RESEARCH

A new strobilurin fungicide for turfgrass disease control

A hundred years of research have led to the development of more effective fungicides against turfgrass disease.

Bruce Martin, Ph.D.

The use of fungicides as a disease-management tool for turfgrasses has progressed since the first fungicide mixture, Bordeaux mixture, was used for brown patch control in the early 1900s. Bordeaux mixture was the first inorganic fungicide, consisting of lime and copper sulfate. Fungicides that were developed and used for crop protection were also frequently adapted for use in turf. Metal-containing fungicides, including copper compounds, mercuric and mercurous chloride, chlorophenol mercury and others, followed and were widely used to control snow mold and other turfgrass diseases. The 1930s and '40s gave rise to the first synthetic organic fungicides such as thiram. Mercury fungicides were still widely used, as was as a new fungicide, cadmium succinate. In the 1950s and 1960s, the dithiocarbamate fungicides, including zineb and maneb, and heterocyclic compounds such as ethazole and pentachloronitrobenzene (PCNB) were registered for turf diseases. A more detailed account of the history of fungicide use in turfgrass can be found in the third edition of "Diseases of Turfgrass" by Houston Couch, Ph.D.

Fungicide modes of action

Until the 1970s, turfgrass fungicides were all contact materials, which, with suitable formulations, could protect plant surfaces for relatively short periods of time (typically 7 to 10 days). The terminology introduced by Couch provides a good framework for understanding how fungicides work on or within plants.

Couch distinguishes fungicides by their topical or physical mode of action: contact fungicides stay on the outside of plants, and *penetrants* penetrate the plant in some manner. *Localized penetrants* diffuse into leaf surfaces. *Acropetal penetrants* are transported by xylem toward the leaf tips after they penetrate (upward movement).

Although acropetal penetrant fungicides are frequently referred to as systemic, they are not because they do not move in phloem toward the root tips (downward or basipetal movement). Couch defines a *systemic penetrant* as a fungicide that is transported by both xylem and phloem. Penetrant fungicides in general offer the possibility of prolonging disease control, as the fungicide protects plant surfaces, but they also may inhibit pathogens in the early stages of infection inside the plant. Penetration of the plant surface also inhibits weathering of the fungicide and therefore may prolong the effectiveness of the dose.

In the early 1970s, the first xylem-mobile (acropetal penetrant) fungicide for turfgrass use was developed and quickly became very valuable as a turfgrass fungicide: benomyl, best known under the trade name Tersan 1991. Benomyl is a benzimidazole-class fungicide, which was recently canceled for all uses in the United States. The other fungicide still in use belonging to the benzimidazole class of chemistry is thiophanate methyl, currently sold under many trade names. Shortly after benomyl was registered, a new contact fungicide, chlorothalonil, was registered; it is the sole nitrile fungicide. The dicarboxamide fungicide iprodione, which acts as localized penetrant, also was introduced for turf disease control in the early 1970s.

In the 1980s the first DMI (demethylation inhibitor) fungicide, triadimefon (Bayleton), was registered for turf. During the 1980s and early 1990s several new DMI fungicides were registered, including propiconazole (Banner), fenarimol (Rubigan), cyproconazole (Sentinel) and myclobutanil (Eagle). Other DMI fungicides now under development may be registered for turfgrass disease control.

In the late 1970s, metalaxyl (Subdue), a revolutionary new xylem-mobile penetrant fungicide was introduced. Currently, both metalaxyl and its more active analog, mefanoxam (Subdue Maxx), are used for Pythium blight, damping-off and downy mildew control. Later, the only truly systemic fungicide, fosetyl Al (Chipco Aliette and

Insignia exhibits excellent brown patch control, and it is also the first strobilurin labeled for turfgrass that has at least some effective activity against dollar spot. In the above test plots with dollar spot and brown patch on A-1 creeping bentgrass, no fungicide was applied in the test plot on the lower left; and Insignia was applied at a rate of 0.9 ounce/1,000 square feet at a 28-day interval in the plot on the lower right and at a rate of 0.5 ounce/1,000 square feet at a 14-day interval in the plot on the upper left.

KEY points

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- **A new group of fungicides for turfgrass disease control,** the *strobilurins*, became available in the 1990s.
- **Strobilurins** are reduced-risk fungicides with different physical modes of action,but the same biochemical mode of action.
- **Although some organisms in some areas have devloped resistance to strobilurins,** the fungicides are effective in controlling many common turf diseases.
- **Much remains to be learned about the strobilurin fungicides,** but they are valuable tools for turfgrass disease control.

Chipco Signature), was registered for Pythium blight and root rot. Fosetyl Al is mobile in both the xylem and phloem of treated plants and therefore moves down and up in the plant.

Strobilurins

History

Late in the 1990s, an entirely new group of fungicides, the *strobilurins*, was developed for turfgrass disease control. The first strobilurin fungicide for turf disease control, azoxystrobin, was developed by Syngenta and first sold in 1996 under the trade name Heritage. Trifloxystrobin (Compass) followed in 1999.

Strobilurin fungicides were developed following the discovery of naturally occurring fungicidal compounds structurally similar to β-methyoxyacrylic acid. In fact, the term *methoxyacrylates* initially was used to describe the chemical class we call strobilurins. These compounds (strobilurin A, oudemansin A) are produced naturally in certain species of mushroom fungi, including *Strobilurus tenacellus* and *Oudemansiella mucida*. Although these compounds are fungicidal, they are volatile and quickly degraded by light and are not stabile enough for practical disease control.

Research with these compounds and development of candidate fungicides began in the early 1980s. Researchers in several companies, led by BASF and Syngenta, worked to develop stabile compounds with unique physical modes of action and properties. The first two strobilurins resulting from this research were azoxystrobin from Syngenta and kresoxim-methyl from BASF (kresoxim-methyl is not sold for turf disease control). In 1999, Novartis began selling Compass for turf disease control. However, the merger of Novartis and Zeneca into Syngenta required the sale of Compass to Bayer in 2000.

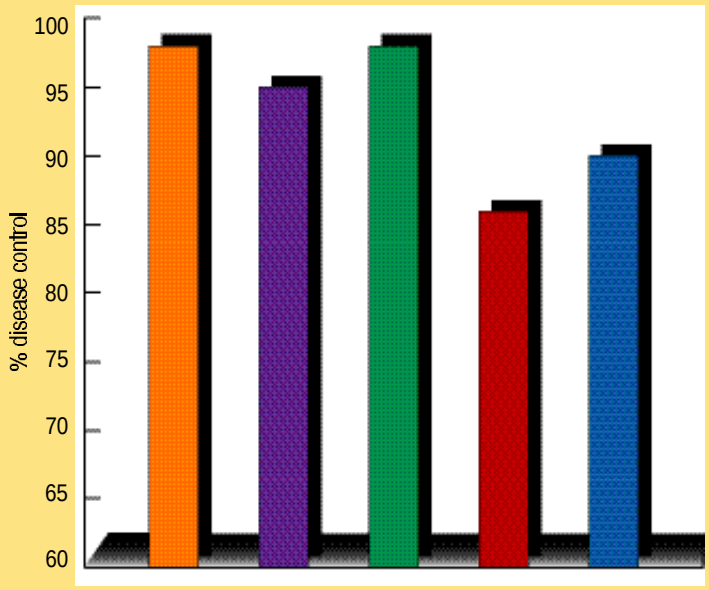
Insignia

The newest strobilurin fungicide for turf, pyraclostrobin, is expected to be registered and sold under the trade name Insignia early this year. This fungicide was developed by BASF and has been tested extensively (as BAS 500) in recent years for a wide range of turf diseases.

Like Heritage and Compass before it, Insignia has been designated a reduced-risk candidate for registration by the EPA. All three of these fungicides have low use rates and low mammalian toxicity, are nonleach-

BROWN PATCH IN CREEPING BENTGRASS

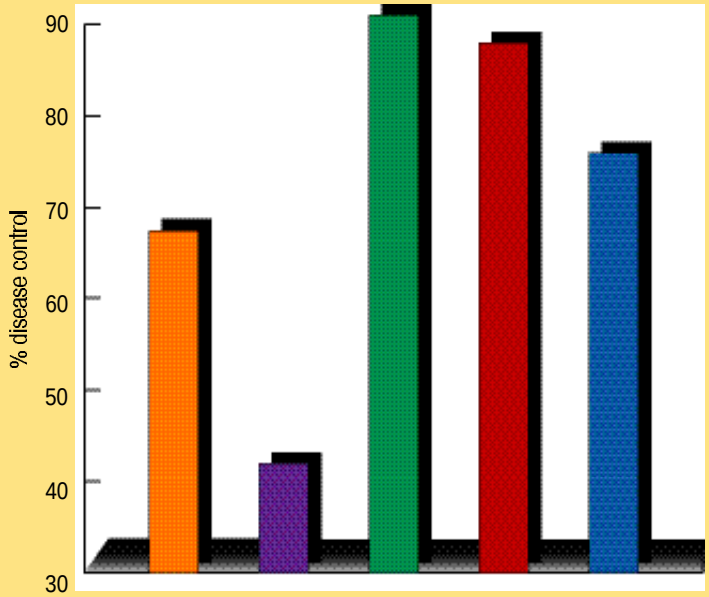
Fungicide treatments in ounces/1,000 square feet
Insignia,0.5 Insignia, 0.9 Heritage,0.2 Compass, 0.2 Daconil Ultrex,3.2



All treatments were applied at 14-day intervals except for the 0.9-ounce Insignia treatment. Data are derived from five trials.

DOLLAR SPOT IN CREEPING BENTGRASS

Fungicide treatments in ounces/1,000 square feet: Insignia, 0.5
Insignia,0.9 Banner Maxx,1.0 Chipco 26GT, 3.0 Daconil Ultrex,3.8



All treatments were applied at 14-day intervals except for the 0.9-ounce Insignia treatment.Data are derived from four trials.

ing and have other favorable characteristics. Insignia is highly toxic to fish and aquatic invertebrates, but low use rates, rapid soil degradation and its strong adsorption to soil should minimize risk if it is used properly. Among other things, proper usage means preventing runoff and spray drift from coming in contact with bodies of water.

Physical modes of action

Transported in xylem

Physical modes of action differ in strobilurin fungicides. Azoxystrobin is xylem-mobile. Radioactive labeling experiments have clearly shown that the fungicide moves acropetally in the xylem and provides disease control from the point of application upward in the xylem stream. Therefore, if the fungicide is in a leaf axil, it will protect the entire leaf in a short time by absorption and translocation in the xylem. Likewise, if absorbed through the root system, it can move within the xylem and protect roots as well as foliage. Azoxystrobin is gradually taken into plant surfaces, with 3 to 25 percent taken into the plant more than 24 hours after application. This concentration is enough to provide disease control. Azoxystrobin also provides prolonged control of certain other diseases, such as brown patch (*Rhizoctonia solani*).

This is similar to the movement of DMI fungicides within plants. Hence, DMI fungicides, as well as azoxystrobin, have been very useful for control of root-rot diseases, such as summer patch (caused by *Magnaporthe poae*) and take-all patch (caused by *Gaeumannomyces graminis* var. *avenae*).

Mesostemic action

Trifloxystrobin is not transported in the xylem. Instead, the physical mode of action has been described as *mesostemic*. This is analogous to local penetrant movement of dicarboxamide fungicides, such as iprodione (Chipco 26019) or vinclozolin (Curalan and others). Yet, trifloxystrobin is different because the material breaks down into four fractions that vary in mobility around the site of application. One fraction is strongly attracted to lipids and binds to the cuticle and wax layer of leaves. Another fraction can move by surface moisture and vapor activity and can be redistributed around the point of application and beyond. Yet another fraction can move across the leaf blade, providing disease control on the opposite side of the leaf from the application point. The mesostemic movement of trifloxystrobin was described in a 1999 *GCM* article by Agnew (1).

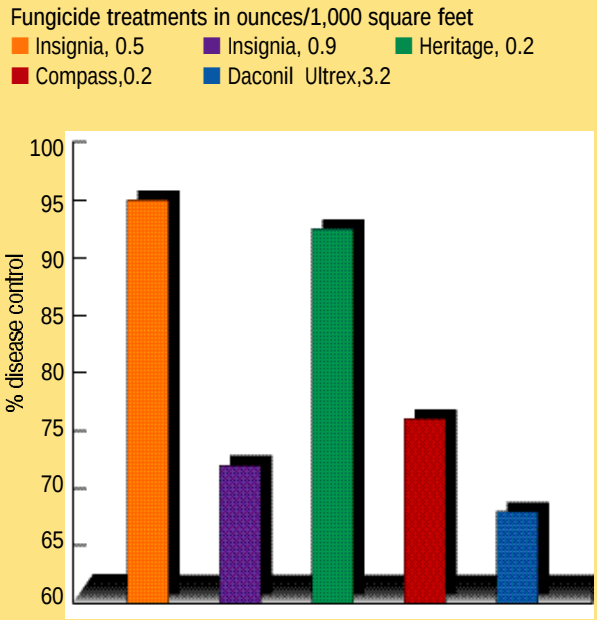
Lipophilic properties

Like trifloxystrobin, pyraclostrobin, the active ingredient in Insignia, is not transported in the xylem. However, pyraclostrobin is most strongly lipophilic, or attracted to waxes on and within the leaf. According to BASF, pyraclostrobin penetrates the leaf within minutes of application and is stored primarily in the waxes of the leaf cuticle. This property allows Insignia to be rainfast two hours after application. Because of the high lipophilic properties and quick local penetration of pyraclostrobin, thorough coverage in application is very important. The same is true for trifloxystrobin. Thorough coverage is not as important with azoxystrobin because of its xylem mobility and because rain redistributes fungicide residues that have not yet been absorbed within the plant. In general, thorough coverage in spray applications is a very good practice, regardless of the fungicide.

Biochemical mode of action

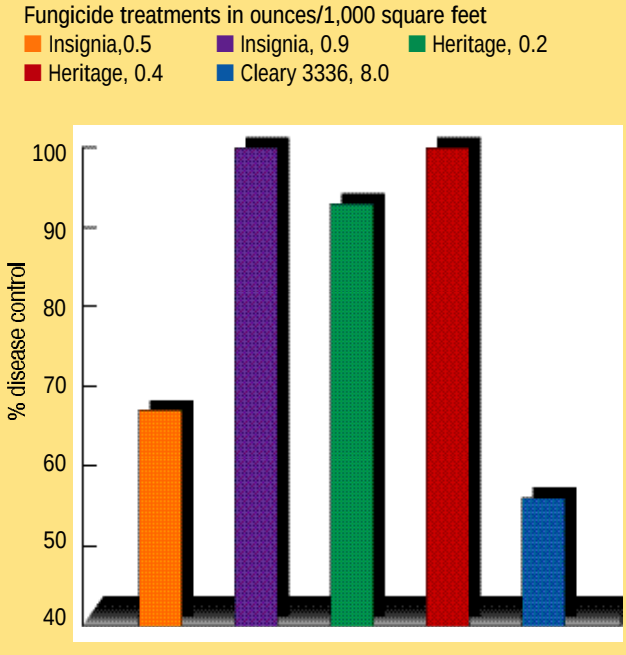
Heritage, Compass and Insignia all work

GRAY LEAF SPOT, PERENNIAL RYEGRASS



All treatments were applied at 14-day intervals except for the 0.9 ounce Insignia treatment.Data are derived from three trials.

SUMMER PATCH



All treatments were applied at 14-day intervals except for the 0.9-ounce Insignia and 0.4-ounce Heritage treatments, which were applied at 28-day intervals. Data are taken from Majumdar et al.in *Fungicide and Nematicide Tests*, vol.55,p.513.

by inhibiting cellular respiration, that is, by stopping the energy production within the fungal cells. Therefore, spores that are undergoing germination or that otherwise require high amounts of energy (for example, swimming zoospores of *Pythium*) are quickly killed.

These fungicides all bind to the Q_o site of cytochrome *b*, which is a site of the respiration cytochrome *bc*1 complex on the outside of the mitochondrial membrane. (The mitochondria are the energy-producing organelles within cells.) This is important in the case of fungicide resistance. All three fungicides have identical biochemical modes of action and therefore belong to the Q_oI cross-resistance group.

It should be noted that some fungicides have chemical structures that do not resemble those of strobilurins, yet inhibit fungi in exactly the same way. Two such fungicides are famoxadone, developed by DuPont, and fenamidone, developed by Aventis; they are currently not used as fungicides. They also belong in the Q_oI cross-resistance group. This means that a pathogen population that is resistant to one fungicide within the Q_oI cross-resistance group will be resistant to all others within that group.

Resistance to azoxystrobin and trifloxystrobin has been confirmed in populations of *Pyricularia grisea*, the causal agent of gray leaf spot, as well as *Colletotrichum graminicola*, the causal agent of anthracnose. One case of resistance to *Pythium aphanidermatum*, a cause of Pythium blight, has also been confirmed. On several golf courses, this resistance has led to the complete failure of these fungicides for control of these diseases. Therefore, it is extremely important that resistance be managed properly for the strobilurins and other fungicides in the Q_oI cross-resistance group.

Currently, the industry-led Fungicide Resistance Action Committee (FRAC) recommends that, for all diseases, these fungicides be applied preventively or early in the stages of fungal development before infection. For gray leaf spot and anthracnose, where resistance is a high risk, do not apply sequential (back-to-back) applications of strobilurin fungicides. For other diseases where resistance has not been detected, apply no more than two sequential applications of strobilurin fungicides, rotate with fungicides that have a multisite mode of action whenever appropriate and use best cultural practices to minimize disease pressure. Follow the current labeling suggestions of these fungicides regarding maximum use rates in a yearly season.

Effectiveness of Insignia

Brown patch and dollar spot

Even though resistance is a very important issue, these fungicides have proven very effective for excellent control of many turfgrass diseases. Insignia is effective against many of the major turfgrass diseases at label rates of 0.5 to 0.9 ounce of product/1,000 square feet for 14 to 28 days. Effectiveness differs among these diseases, but several unique characteristics apply to Insignia. Although it is not mobile in the xylem, it still exhibits excellent brown patch control. It is also the first strobilurin labeled for turfgrass that has at least some effective activity against dollar spot. Effectiveness against dollar spot appears to last for 14 days, but disease control is lost when Insignia is applied at higher rates and longer intervals (0.9 ounce/1,000 square feet, 28 days). However, if Insignia is not rotated with a different, effective dollar spot fungicide, then dollar spot can resurge in sites previously treated with Insignia. Similar disease resurgence phenomena have been documented with Compass, Heritage and Prostar.

Anthracnose and gray leaf spot

Insignia is also effective against anthracnose, although resistance most likely will be an important issue with this disease. The same is true for gray leaf spot control. The data shown for gray leaf spot control were derived from three trials, before the development of resistance in some sites with gray leaf spot in perennial ryegrass. It is too early to determine how Insignia will perform in sites with confirmed resistance to azoxystrobin and trifloxystrobin, but, considering cross-resistance, effectiveness will be reduced compared to control of sensitive strains of *Pyricularia grisea*.

Pythium blight and summer patch

Insignia is also active for Pythium blight control. Because it belongs to a different biochemical mode of action, Insignia is effective against *Pythium* populations with resistance to metalaxyl and mefanoxam, providing another tool in those cases. Interestingly, although the fungicide apparently is not mobile within root systems, it has effectively controlled summer patch at higher rates of use.

More to learn

Much remains to be learned about all the strobilurin fungicides. Regional research is needed to determine how best to deploy them for most effective disease control and to avoid or prolong the development of resistance in some pathogen populations. However, these fungicides clearly are valuable tools for turfgrass disease control.

TURFGRASS DISEASES EFFECTIVELY CONTROLLED BY INSIGNIA

- Anthracnose
- Bentgrass dead spot
- Brown patch
- Dollar spot (suppression)
- Fairy ring
- Fusarium patch
- Gray leaf spot
- Gray snow mold
- Leaf spots and melting out
- Pink patch
- Pink snow mold
- Pythium blight
- Red thread
- Rust
- Summer patch
- Take-all patch

Acknowledgments

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Bruce Martin,Ph.D.(sbmrtn@clemson.edu),is a professor at Clemson University's Pee Dee Research and Education Center in Florence, S.C.