital resistance management against powdery mildew, Alternaria, Microdochium, Cercospora, and target leaf spot. It is used strategically to protect the powdery mildew efficacy of the triazole fungicides; Rally and Nova (myclobutanil) and Procure (triflumizole). It is also an important tool for broad-spectrum resistance management when used as a tank mixing or alternation partner with strobilurin fungicides. Boscalid alone is the only efficacious alternative to clorothalonil for the gummy stem blight control where this pathogen has developed resistance to the QoI fungicides. Endura and Pristine provide excellent control of these resistant strains. Although the older fungicides such as Bravo and Dithane have multisite modes of action, they are generally much less effective on most target pathogens and need to be used in programs with more efficacious products like Pristine.

3. Boscalid plays a significant role in managing canteloupe diseases within Integrated Pest Management programs. Pristine is the most active canteloupe fungicide on the key diseases overall and has the broadest-spectrum of diseases controlled. It is also the only product containing two modes of action that controls all of the key cantaloupe diseases. Boscalid is essential for the control of gummy stem blight that are resistant to strobilurin fungicides. These factors contributed to Pristine usage on 28% of the cucurbit acres in 2005.

3. CARROT

Nearly 100,000 acres of carrots are grown in the US, of which 90 % are treated with an average of 6 to 7 fungicide applications per season. Most carrots are grown in California, Florida, Texas and Michigan.

Important Diseases:

Alternaria leaf spot (*Alternaria dauci*) is the most important carrot disease. Alternaria is most prevalent on older leaves. The fungus needs free moisture on the leaf to successfully infect. The fungus causes dark brown to black leaf spots that may coalesce under severe disease pressure. Yield and quality are affected when severe infection of the foliage occurs.

Cercospora leaf spot (*Cercospora carotae*) is also an important carrot disease. Cercospora is most prevalent on the younger leaves. The fungus also needs free moisture on the leaf to successfully infect. The fungus mainly affects the leaves, causing brown to gray leaf spots that coalesce under severe disease pressure. Yields are affected when severe infection of the foliage occurs. Alternaria and Cercospora leaf spots often occur as a disease complex.

Powdery mildew (*Erysiphe polygoni*) is an important disease especially in the western United States. The fungus attacks all green parts of the plant. Fungicides are the most important means of controlling this disease. Due to its short asexual reproduction cycle, the fungus is prone to development of fungicide resistance. Resistance to benzimidazole fungicides has been reported in powdery mildews on other crops.

Southern root rot (*Sclerotium rolfsii*) is a soilborne disease that affects the underground organs of over 200 plant species. Initial symptoms include retarded growth and wilting. Infected roots are covered with mycelium on which vast numbers of spherical sclerotia are produced. Scleriotia remain in the soil and are dispersed by equipement and irrigation water. Control measures are aimed at reducing inoculum levels by crop rotation and modification of irrigation and fertilization practices. Few fungicides are currently registered for control of this fungus.

Pristine® fungicide and Endura® fungicide advantages over current control options:

The key fungicides currently used for foliar disease control in carrot production are Amistar, Bravo, Cabrio EG, Endura, Flint, Pristine, Quadris, Quadris Opti, Ridomil Gold Bravo, and Switch. Of these, only Pristine, Quadris Opti, sulfur, and Switch contain 2 active ingredients with 2 different modes of action. Products with multiple modes of action can provide an effective means of resistance management provided that each active ingredient has sufficient biological activity on target pathogens. **Pristine is presently the only fungicide that alone can provide effective resistance management of all three key foliar diseases (Cercospora, Alternaria, and powdery mildew) on carrots.**

Pristine (boscalid + pyraclostobin) is a very effective broad-spectrum fungicide available for use on carrot. It controls Cercospora, Alternaria, powdery mildew and provides considerable suppression of Southern root rot. It is the only fungicide product containing two active ingredients that have activity against all three key carrot diseases providing vital resistance management against Cercospora, Alternaria, and powdery mildew. Pristine has a PHI of zero days, allowing the growers flexibility of applying the product shortly before harvest.

Endura (boscalid) is labeled for the control of Alternaria leaf spot however, it is also active against powdery mildew, and Cercospora leaf spot. The level of activity against all three diseases is sufficient to provide effective resistance management. Endura possesses a unique single site mode of action useful in conjunction with other fungicides with different modes of action for resistance management.

Cabrio EG, Amistar, Quadris, and Flint are strobilurin fungicides with a single site mode of action. They must be used in alternation or tank mixed with non-strobilurin fungicides with different modes of action for resistance management.

Cabrio EG (pyraclostobin) controls all three key carrot diseases (Alternaria leaf spot, Cersospora leaf spot, and powdery mildew).

Amistar and Quadris (azoxystrobin) are labeled for the control of Cercospora, Alternaria and Southern root rot (*Sclerotium rolfsii*). They also can be soil applied for the control of Rhizoctonia root rot. They are not labeled for the control of powdery mildew.

Flint (trifloxystrobin) is labeled for the control of Alternaria, Cercospora, powdery mildew, and rust. It cannot be used within 7 days of harvest.

Switch (cyprodinil + fludioxanil) is labeled only for the control of Alternaria. It may not be applied within 7 days of harvest.

Ridomil Gold Bravo (mefanoxam + clorothalonil) lists Cercospora and Alternaria control on the label. The clorothalonil component is solely responsible for this activity. The mefanoxam component only provides some activity against Pythium cavity spot. The pre-harvest interval for the mefenoxam-premix is 7 days.

Quadris Opti (azoxystrobin + clorothalonil) controls Cercospora and Alternaria. Although it provides resistance management for these two diseases, it is not labeled for powdery mildew control.

Bravo (clorothalonil) is an older fungicide product labeled only for Cersospora and Alternaria. It is commonly used because it is relatively inexpensive. It does not control powdery mildew. There are no known instances of fungal resistance to Bravo making it a useful alternation fungicide for resistance management within commercial programs.

Sulfur fungicides are widely used on carrots primarily to assist in the control of powdery mildew.

Resistance Management

Management of pathogen resistance development to commercial fungicides requires the use of multiple modes of action and effective rates of application within the spray program. The two modes of action, disease control performance, and broad-spectrum of activity of Pristine® fungicide make it the best choice as an alternation partner for other chemistries to reduce the potential for resistance development.

Summary

1. There are insufficient fungicide alternatives to Pristine that can provide excellent control and resistance management of all three key foliar carrot diseases including Alternaria leaf spot, Cercospora leaf spot, and powdery mildew. The only other alternatives for powdery mildew control are strobilurin fungicides, Cabrio EG and Flint, with the same single site mode of action and are less effective than Pristine.

2. Pristine plays a vital role in the management of resistance for all three key carrot diseases because both fungicide components have activity on these diseases and boscalid possesses a unique mode of action. No other carrot fungicide contains two active ingredients with two modes of action that are active on all three of these key carrot diseases. This is expecially important in resistance management for powdery mildew where the only alternatives for powdery mildew

control are strobilurin fungicides. Without a suitable alternation partner, the only resistance management tool available to growers is Pristine.

3. Pristine® fungicide plays a significant part in managing carrot diseases within Integrated Pest Management programs. Reasons for this are spectrum of activity, dual modes of action, and excellent disease control. These factors contributed to Pristine usage on an estimated 17% of the root and tuber vegetable acres in 2005.

4. CHERRY

There are approximately 130,000 acres of cherries grown in the US. This includes both bearing and nonbearing cherry acres. Sweet cherries are grown on 61,000 acres, with most production occurring in Washington, California, Oregon and Michigan. Tart cherries were grown on 69,000 acres, with 28,000 acres in Michigan alone. Most of the cherries are treated with fungicides with an average of 4-7 applications depending on variety and location.

Important Diseases:

The most important cherry diseases are brown rot, blossom blight, cherry leaf spot and powdery mildew.

Blossom blight / Brown rot (*Monilinia laxa, M. fructicola*) are major diseases of all stonefruits in all areas where they are grown. Blossom blight, caused by *M. laxa* and *M. fructicola* reduces yields by infection of and destruction of the flowers during spring and subsequent reduction in fruit set. The fungus can also cause twig dieback after moving in from the infected flowers. Both fungi are dispersed as conidia by wind and rain. The fungi overwinter on infected twigs, flowers and fruit. *M. laxa* and *M. fructicola* also cause brown rot on all stone fruit species (apricot, cherry, peach, nectarine, prune and plum). The main economic damage on stonefruits is infection of the fruit, in addition to blossom and twig blight. Fruit becomes more susceptible to brown rot as it ripens. Other than cultural control measures, fungicide treatments are an important part of a brown rot disease management program. Fungicide sprays are aimed at protecting the flowers from bud break until petal fall, and at protecting the fruit up to the day of harvest. At least 2 fungicide applications are applied during bloom and another 2 applications are needed during fruit development and maturation.

Powdery mildew (*Podosphaera clandestina*) affects foliage and fruits of all stonefruit. The fungus develops a white powdery growth on affected tissues and spreads by airborne conidia. Fruit infection causes most damage, as it distorts the fruit. Most fruit become resistant to infection after pit-hardening with the exception of cherries, the fruits of which remain susceptible until harvest. Depending on the powdery mildew species and host involved, the fungus either survives the winter in infected buds or as cleistothecia. Fungicides are the most important means of control for powdery mildew. They are generally applied beginning at petal fall and reapplied every 7-10 days through harvest. Due to their short asexual reproduction cycle, powder mildew fungi are prone to development of fungicide resistance. Resistance to certain DMI-fungicides is suspected in cherry powdery mildew in the Pacific Northwest.

Cherry leaf spot (*Blumeriella jaapii*) is a disease that affects the foliage of cherries. It is most prevalent in areas with higher precipitation and higher air humidity. The fungus overwinters on leaves on the orchard floor and produces conidia from bloom to several weeks after petal fall, that are dispersed by water and wind. Foliage remains susceptible throughout the season and severe disease severity may cause defoliation of the trees. Fungicides are applied to control this disease whenever environmental conditions are favorable for infection beginning at petal fall and reapplied every 7-10 days through harvest. In addition, additional applications are made to the trees beginning 2-3 weeks after harvest.

Pristine® fungicide advantages over current control options:

The key fungicides used on cherries are Abound, Bravo, Cabrio EG, Captan, Elite, Flint, Indar, Nova, Orbit, Pristine, Procure, Rally, Rovral, sulfur and Vangard. Of these, only Pristine, contains 2 active ingredients with 2 different modes of action providing resistance management of blossom blight, brown rot, and powdery mildew.

Pristine® fungicide (boscalid + pyraclostobin) is a very effective broad-spectrum fungicide available for use on cherry. It controls all four of the key cherry diseases (brown rot, blossom blight, powdery mildew and cherry leaf spot). Both components are active against brown rot, blossom blight and powdery mildew providing effective resistance management of these diseases. Boscalid is very active against cherry leaf spot. It's unique mode of action provides another resistance management tool for cherry leaf spot when used in alternations with other fungicides active against this disease. Pristine has a PHI of zero days, allowing the growers flexibility of applying the product shortly before harvest.

Cabrio EG, Abound, and Flint are strobilurin fungicides with a single site mode of action. They must be used in alternation or tank mixed with non-strobilurin fungicides with different modes of action for effective resistance management. In general the strobilurins are not as effective as Pristine on all four key diseases of cherry.

Although the strobilurin fungicides are similar in chemistry and posess the same mode of action, they differ in their spectrum of activity. Cabrio EG (pyraclostobin) controls blossom blight and powdery mildew. Abound (azoxystrobin) is labeled for the control of blossom blight, brown rot and powdery mildew. Flint (trifloxystrobin) is only labeled for the control of powdery mildew and cherry leaf spot. Flint cannot be used within 7 days of harvest.

Bravo (clorothalonil), an older fungicide product is labeled only for cherry leaf spot. There are no known instances of fungal resistance to Bravo making it a useful alternation fungicide for resistance management within commercial programs for cherry leaf spot only.

Captan is also an older fungicide. It is labeled for blossom blight, brown rot, cherry leaf spot and Botrytis fruit rot. It has no activity on powdery mildew. It is commonly used because it is very inexpensive and fairly broad-spectrum, however it is generally less effective than Pristine. Since, there are no known instances of fungal resistance to Captan, it is useful as a mixing or alternation partner for other fungicides for resistance management.

Most of the cherry fungicides belong to the triazole (DMI) class of chemistry. These include Elite (tebuconazole), Indar (fenbuconazole), Rally and Nova (myclobutanil), Orbit (propiconazole), and Procure (triflumizole). All of these have the same mode of action and are similar in their spectrum of activity. All except Indar are labeled for all four key cherry diseases. Indar is not labeled for the control of powdery mildew. This class of chemistry is prone to resistance development and should be used in conjunction with other fungicides with different modes of action.

Rovral (iprodione) is labeled for the control of blossom blight and brown rot but can only be applied up to petal fall and only 2 applications are allowed. Resistance to iprodione has been reported further reducing the utility of this fungicide.

Vangard (cyprodinil) use is only allowed on tart cherries. It is only labeled for the control of blossom blight and brown rot. It has a two day preharvest interval. Cyprodinil has a single site mode of action and should be used in conjunction with other fungicides for resistance management.

Sulfur fungicides are widely used on cherries to assist in the control of powdery mildew.

Resistance Management

Management of pathogen resistance development to commercial fungicides requires the use of multiple modes of action and effective rates of application within the spray program. The use of weaker products allow for greater survival and potentially greater probability for these survivors to develop resistance. The two modes of action, disease control performance, and broad-spectrum of activity of Pristine make it the best choice as an alternation partner for other chemistries to reduce the potential for resistance development.

Summary

1. Pristine® fungicide is an important fungicide used in cherry production. There are insufficient efficacious alternative fungicides that control all four key diseases of cherry and provide two modes of action for resistance management. Pristine controls all four of the key cherry diseases (brown rot, blossom blight, powdery mildew and cherry leaf spot). Most other fungicides lack control of one or more of the key diseases of cherry except some of the triazoles. These triazoles are prone to resistance development and should be used in conjunction with other fungicides with different modes of action.

2. Pristine contains two active ingredients (2 modes of action) that are effective against blossom blight and powdery mildew providing effective resistance management of these diseases. The boscalid component is very active against cherry leaf spot. Its unique mode of action provides another resistance management tool for cherry leaf spot when used in alternations with other fungicides active against this disease.

3. Pristine plays a significant part in Integrated Pest Management programs for cherry production because of its broad-spectrum activity and resistance management. These characteristics contributed to the use of Pristine on 36% of the stonefruit acres in 2006.

5. CUCUMBER

Cucumbers are grown on approximately 200,000 acres in the United States. The largest acreages are in North Carolina, Michigan, South Carolina, Texas, and Wisconsin.

Important diseases:

The most important foliar diseases of cucumbers are powdery mildew, downy mildew, gummy stem blight, target leaf spot, and anthracnose. All of these diseases, except powdery mildew, require wet weather conditions for infection.

Powdery mildew (*Sphaerotheca fuliginea, Erysiphe cichoracearum*) is prevalent in all regions of the US including the arid growing regions of California and Arizona. Resistance of *S. fuliginea* to benzimidazoles, DMI-fungicides, and QoI fungicides has been reported in the United States.

Downy mildew (*Pseudoperonospora cubensis*) prevails in the temperate-tropical regions of the US where adequate free moisture is available, especially dew. It is one of the most important cucurbit diseases. Resistance of *Pseudoperonospora cubensis* to mefenoxam and QoI fungicides has been reported, although resistance to QoI fungicides has not been confirmed in the United States to date.

Gummy stem blight (*Didymella bryoniae*) affects fruit, stems and leaves of cucumbers. It occurs primarily in the Southern and Eastern regions of the US. Resistance to QoI fungicides (azoxystrobin) was first detected in 2001 in several counties in Maryland, Delaware and Georgia. In laboratory tests with *Didymella bryoniae*, this mutation has conferred resistance to all QoI fungicides, including azoxystrobin, trifloxystrobin, kresoxim-methyl and pyraclostrobin.

Anthracnose (*Colletotrichum* spp.) and Alternaria blight (*Alternaria cucumerina*) diseases are very common on the fruits and foliage of cucumbers. These diseases also thrive in warm and moist environments that often occur in the East and Southeast US.

Target spot (*Corynespora cassiicola*) is also called Corynespora blight. It is common on cucumbers and can be devastating in the South and mid-Atlantic states under conditions of high humidity and warm temperatures. Young expanding fruit are not susceptible. There are some resistant cucumber varieties however susceptible varieties require repeated fungicide applications to control this disease.

Pristine® fungicide and Endura® fungicide advantages over current control options:

The most important fungicides currently available for foliar use in cucumbers are Amistar, Bravo, Cabrio EG, Dithane, Endura, Flint, **Gavel**, Nova, **Pristine**, Previcur Flex, Procure, Quadris, **Quadris Opti**, Rally, **Ridomil Gold MZ**, **Ridomil Gold Bravo**, and **Tanos**. Those fungicides shown in **bold** (above) are premixes containing 2 active ingredients, however, there are key differences in spectrum of activity and resistance management.

Pristine (boscalid + pyraclostobin) is the most active broad-spectrum cucumber fungicide. It controls all of the key and many minor foliar diseases:

Downy Mildew (*Pseudoperonospora cubensis*)
Powdery Mildew (*Sphaerotheca fuligena, Erysiphe chichoracearum*)
Anthracnose (*Colletotrichum orbiculare*)
Alternaria Blight (*Alternaria cucumerina*)
Gummy Stem Blight (*Didymella bryoniae*)
Microdochium Blight (*Microdochium tabicinum*)
Cercospora Leaf Spot (*Cercospora citrulina*)
Target Leaf Spot (*Corynespora cassiicola*)

The combination of boscalid and pyraclostrobin provides vital resistance management against powdery mildew, Alternaria, Microdochium, Cercospora, and target leaf spot. Although the gummy stem blight pathogen has developed resistance to the QoI fungicides in some areas, Pristine continues to provide excellent control of these resistant strains. The high level of control demonstrates synergy between the boscalid and pyraclostrobin components.

Endura® fungicide (boscalid) is presently labeled for the control of Alternaria blight, gummy stem blight and suppression of powdery mildew however it also has significant activity against Microdochium, Cercospora, and target leaf spot. This activity provides an important tool for resistance management of these diseases when used as a tank mixing or alternation partner with complementary fungicides including strobilurins and traizoles. Recent data has shown that when Endura is combined with penetrating adjuvants, it provides excellent control of powdery mildew.

Cabrio EG, Amistar, Quadris, and Flint are strobilurin (QoI) fungicides with a single site mode of action. They must be used in alternation or tank mixed with non-strobilurin fungicides with different modes of action for effective resistance management. Although the strobilurin fungicides are similar in chemistry and posess the same mode of action, they differ in their spectrum of activity.

Cabrio EG (pyraclostrobin) is a broad-spectrum strobilurin fungicide with activity against all of the key cucumber diseases. Cabrio EG is labeled for the control of downy mildew, powdery mildew, anthracnose, Alternaria blight, gummy stem blight (no longer effective on gummy stem blight in many areas due to resistance), Microdochium blight, Cercospora leaf spot, and target spot.

Amistar and Quadris (azoxystrobin) are labeled for the control of anthracnose, belly rot, downy mildew, gummy stem blight (no longer effective on gummy stem blight in many areas due to resistance), Alternaria, Cercospora leaf spot, Microthecium and powdery mildew.

Flint (trifloxystrobin) is a strobilurin fungicide with a narrow spectrum of activity. It is only labeled for powdery mildew control and suppression of downy mildew..

Although the Ridomil combination products (Ridomil Gold MZ and Ridomil Gold Bravo) have 2 active ingredients, the mefanoxam component is only active against downy mildew and Pythium. Resistance to mefanoxam is fairly widespread in downy mildew and has limited its use to premixes with Bravo and mancozeb, that are chiefly responsible for the disease control.

Bravo (chlorothalonil) is the most commonly used fungicide onn cucumber because it is relatively inexpensive and fairly broad-spectrum. There are no known instances of resistance to chlorothalonil from any of the cucurbit pathogens making it a useful alternation fungicide for resistance management within a commercial program. Its importance has recently increased in cucurbit production following the detection of resistance in D. bryoniae (gummy stem blight) to QoI fungicides, one of the few other fungicide classes with efficacy against this pathogen. Chlorothalonil's weaknesses are many including lack of powdery mildew control, high application rates, short reapplication intervals, visible residues, crop injury potential, and tank mix incompatibilities.

Dithane (mancozeb) is an old EBDC fungicide with a fairly broad-spectrum of activity and a low potential for resistance. It has no activity on powdery mildew or Alternaria blight and is only moderately effective on downy mildew, anthracnose and gummy stem blight. Other weaknesses are the need for high rates and visible residues.

Rally/Nova (myclobutanil) and Procure (triflumizole) are triazole (DMI) fungicides that have a narrow disease spectrum with activity only against powdery mildew. Resistance of powdery mildew to another member of the DMI-family, triadimefon (Bayleton), was reported in previous years and has contributed to withdrawal of this product from the cucurbit market. Due to cross-

resistance between the different DMI-fungicides, there are also concerns about reduced sensitivity in powdery mildew populations to myclobutanil and triflumizole and subsequent reduction in efficacy.

Previcur Flex (propamocarb) has activity only against downy mildew and Pythium seedling disease and root rot. It has a single site of action and therefore may be prone to resistance development. It is used within tank mixtures and alternation programs for resistance management.

Tanos (femoxadone + cymoxanil) is primarily targeted against downy mildew. The 2 active ingredients confer some resistance management against this disease. It is also labeled for the control of Alternaria and anthracnose.

Gavel (mancozeb + zoxamide) includes Alternaria leaf spot, Cercospora leaf spot, downy mildew and fruit and stem rot on the label however the main target is downy mildew. The mancozeb in the premix provides some control of the other diseases but is primarily used for downy mildew resistance management.

Quadris Opti (azoxystrobin + clorothalonil) is a fairly broad-spectrum fungicide listing diseases that can be controlled by either active ingredient. See discussion above for azoxystrobin and clorothalonil regarding resistance, crop safety, and tank mix compatibility. It has only moderate activity against powdery mildew, a key disease affecting most canteloupes.

A comparison of biologiocal activity for pristine and key competitive fungicides is presented in Table 1. Pristine offers the most effective and broad-spectrum control of the most important cucurbit diseases.

Table 1. Comparison of Use Patterns and Biological Activity for Endura, Pristine® fungicide and Competitive Cucurbit Fungicides

Product	Rate (lb ai/A)	PHI (days)	Spray Interval (days)	Biological Activity				
				Downy Mildew	Powdery Mildew	Anthra cnose	Alternaria	Gummy Stem Blight
Pristine	0.25-0.45	0	7-14	+++	++++	+++	+++	+++ (if QoI-resistant: +++)
Cabrio EG	0.1-0.2	0	7-14	+++	+++	+++	+++	+++ (if QoI-resistant: -)
Endura	0.2-0.3	0	7-14	+	++	+	+++	+++ (if QoI-resistant: +++)
Quadris	0.18-0.25	1	5-7 (DM, PM) 7-14 (others)	++	++	++	+++	++ (if QoI-resistant: -)
Bravo	1.1-2.5	0	5-7	++	+	++	++	++
Mancozeb	1.5-2.25	5	7-10	++	-	++	-	+
Tanos	0.25	3	5-7	+++	-	+	+	-
Gavel	1.13-1.5	5	7-10	++	-	++	++	+
Rally, Nova,	0.06-0.12	0	7-10	-	++++	+	-	-

Resistance Management

Management of pathogen resistance development to commercial fungicides requires the use of multiple modes of action and effective rates of application within the spray program. The use of weaker products (e.g. azoxystrobin) allow for greater survival and potentially greater probability for these survivors to develop resistance. The disease control performance and broad-spectrum of activity of Pristine® fungicide make it the best choice as an alternation partner for other chemistries to reduce the potential for resistance development and to manage existing resistance in gummy stem blight and powdery mildew populations.

Summary

1. Although there are numerous fungicide products available for use in cucumber production, there are insufficient alternatives that can match the spectrum and level of activity afforded by Pristine. It provides excellent control of all major foliar diseases of cucumber. The boscalid component provides efficacy against gummy stem blight resistant to solo QoI-fungicides such as azoxystrobin and Cabrio EG. Pristine and Endura are major components within commercial disease control programs for gummy stem blight control as alternation partners with Bravo.

2. Boscalid plays a critical role in managing pest resistance. The combination of boscalid and pyraclostrobin within Pristine provides vital resistance management against powdery mildew, Alternaria, Microdochium, Cercospora, and target leaf spot. It is used strategically to protect the powdery mildew efficacy of the triazole fungicides; Rally and Nova (myclobutanil) and Procure (triflumizole). It is also an important tool for broad-spectrum resistance management when used as a tank mixing or alternation partner with strobilurin fungicides. Boscalid alone is the only efficacious alternative to clorothalonil for the gummy stem blight control where this pathogen has developed resistance to the QoI fungicides. Endura and Pristine provide excellent control of these resistant strains. Although the older fungicides such as Bravo and Dithane have multisite modes of action, they are generally much less effective on most target pathogens and need to be used in programs with more efficacious products like Pristine.

3. Boscalid plays a significant role in managing cucumber diseases within Integrated Pest Management programs. Pristine is the most active cucumber fungicide on the key diseases overall and has the broadest-spectrum of diseases controlled. It is also the only product containing two modes of action that controls all of the key cantaloupe diseases. Boscalid is essential for the control of gummy stem blight that are resistant to strobilurin fungicides. These factors contributed to Pristine usage on 28% of the cucurbit acres in 2005.

6. HOPS

Approximately 30,000 acres of hops are grown in the United States. The main production areas are in the states of Washington, California, Oregon, and Idaho.

Important diseases:

Hops are perennial vine crops that are grown on trellises. The estimated lifespan of the crop is 20 years under this system of production. Until recently, the only significant disease on hops has been downy mildew. The causal organism for downy mildew is *Pseudoperonospora humuli.* Within the last five years, powdery mildew, caused by *Erysiphe chicoracearum* has become increasingly important, requiring the use of new powdery mildew fungicides.

Pristine® fungicide advantages over current control options:

The key fungicides currently used in hops are Accrue, Aliette, Curzate, Flint, Fosphite, Kocide, Quintec, and Pristine. Of these, only Pristine contains 2 active ingredients with 2 different modes of action.

Pristine (boscalid + pyraclostrobin) is unique in that it is the only fungicide available for use on hops that provides excellent control of both powdery mildew and downy mildew. Since both active ingredients have activity on powdery mildew, it provides effective resistance management on this disease. For downy mildew resistance management, Pristine's use is recommended for no more than two sequential applications before alternating to a non-strobilurin fungicide that is active on downy mildew.

Accrue (spiroxamine), Flint (trifloxystrobin) and Quintec (quinoxyfen) are used only for powdery mildew control, although Flint can also provide suppression against downy mildew. Aliette (fosetyl aluminum), Curzate (cymoxanil), Fosphite (potassium salts of phosphorous acid) and Kocide (copper hydroxide) are labeled only for downy mildew control. Curzate must be mixed with another protectant fungicide active against downy mildew for resistance management. All of these products except Aliette, Fosphite, and Kocide, are prone to resistance development due to their single site modes of action.

Resistance Management

Management of pathogen resistance development to commercial fungicides requires the use of multiple modes of action and effective rates of application within the spray program. The two modes of action, disease control performance, and broad-spectrum of activity of Pristine make it the best choice as an alternation partner for other chemistries to reduce the potential for resistance development.

Summary

1. There are insufficient efficacious alternative fungicides available for use on hops that effectively control both powdery mildew and downy mildew diseases. Only Pristine can control both key diseases and contains two modes of action providing effective resistance management for powdery mildew.

2. Pristine plays a significant part in managing resistance in powdery mildew and downy mildew populations. It is an excellent alternation partner with other fungicides that contain single site modes of action such as Accrue and Quintec.

3. Pristine® fungicide plays a vital part in Integrated Pest Management for disease control in hops. The most biologically sound disease control program for both mildew diseases is a fungicide program that alternates Pristine® fungicide with Accrue or Quintec tank mixed with Curzate and Aliette.