COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY COLLEGE OF AGRICULTURE, FOOD AND ENVIRONMENT

Plant Pathology Fact Sheet PPFS-GEN-12

Foliar Fungicide Use in Corn and Soybeans

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Introduction

Interest in the use of foliar fungicides for corn and soybean has expanded dramatically in the U.S. over the past few years, resulting in a major change in how these crops are being produced on many farms. Until recently, foliar fungicides for soybeans and corn were reserved for seed production fields to protect seed quality in very specific circumstances or for specialty crops. Applications for the purpose of protecting crop yield were rarely economical. However, the current trend in Kentucky, as well as many other corn/soybean producing states, is towards an increased use of foliar fungicides on these crops as a means of maximizing yields.

Several factors have played a role in the escalation of fungicide use on these crops. A major player has been the development of strobilurins (also called 'Q_oI fungicides'), broad-spectrum fungicides registered for the control of foliar diseases of a number of crops, including soybean and corn. Additionally, soybean rust concerns and subsequent educational programs led to a greater

awareness of fungicides (and subsequent use) by growers. Most recently, higher crop value resulting from rising crop prices has also been a significant factor, as have extensive marketing activities by fungicide companies. Claims made by several of these manufacturers have extended beyond disease management and include assertions of improved stress tolerance and growth efficiency which maximize yields.

This fact sheet will discuss the use of fungicides for controlling various corn and soybean diseases, the importance of making a disease risk assessment, and the potential for negative impacts of unnecessary fungicide applications. In addition, recent 'plant health' claims made by some fungicide manufacturers will be addressed.

Fungicide Use for Disease Management

The best chance that a fungicide treatment will result in a net economic gain for corn or soybean occurs when disease conditions exist which justify making an application. That is, fungicides often result in higher yields when there is enough disease to cause significant yield reductions, such as when a susceptible host is grown in an environment highly favorable to disease development. In contrast, research in Kentucky and throughout the Corn and Soybean Belts shows that a fungicide spray commonly does not provide an economic yield benefit when disease pressure is low (Tables 1 & 2). In fact, research has shown that for both corn and soybean, the probability of achieving an economic yield increase from a fungicide application in the absence of significant visible disease is usually no better than flipping a coin. Furthermore, in corn, few corn hybrids consistently provide a significant yield benefit from one year to the next when disease pressure is low. Thus, deciding which fields have significant disease risk can help a producer allocate fungicide applications to fields most likely to benefit from such an application.

Risk assessment

Using corn as an example, Figure 1 lists factors that are associated with increased risk of foliar diseases, particularly gray leaf spot and northern leaf blight. The most

Table 1. Response in corn to fungicide application in university trials in 2009[1]

	Headline 6 fl oz/A		Quilt 14 fl oz/A		Stratego 10 fl oz/A	
Disease level in untreated check[2]	No. cases	Average yield gain (bu/A)	No. cases	Average yield gain (bu/A)	No. cases	Average yield gain (bu/A)
<5%	130	4.0 ± 11.4	43	1.2 ± 13.9	40	5.9 ± 11.5
>5%	37	9.6 ± 12.0	31	8.3 ± 12.9	25	4.0 ± 14.5

[1]One application at VT/R1 or R2.

[2]At dent stage. Provides an estimate of overall disease pressure.

Table 2. Response in soybean to Headline fungicide[1] in university trials[2] in 2006

	Headline 6 fl oz/A	
Yield response from fungicide	No. cases	Average yield gain and range (bu/A)
Significant increase[3]	15	6.3 (17.7 to -3.0)
No statistical increase	59	1.7 (16.3 to -6.0)
Combined	74	2.8 (17.7 to -6.0)

[1]One application at beginning pod (R3).

[2]Replicated, randomized tests conducted in DE, KY, IA, IN, IL, MD, MI, MO, MN, NE, ND, NY, OH, SD, WI and Ontario, Canada (disease pressure was minimal in all tests).

[3]$P \leq 0.05$

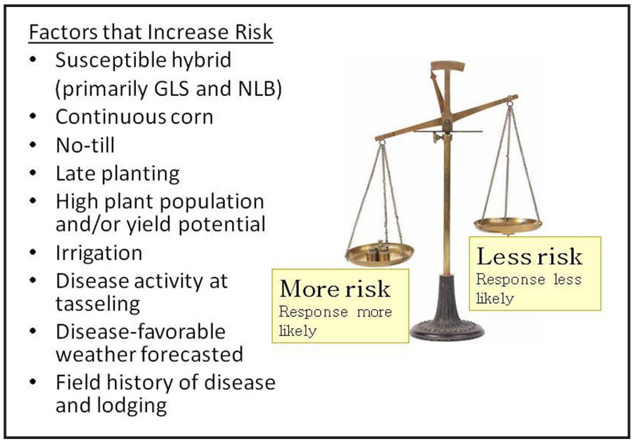

FIGURE 1. WEIGHING THE RISKS OF DISEASE USING A RISK ASSESSMENT CAN HELP DETERMINE THE LIKELY RESPONSE OF CORN TO FOLIAR FUNGICIDES.

important factors are listed at the top. The more of these are in place by the time of tasseling, the greater the possible benefit of a fungicide spray.

As with corn, soybean is most likely to experience an economic yield response to a fungicide when there is an elevated disease risk. FIGURE 2 lists the factors that increase disease risk in soybean. There is some overlap with the risk factors in corn, but there are some significant differences also.

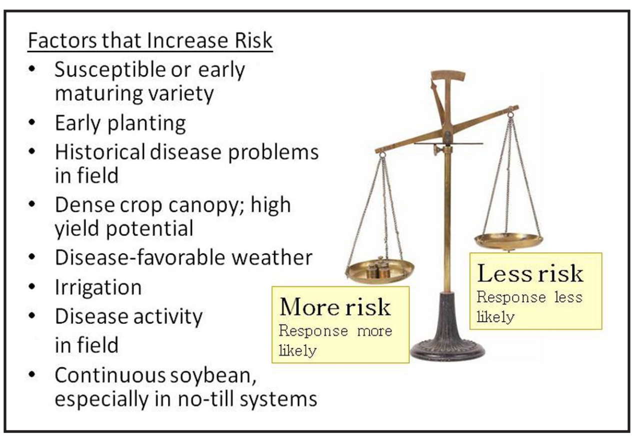

FIGURE 2. A RISK ASSESSMENT CAN BE USED TO DETERMINE THE LIKELY RESPONSE OF SOYBEAN TO FOLIAR FUNGICIDES.

The response to a fungicide treatment cannot be predicted with certainty. Throw into the mix different types and degrees of crop stresses, varying crop genetics, and it is not hard to see that making the most appropriate fungicide use decision for a corn or soybean crop is not so clear-cut. However, while these decisions cannot be made with 100% accuracy, the results will be much more consistent when fungicide use is based on disease risk.

For fields that are at low risk for disease, many producers will still apply fungicides for one reason or another. In these cases, it is strongly suggested that growers keep a portion of each field unsprayed for comparison purposes. The comparison should be based not just on crop appearance or yield, but on how much (or how little) money the fungicide treatment put back into the farm enterprise. The odds are that treated corn or soybean will yield more than untreated crops. However, the economics of treating, even in a high price environment, are much less certain.

Diseases which could warrant fungicide use

Corn

The principal diseases that might justify a fungicide treatment in some corn fields are gray leaf spot and northern leaf blight (FIGURE 3). Both of these are caused by fungi that overwinter in corn residues of leaf blades and sheaths, so they are naturally more severe when corn follows corn under conservation tillage. In most fields, however, a combination of rotation and selection of a hybrid with moderate to high resistance (when available) should help keep these diseases from causing damaging yield losses, without applying a fungicide.

Sometimes fungicides are marketed for their ability to control common rust and southern rust (FIGURE 3). Southern rust certainly can be a destructive disease in Kentucky. This disease typically comes in too late to threaten the large majority of Kentucky

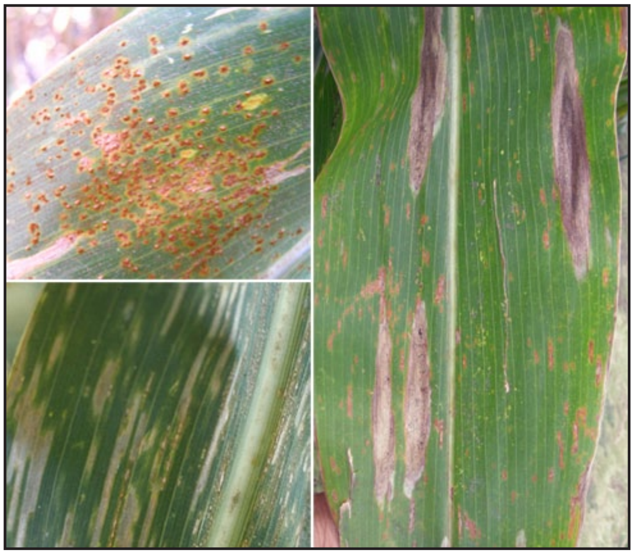

Figure 3. Corn diseases: Southern rust (top left), gray leaf spot (lower left), and northern leaf blight (right).

corn crops, although it can be damaging in certain late-planted fields in some growing seasons. Corn producers with late-planted fields are encouraged to monitor the progress of southern rust by staying tuned in to trusted sources of information, like the *Kentucky Pest News*. Progress of these diseases can also be monitored online at the ipmPIPE Web site (refer to Additional Resources). Keeping tabs on southern rust activity will help provide advance warning if the disease threatens the health of Kentucky corn crops. Common rust is almost always a cosmetic problem in Kentucky since the hybrids grown here typically have sufficient levels of resistance to protect crops from damage. Therefore, in Kentucky, fungicides are almost never needed for common rust control.

Of course, many other diseases can attack corn: anthracnose, various stalk rot diseases, ear rots, kernel rots, common smut, Stewart's wilt, the virus complex, brown spot, northern leaf spot, Holcus spot, etc. With rare exceptions, fungicides will have little to no economic impact against these diseases.

Soybeans

Soybean diseases that might, under the right environmental conditions, warrant a fungicide application in Kentucky include: anthracnose, brown spot, Cercospora leaf blight, frogeye leaf spot, pod and stem blight, and soybean rust (Figure 4). Another common disease, downy mildew, is a cosmetic problem and while present in most fields, almost never requires control. *A critical point to remember is that fungicides are not helpful against the diseases that usually cause the most yield losses in the state* (charcoal rot, soybean cyst nematode, stem canker, and sudden death syndrome). These disease are either not controlled by fungicides, or the timing of application is inappropriate to achieve control. Also, many other common bacterial, viral, and fungal diseases occur on soybean in Kentucky. As with corn, these diseases are rarely impacted by applications of foliar fungicides.

Figure 4. Soybean diseases: pod and stem blight and anthracnose (upper left), Cercospora leaf spot (upper right), brown spot (lower left) and frog-eye leaf spot (lower right).

Spray coverage and timing

Achieving good results with fungicides requires excellent spray coverage, regardless of the crop. Both aerial and ground applications have produced good results in corn and soybean.

There is a recent trend towards greatly reduced spray volumes for both ground and aerial application. For example, some fungicide labels now indicate that it is acceptable to apply as little as 10 gallons per acre by ground and 2 gallons per acre by air. Under ideal spraying conditions, such low rates of application can produce good results. However, using such a low volume is certainly 'on the edge' and the chances of poor treatment performance could be high if an application is attempted during less than ideal conditions, if the application is made by a marginally competent applicator, or the application equipment is not set up and/or functioning properly.

Timing is also critical. Fungi have certain life stages that are vulnerable to fungicides. Similarly, plants have vulnerable stages which might require protection when the risk of target diseases is high. Either case, if a fungicide is applied too early or too late, it will not produce the desired results.

In the case of fungicide applications on corn, the greatest benefit usually comes from a single application at tasseling (VT) through silking (R1). There have been marketing efforts promoting the use of fungicides on early-stage corn (V4 to V8). The advantage of applying fungicide this early is that it may be tank-mixed with an herbicide, so there is no additional cost for application. Based on university research thus far, the early applications, in general, do not provide as much benefit when compared to a VT/R1 application. Furthermore, there is no published evidence that making two applications of fungicide in Kentucky corn is economical. Applications of surfactants or crop oil at V14 has been associated with arrested ear development. Thus, late-vegetative application of fungicide is not recommended.

In the case of soybean, the most efficacious applications are usually made at the early pod (R3) growth stage. Earlier or later applications may be indicated should soybean rust ever need to be controlled in Kentucky. Applications made during the early vegetative stages would be required to get acceptable control of stem canker in a susceptible variety. Fortunately, stem canker is rarely present at sufficient levels to reduce yields, field-wide.

Fungicides provide protection for a limited time and if applied prematurely, they will lose their effectiveness by the time the disease actually makes its appearance. The two reasons that the length of time a fungicide application is limited are:

1. Fungicides degrade and are lost from treated leaf surfaces and
2. New, unprotected leaves emerge after the fungicide application

A majority of scientists agree that most modern fungicides can be expected to maintain efficacy for 21 days. Longer periods have been reported, but it would be a mistake to count on more than 21 days of efficacy.

Mixing fungicides and insecticides

Some producers ask if an insecticide should be included with the fungicide application in place of an adjuvant to provide better distribution of the fungicide on plants, as well as to protect against possible insect damage. UK entomologists respond that an insecticide should be used only if there is a specific threat from insect pests. Routinely including an insecticide in the fungicide application is costly, wasteful, and environmentally damaging if there is no specific insect threat in that field. Adjuvants, which are much cheaper to buy than insecticides, have been developed by the manufacturer specifically to enhance spray coverage. Bottom line: use adjuvants when called for by the fungicide label and only use insecticides to control threatening insect populations as determined through field scouting.

Additional Fungicide Label Claims

Labels of several of strobilurin-based fungicide products include claims of benefits beyond disease control. These labels include claims of optimizing physiological and biochemical processes in crops. Reported benefits may include improved host plant tolerance to yield-robbing environmental stresses, such as drought, heat, cold temperatures, and ozone damage. Specific claims include: increased standability related to induced tolerance to stalk rot diseases (corn), greater tolerance to hail damage (corn), more uniform seed size (corn, soybean, and edible legumes), and better seed quality (soybean and edible legumes). Additional claims may consist of one or more of the following: improved plant utilization of nitrogen, increased photosynthetic rate, reduced rate of chlorophyll degradation (greening effect), heightened plant defense systems to bacterial and viral infections, and enhanced water-use efficiency. Marketing efforts state that these benefits often translate into healthier plants producing greater yields at harvest ("yield bump"), especially under stressful conditions.

Many of these claims are supported by extensive industry research tests conducted in greenhouses and growth chambers. However, controlled studies under field conditions in the U.S. have been limited. University research indicates that some of these benefits do occur. However, they do not occur predictably nor often enough to use the product purely as a growth promoter.

Greening effect

When plants look healthier and stay green longer following a pesticide treatment, this is often referred to as a 'greening effect.' Most producers consider the greening effect to be a good thing, believing that it translates into higher yields. However, this is not always the case as there have been numerous situations in research plots and grower fields where yields of corn or soybean were not improved by fungicide treatment, even when the greening effect was evident.

Figure 5. While the greening effect was observed on the fungicide-treated corn (right) there was no significant yield increase over the untreated corn (left) in this University of Illinois research study.

The greening effect can have a negative impact as well. It can slow or even delay harvest, and grain (mainly corn) may require drying if harvested at a higher moisture content compared to non-treated crops. This translates into additional drying costs and a slower harvest. Conversely, if crop harvest is delayed until the desired harvest moisture content is reached in the field, there can be a yield and/or quality penalty, depending on the crop. When soybean harvest is postponed, for example, pod and stem blight levels may increase, which can reduce the quality of grain destined for seed use. This may necessitate additional grain clean-out and/or the use of seed-treatment fungicides prior to planting next season.

Corn stalk quality

Certain strobilurin fungicides are being marketed for their ability to enhance corn stalk quality. Indeed, improved stalk health in corn sometimes occurs following a fungicide application. Commonly, that improvement in stalk health is due to control of foliar diseases (gray leaf spot, for example). When foliar disease pressure is severe, the blighted leaves cannot produce enough photosynthates (sugars) to adequately fill the ear. When this happens, the plant may 'rob' the stalk for additional sugars, which can damage the integrity of the stalk and allow additional colonization by stalk rotting pathogens. When foliar fungicides do impact stalk rot, it is usually because they are controlling foliar pathogens, thus, indirectly helping to preserve stalk integrity. Therefore, as with yield benefits, a producer is most likely to see improved stalk health in those fields with high disease risk (refer to Figure 1).

In a few experiments, application of a strobilurin fungicide has resulted in improved stalk strength at harvest even where foliar disease pressure was minimal. The reason for improved stalk strength in these cases is unclear, although it may be due to the late-season greening effect discussed above. This is an aspect of fungicide use in corn that we are continuing to research.

Impact of Questionable Fungicide Applications

Fungicide treatments made when disease pressure is low, as well as those that are improperly applied (e.g. wrong time and/or incorrect rate), can have a negative impact on more than just cost and returns. Other concerns related to frequent fungicide usage are as follows.

Fungicide resistance

The use of fungicides increases the risk of fungicide resistance. Anytime a fungus is exposed to a fungicide, even when fungal activity is low, the selection pressure on the fungus is increased towards resistance.

Resistance to strobilurins is an important concern worldwide since these fungicides are known for being prone to resistance development. Strobilurin-resistant isolates of *Cercospora sojina*, the cause of frogeye leaf spot of soybean, have been found in several states, including Kentucky. This is certainly a "warning shot" when it comes to strobilurin use for both soybean and corn. Specifically, the widespread occurrence of strobilurin-resistant *C. sojina* in a field in west Tennessee demonstrates that strobilurin-resistance can develop in field crops in response to overuse of strobilurin fungicides in a production setting.

Another family of fungicides commonly used on corn, the DMI fungicides (also called 'triazoles'), are also prone to the development of fungal resistance. For decades, scientists have watched as fungi all over the world have become incrementally more and more resistant to DMI fungicides. The use of any fungicide for 'plant health' reasons increases the risk of developing resistance.

While there is no way to prevent resistance to strobilurins and DMIs, short of never using them, one can only hope to slow down the development of resistance. The best way to do that is to minimize the use of the at-risk fungicides.

Factors that increase the potential for fungicide resistance include:

- *Over-use or repeated applications of fungicides of the same chemistry*, whether they are used alone or in mixes with other fungicides. Even if the product name is different, as long as the active ingredients are in the same fungicide family, from the point of view of the fungus, it is the same fungicide.
- *Applying fungicides at half-rates*. For DMI fungicides, rates lower than the label recommendation will not be successful in killing all the target pathogens; those that survive are likely to be less sensitive to the

fungicide the next time it is applied. In the case of strobilurin fungicides, resistance development is usually not impacted by application rate and can occur equally at low or high rates of application.

- *Applying a pesticide when disease pressure is already high*. A field that has been severely damaged by disease cannot be cured and there is a good chance that surviving target organisms could result in the development of resistance.

Impact on insect/mite populations

The use of some fungicides, such as the strobilurins, may also incite flares in certain insect and mite populations under field conditions. This can occur when the fungicide suppresses off-target fungi that function to keep these arthropod pest populations in check under normal conditions. There is some evidence that indiscriminate use of fungicides in soybean has resulted in increased insect/mite activity in some states.

Off-target impacts of fungicide applications

Applications of any pesticide in the absence of a specific target pest(s) is contrary to integrated pest management principles and, in the long term, not sustainable. As a result, the environment becomes unnecessarily contaminated. Some pesticides have been shown to adversely affect the soil biology by destroying helpful organisms, such as earthworms. Certain fungicides used in grain crops may also impact tadpole populations active at the time of application.

Bottom line

The best reason to apply a corn or soybean fungicide is when the risk of certain important diseases is sufficiently high to cause concern. Application of a fungicide for other reasons (e.g. more stress tolerance or improved growth efficiency) runs a risk of unnecessarily raising production costs, contaminating the environment, and increasing pesticide residues in the kernels or seeds. Validly conducted research trials consistently show that the growth-promoting and/or stress tolerance benefits of fungicides, in the absence of significant disease, are not yet predictable in either corn or soybean. While an economic yield increase is possible, it is not assured.

We caution producers that widespread use of fungicides in corn and soybean when disease pressure is low is not likely to lead to increased yield and profitability over the long term. Public sentiment regarding unjustified applications of fungicides (or any pesticide) may ultimately lead us closer to prescription agriculture and/or the loss of key fungicides.

Additional Resources

Unless otherwise noted, the following Internet resources are from the University of Kentucky. Hard copies of many UK publications are also available at local County Extension offices.

General

- Integrated Pest Management Information Platform for Extension and Education (USDA ipmPIPE)
http://scr.ipmpipe.org
- Kentucky Pest News
http://www.ca.uky.edu/agcollege/plantpathology/extension/kpnindex.htm

Corn

- Comprehensive Guide to Corn Management in Kentucky, ID-139
http://www.ca.uky.edu/agc/pubs/id/id139/id139.htm
- Corn Stalk Rots, PPA-26
http://www.ca.uky.edu/agc/pubs/ppa/ppa26/ppa26.htm

- Diseases of Concern in Continuous Corn (2008)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-AG-C-1.pdf
- Early Season Fungicide Applications to Corn (Pioneer Crop Insights, 2010)
https://www.pioneer.com/home/site/us/agronomy/library/template.CONTENT/guid.53C0A4C3-2E0A-EB44-D536-032F7CA7653F
- Gray Leaf Spot of Corn, PPA-35 (1995)
http://www.ca.uky.edu/agc/pubs/ppa/ppa35/ppa35.pdf
- Kentucky Integrated Crop Management Manual for Field Crops: Corn, IPM-2 (2009)
http://www.uky.edu/Ag/IPM/manuals/ipm2corn.pdf
- Kentucky Plant Disease Management Guide for Corn and Sorghum, PPA-10a
http://www.ca.uky.edu/agc/pubs/ppa/ppa10a/ppa10a.pdf
- Management of Foliar Diseases in Corn with Fungicides (Pioneer Crop Insights, 2007)
https://www.pioneer.com/home/site/us/agronomy/library/template.CONTENT/guid.C56F4406-88D7-412B-BC05-6986E85995C3

Soybean

- Australasia Soybean Rust—An Exotic Pest Threat (2003)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ppfsags21.pdf
- Brown Spot of Soybean (2003)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ppfsags1.pdf
- Cercospora Leaf Blight in Kentucky, (2009)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ppfsags20.pdf
- Foliar Fungicide and Insecticide Effects on Soybean Yield (Pioneer Crop Insights, 2008)
https://www.pioneer.com/home/site/us/agronomy/library/template.CONTENT/guid.89D0CD5C-457C-42F6-9BD3-C8E18B06692C
- Foliar Fungicide Use to Protect Seed Quality (1994)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ppfags11.htm
- Kentucky Integrated Crop Management Manual for Field Crops: Soybeans (2009)
http://www.uky.edu/Ag/IPM/manuals/ipm3soy.pdf
- Kentucky Soybean Rust Information
http://www.uky.edu/soybeanrust
- National Soybean Rust Web site (Southern IPM Center)
http://www.sbrusa.net
- Soybean Foliar Spots and Blights (2003)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ppfsags19.pdf
- Soybean Loss Prediction Tool for Managing Soybean Rust (2010)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ppfsags10.pdf
- Soybean Rust Fungicide Use Guidelines, (2010)
http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ppfsags23.pdf

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Photos by Scott Bretthauer, University of Illinois (page 1); Paul Vincelli, University of Kentucky (Figs. 1 & 3); Don Hershman, University of Kentucky (Figs. 2 & 4); Carl Bradley, University of Illinois (Fig. 5)