USING FOLIAR FUNGICIDES TO MANAGE SOYBEAN RUST
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For updates and current information, visit: http://www.oardc.ohio-state.edu/SoyRust/

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An Activity of NCERA-208

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Chapter 1

Economic Importance of Soybean Rust

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Soybean rust, a disease that causes serious crop losses in many parts of the world, was first detected in the continental United States in November 2004. Soybean rust is caused by the fungus *Phakopsora pachyrhizi*. Long known to occur in Asia, the fungus spread to Zimbabwe, South Africa; Paraguay; Brazil; Colombia; and now the United States during the last 10 years. Yield losses in other parts of the world due to soybean rust have been reported to range from 10 to 90 percent.

Annual yield losses for North American soybean production are predicted to be at least 10 percent in the upper Midwest, Northeast, and Canada, and 50 percent or greater in the Mississippi Delta and southeastern states. However, losses in hard-hit areas anywhere in North America could exceed 80 percent if effective management tactics are not deployed.

Soybean Rust Disease Symptoms

The first symptoms of soybean rust are small brown or brick-red spots on the upper leaf surface (Figure 1.1). The spots, which are initially less than half the size of a leaf hair, are frequently best seen by holding leaves up to a light source so that they are backlit.

Eventually, pustules will form in the spots, primarily on the undersides of leaves. Pustules initially have raised centers that eventually break open (circular opening) to reveal masses of urediniospores. Spore masses can readily be seen using a 20x hand lens. As pustules become numerous, leaves turn yellow and drop prematurely. Prematurely defoliated plants have fewer pods, fewer seeds per pod, and poorly filled seeds.

Be aware that in the early stages of infection, soybean rust looks very similar to many other soybean foliar diseases, including brown spot, bacterial blight, bacterial pustule, Cercospora leaf blight, downy mildew, and frogeye leaf spot and abiotic factors such as burning herbicide compounds.
Figure 1.1. Soybean rust.

- Upper leaf symptoms
- Pustules (with spores) under 20x hand lens
- Backlit leaf
- Top leaf—mid-stage of infection
- Bottom of leaf with severe infection
- Top of severely infected leaf
Soybean Rust Disease Cycle

Spots and pustules form in leaves when fungal spores, called urediniospores, blow into fields, land on soybean leaves, and infect leaves under favorable conditions. Spots are evident about four days after infection, and pustules can be seen after about 10 days. One pustule can produce urediniospores for about three weeks. Wind disperses these spores, which in turn results in more infections. Rapid increases in disease incidence and severity usually coincide with canopy closure and the beginning of crop flowering.

This cycle of infection and development of pustules and urediniospores will continue until the plant is totally defoliated or until weather no longer favors disease development. Defoliation may occur when as little as 30 to 40 percent of the total leaf area shows symptoms and signs of rust. Premature defoliation can occur four to six weeks after initial infection.

Soybean rust, like most rusts, is capable of progressing rapidly once initial infection takes place. Rusts produce spores that reinfect the host plant population in a field, leading to a very rapid increase in disease under favorable conditions. Soybean rust progresses rapidly when dew periods are long (and frequent) and/or rain events are frequent, and when temperatures are optimum for infection (Table 1.1). Note: Infections can occur over a broad temperature range (59 to 84˚F), but will take a longer time to mature into new pustules at temperature extremes. The most favorable period for soybean rust is likely to vary for different parts of the country, but risk may be greatest, nationwide, in July.

<table>
<thead>
<tr>
<th>Rust</th>
<th>Infection Optimum</th>
<th>Time needed for Infection (hrs)</th>
<th>Generation Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat leaf</td>
<td>59–73˚F</td>
<td>6–8</td>
<td>7–10</td>
</tr>
<tr>
<td>Corn (common)</td>
<td>61–77˚F</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Soybean</td>
<td>68–77˚F</td>
<td>6</td>
<td>9–10</td>
</tr>
</tbody>
</table>

Table 1.1. Infection optimum temperatures and generation times for soybean rust as compared to two other common rusts.
Because of the way successive infections develop with rust fungi, they are referred to as “compound interest” diseases. Just as money invested at compound interest increases exponentially, the number of rust pustules in a field increases exponentially. The difference is that your bank account may earn 3 to 5 percent, or a good mutual fund may earn 12 percent per year; however, once rust becomes established in a field, rust may increase at a 300-percent rate compounded every 9 to 10 days as in the case of soybean rust (Figure 1.3)!
DISEASE PROGRESS CURVE

Figure 1.3. A typical rust disease progress curve. Since rusts produce more spores capable of reinfecting the host plant, disease severity starts slowly but increases logarithmically until the food source — leaves — becomes limiting or the environment becomes less favorable for growth and reproduction.

Fungicides provide protection and delay soybean rust epidemics as long as they remain in sufficient concentration in or on the soybean leaf. For fungicides to be optimally effective against soybean rust, they must be applied at the proper time. Experience from Africa, Brazil, and the southern United States indicates that early treatment is critical for optimum fungicide performance with soybean rust.

**Annual Survival and Movement of Phakopsora pachyrhizi**

The soybean rust fungus is an obligate parasite and cannot survive outside host tissue except as short-lived urediniospores. As a result, this fungus will only overwinter in southern areas that are free from killing frost (Figure 1.4). In these areas, the fungus continually infects other hosts, i.e., kudzu. In any given year, the onset of an epidemic will depend upon where the soybean rust fungus overwinters, how much overwinters, if weather conditions favor build-up of infection in these areas, and the existence of sufficient tracts of winds and storms to move spores out of overwintering locations and into new regions.
Management Overview

As in other countries where soybean rust occurs, fungicides will be the primary means of managing soybean rust in the United States and Canada until acceptable resistant cultivars are developed. As soybean rust has spread around the world, fungicide use has become commonplace. Although the disease can cause significant losses in yield and quality, producers in other parts of the world have learned to manage soybean rust economically through the use of fungicides. The economic return on those products varies based on age of plant when disease initiates (R1 vs. R5), disease pressure, crop yield potential, and efficacy of available products. Nevertheless, fungicides have produced acceptable control of soybean rust when properly used.

Despite the significant benefits, controlling soybean rust with fungicides comes with a cost. For example, soybean producers in Brazil spent close to $1 billion on fungicide control of soybean rust during 2003-04. In addition, some Brazilian producers have reported difficulties in deploying appropriate fungicide treatments when needed. Difficulties include fungicide availability, inability to detect initial soybean rust symptoms, inability to spray all of the crop as quickly as needed, application errors, physical barriers to application, and relative high cost of treatment. U.S. soybean producers are likely to encounter similar problems.

Costs of applying fungicide for soybean rust control are estimated to range from $10 to $35 per acre per application.

Figure 1.4. Potential sites in North America, the Caribbean, Central America, and South America where soybean rust may overwinter. (Yang et al., 2004.) Used with permission.
Early detection of soybean rust in a region is key to successful management of the disease. Fungicides must be applied in the early stages of a soybean rust epidemic (i.e., pre-infection to less than 5 percent incidence on leaves in the lower canopy) to be highly effective. Incidence in this case refers to only five out of 100 plants having rust, and there may be only one to two pustules on the leaves. Rust is difficult to detect at these low levels.

Disease control may be severely compromised if applications are made before any infections occur in a field or after soybean rust is firmly established (>10 percent incidence in the mid-canopy). Making applications later in a disease epidemic may be an exercise in futility. Reports from Brazil indicate that when 20 to 30 percent of the soybean leaves in the mid canopy are affected by soybean rust, fungicides are no longer able to protect plants sufficiently from additional infections, or yield reduction is already so great that a fungicide application cannot recover treatment cost. Generally speaking, 10 percent disease incidence in the lower canopy should be considered the maximum action threshold for initial application of fungicides for soybean rust management using a curative strategy. This amount of disease is very small and will require thorough scouting in the field. A note of caution: More disease is often present than can be detected using traditional field scouting methods. This is because some infections will be in the pre-symptomatic stages when observations are made.

Data from Africa, South America, and now North America indicate that not all fungicides have equal efficacy against soybean rust. Also, some fungicides may be phytotoxic on certain soybean cultivars, under some conditions. Research is in progress on fungicide efficacy under North American conditions, to determine which cultivars may be injured by which products, and which combinations result in measurable yield loss. Thus, the decision as to which fungicide to apply can have a great influence on the outcome.

Because of the differences in efficacy and activity, it is critical for producers to have access to products with multiple modes of action, which provide for effective disease control but also minimize the chance that the fungus will become resistant to a fungicide. Preliminary epidemiological models indicate that soybean rust may not be an economic problem in every production year in every region of the United States and Canada. The soybean rust pathogen may, in fact, behave like the wheat or corn rust pathogens, where the timing of rust movement from overwintering locations to the main production regions varies from year to year. In addition, studies in the United States and Canada indicate that the timing of rust movement may be influenced by climate conditions, such as temperature and precipitation, which can affect the growth and development of the rust pathogen.
States have shown that spores are sensitive to ultraviolet radiation; thus, rain storms may become the primary mode of transportation. This will make monitoring and forecasting programs all that more important to both limit unnecessary fungicide use and facilitate effective deployment of fungicides when they are needed.

**Importance of Applying Fungicides Correctly**

Fungicides must be applied correctly to achieve effective, economical control of soybean rust. Because soybean rust tends to develop initially in the lower and mid canopy, thorough coverage of foliage, including penetration of spray into the canopy, is essential for achieving successful control of rust. Fungicides are best applied at higher gallons per acre, higher pressures, and with different nozzle tips than herbicides. Research is under way to improve fungicide spray technology for best management of soybean rust. Results from these studies may also help with future delivery of insecticides to soybean.

The most important thing to remember about soybean rust control with fungicides is coverage. Control is directly related to how thoroughly the fungicide spray covers leaf tissue. Better coverage results when the spray is delivered as fine to medium droplets (about 200 to 300 μm). This is why higher spray pressures, nozzles with smaller orifices, and higher spray volumes per acre are used with fungicides than is customary for herbicides.

Despite the considerable need to improve existing fungicide spray technology, current spray technology (aerial and ground) has performed adequately for soybean rust control in other countries. Similarly, North American soybean producers have access to the appropriate spray technology to achieve excellent results against soybean rust using foliar fungicides. One question that is still to be answered, however, is if North American soybean producers have the capacity to spray fields as quickly as may be needed during a soybean rust epidemic. This could be a special challenge in areas of the country that have historically relied on custom applicators to apply pesticides.

**Recent Fungicide Special Labeling Activities**

The normal route of pesticide registration in the United States is through Section 3 of the Federal Insecticide, Fungicide, and Rodenticide Act of 1947 (FIFRA). This Act has been amended several times (most extensively in 1972), but it remains the foundation for pesticide regulation. Registration of all pesticides is handled by the

Although fungicides are an important soybean rust management tool, it should be noted that only a few fungicides currently have a federal label for use on soybean in the United States and Canada. Registrations and recommendations will change over time as more products move through the registration process and obtain full Section 3 labels, as compared to Section 18 Emergency Use labels, and as we become more familiar with the level of control provided by each of these products. The comments presented here are intended to provide general information about currently registered fungicides. It is always the applicator’s responsibility to read and follow all label instructions. In today’s modern agriculture, regulations and recommendations can change rapidly; therefore, check with your local agricultural supply dealer, or the pesticide manufacturer, for updated label information prior to making applications.
U.S. Environmental Protection Agency (EPA). Section 3 of FIFRA provides the normal pesticide registration process. However, the EPA acknowledges that there are needs for exceptions to the general process. As such, sections are provided in the law that allow for rapid response to critical issues, thus giving states a legal avenue to address special local needs (Section 24c exemptions) or emergency/crisis situations (Section 18 exemption). Thus, producers may have access to products that are not specifically labeled for a given crop or pest, but have been shown to effectively control the pest in question. For clarifications on these rules, contact your state or provincial Department of Agriculture.

In response to the recognition that soybean rust could become a serious problem in North America and that there was an inadequate supply of labeled, efficacious fungicides, a Section 18 template was developed in the winter of 2003 to facilitate submission of Section 18 applications to EPA from each soybean-producing state. Several products were proposed, based on the best available information, from among products that had been evaluated against soybean rust in other countries. Over the coming years, the preferred products will likely change as more data are generated in the United States. Each state must request a Section 18 from EPA for a product to be legally available for use by growers in that state.

In Canada, a similar need for efficacious fungicides resulted in an Emergency Use Submission to the Pest Management Regulatory Agency (PMRA) in 2004. More products will be submitted to PMRA in the future. As well, a full Canadian registration of these products will be pursued for soybean rust control.

**Purpose of Publication**

Foliar applications of fungicides to the soybean canopy will be the standard disease-management practice to limit yield losses due to soybean rust for the foreseeable future. This bulletin reviews the factors involved in making fungicide spray decisions and basic fungicide information, including mode of action, application, and use strategies. Specific recommendations for each state, province, or region are likely to vary depending on whether sources of rust inoculum are within the region, state, or province; how conducive the weather is for soybean rust; the growth stage of soybean when rust becomes a threat; yield potential of the crop; and price of soybeans. For these reasons, be sure to consult local soybean rust management guidelines and information when making decisions on best management practices for soybean rust control.
Chapter 2


Edward Sikora, Auburn University
Donald Hershman, University of Kentucky

It has been three years since soybean rust (*Phakopsora pachyrhizi*) was first detected at the Louisiana State University (LSU) AgCenter Research Farm in the wake of Hurricane Ivan (November 6, 2004) (Figure 2.1 and Figure 2.2). Since then, the priorities of thousands of individuals with direct and indirect connection to the soybean industry in North America have been radically altered due to the impact soybean rust could have on the agricultural economy of the United States and Canada. Although the full effect of soybean rust on soybean production in North America has yet to be determined, its presence has resulted in unprecedented cooperation and communication among soybean producers; university, government, and industry scientists; commodity and industry leaders; and policy makers throughout North America.

Figure 2.1. Rust spores picked up in hurricane Ivan were carried in the storm and deposited in the Gulf Coast and the southeastern United States as the storm hit.

MODIS images courtesy of Liam Gumley/UW-CIMSS. CIMSS.ssec.wisc.edu/tropic/archive/2004/storms/ivan/ivan.html Used with permission.
Economic Importance of Soybean Rust

As outlined earlier in this manual, in other parts of the world, maximum yield losses in soybean due to soybean rust have been reported to range from 10 to 90 percent. It was predicted that annual yield losses for North America would be at least 10 percent in the upper Midwest, Northeast, and Canada, and 50 percent or greater in the Mississippi Delta and the Southeastern states. It was also suggested that losses in heavily-infected areas anywhere in North America could exceed 80 percent if effective management strategies were not used.

After three growing seasons of coexisting with soybean rust, these estimated yield losses have not been realized on a large scale. However, there were substantial yield losses in some producer fields in Alabama and Georgia in 2005 and in Louisiana in 2006. In addition, research plots in these states, as well as in Florida and South Carolina, have suffered substantial yield loss where the disease was not effectively controlled with fungicides. Thus, although reports of substantial yield loss in grower fields have been few, it is very likely that we have yet to experience the losses that could occur once the disease becomes endemic in

Figure 2.2. Soybean rust distribution in the United States following Hurricane Ivan during 2004.

Courtesy of Thomas Weissling and Loren Giesler, University of Nebraska-Lincoln. Used with permission.
kudzu in the deep South (for maximum overwinter survival of the soybean rust pathogen). Clearly, there are many reasons for soybean producers to be concerned about how future soybean rust epidemics might impact the North American soybean crop, even though at this time the fear of soybean rust has subsided.

**Observations from 2005**

In 2005, soybean rust spread from a few overwintered kudzu patches in Florida to numerous sites (soybean and kudzu) throughout Alabama, Florida, Georgia, South Carolina, and North Carolina (Figures 2.3 – 2.5). There were also a few isolated confirmations in Louisiana, Mississippi, and Texas. Spread of soybean rust was slow during most of the 2005 season, but the number of confirmations rapidly increased in November, especially in North Carolina. The slow initial rate of spread can be partly explained by low initial spore levels, most likely the result of soybean rust’s late introduction into the United States in the fall of 2004.
The relatively low spore levels may also account for the lack of significant spread of soybean rust following early season tropical storms in the Southeast that many thought would incite rapid spread of the disease throughout the region. In actuality, soybean rust did not begin to spread broadly until after the beginning of September, following relatively dry conditions in the Southeast in July and August, which likely also hindered development of the disease.

By the end of 2005, soybean rust was confirmed in 138 counties in nine states, with the most northerly report from a patch of kudzu in Kentucky. There were a few reports of yield losses in Georgia and Alabama, but far less than anticipated. The 2005 experience allowed soybean specialists a chance to work with the disease on a limited basis and provided a great educational tool for the many scientists, educators, consultants, and producers who visited soybean rust sites in the South.

**Observations from 2006**

Great concern about soybean rust was warranted in 2006 after the disease had an opportunity to become more established in kudzu in the South during the winter months of 2005-2006. For example, in 2005 it was reported that 10 percent of the kudzu patches in Florida had soybean rust. This number increased to 40 percent in 2006 (Jim Marois, personal communication). The disease was also found overwintering at low levels in kudzu in Alabama (Figures 2.6 - 2.8), Georgia, and Texas. The pathogen survived in protected sites in urban areas, some as far north as Montgomery, Alabama. Montgomery is well over 100 miles from the Florida panhandle, and much farther north than central Florida where many suggested the disease would “retreat” after a hard winter freeze.
Figure 2.7. Soybean-rust infected kudzu in Daphne, Alabama. January 8, 2007. E. Sikora, Auburn University. Used with permission.

Figure 2.8. Soybean-rust infected kudzu, Mobile, Alabama. January 8, 2007. E. Sikora, Auburn University. Used with permission.
Although the mild winter appeared to favor an outbreak of soybean rust during the 2006 season, a severe drought throughout much of the South, stretching from Texas to Georgia, kept the disease in check in most southern locations during the summer months. However, in the East, the path of tropical storm Ernesto (Aug. 28-Sept. 2, 2006), which moved west-to-east across central Florida, then out into the Atlantic Ocean and back across the Carolinas, provided ideal conditions for the spread of soybean rust along the eastern seaboard late in the season. The disease was eventually found throughout North and South Carolina and Virginia.

In addition, favorable weather conditions in southern Louisiana in August allowed the disease to make headway in the lower Mississippi Delta, eventually becoming the probable source of spores for late-season spread of soybean rust into Arkansas, Tennessee, Missouri, Kentucky, Illinois, and Indiana in October (Figure 2.9). The disease was eventually found as far north as West Lafayette, Indiana. By the end of December, soybean rust had been detected in 15 states. This included 274 counties, more than double the number of counties in 2005. Once again, the late movement of the disease into soybean-producing states resulted in few reports of yield loss.

**Observations from 2007**

As in 2006, a similar pattern emerged in the early months of 2007. A mild winter in the South allowed the pathogen to survive in kudzu at similar levels and locations as were observed the previous year. However, a freeze in late April appeared to kill-back much of the kudzu in south Alabama, Georgia, and north Florida, thus reducing the overwintering inoculum of soybean rust in these areas. The spring freeze was followed by a severe drought in this three-state region that slowed the re-growth of kudzu and the build-up and spread of the disease in the Southeast.

However, it appears that rust survived the winter in northern sections of Mexico and/or

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*Figure 2.9. Soybean-rust distribution map, 2006. U.S. Department of Agriculture.*
southern parts of Texas and/or Louisiana. The first report of the disease in Louisiana occurred on May 11, 53 days earlier than the previous year. This was followed by a report of soybean rust in eastern Texas on June 2. By the end of July, the disease had spread throughout the eastern half of Texas and up through central Louisiana, as well as crossing the border into far southern Arkansas and Oklahoma.

In August and early September, hot, dry conditions in the central Plains states and the prolonged drought in the Southeast, kept the disease in check and prevented rapid spread of the pathogen in many areas during this period. However, by the end of September, the floodgates opened and soybean rust was common and increasing in parts of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Oklahoma, South Carolina, and Texas. Rust also was detected in Kansas, Missouri, Kentucky, Illinois, and as far north as central Iowa. Increased activity late in the season was, in part, due to tropical depressions that moved through the Gulf Coast states into the Midwest during late August and mid-September, depositing significant amounts of rainfall and soybean rust spores along the way.

The outbreak of rust in the Midwest had little or no effect on yield as the majority of the soybean crop was well beyond the point of maturity where it could be damaged by the disease. However, as in 2006, the rapid movement of soybean rust late in the season again emphasizes the potential for soybean rust to spread long distances as a result of a major storm systems. By the end of November 2007, when this summary was completed, soybean rust had been detected in 250 counties in 19 states and Ontario, Canada (Figure 2.10).

Figure 2.10. By the end of November 2007, soybean rust had been detected in 250 counties in 19 states and Ontario, Canada. U.S. Department of Agriculture.
Lessons Learned

Two patterns observed in both 2006 and 2007 should be noted when considering potential outbreaks of soybean rust in the years to come:

- The rapid movement of the disease from Louisiana up the Mississippi River Valley and into the major soybean-producing states bordering the Ohio River Valley (Figure 2.10).
- The effect of tropical storm Ernesto when levels of the rust fungus were considered relatively high and weather conditions following the storm were favorable for soybean rust development.

These observations allow us to envision a worst-case scenario in which weather conditions provide soybean rust the opportunity to invade the major soybean production area of the central United States in a short period of time. In this scenario, a mild winter in the South (allowing maximum survival of the soybean rust pathogen) is followed by a relatively wet late-spring, early-summer period (supporting maximum disease buildup). Couple these conditions with an early tropical storm or hurricane that takes a favorable, northerly path through the South in the direction of the Soybean Belt. It’s conceivable that when these conditions coincide, soybean rust could have a significant impact on soybean production in North America, especially if fungicides are not used effectively.

The impact of such a scenario could be lessened by the ability of soybean specialists to predict its occurrence based on the monitoring programs currently in place and supported by predictive models that are currently being developed. Success in managing the disease would ultimately rely on soybean producers applying fungicides in a timely manner based on rust alerts provided by Extension and the agricultural industry.

Information Is Key

Dissemination of timely and accurate soybean rust information has been, and will continue to be, a key to effective soybean rust management. During the first two years, it is estimated that North American soybean producers may have saved as much as $600 million by NOT making unnecessary fungicide applications for soybean rust control. In 2005, many soybean producers had access to trusted information that the risk of soybean rust was low in most areas. In 2006, fewer
growers were poised to spray than in 2005, but most made the appropriate decision not to spray for soybean rust because the risk was, again, very low throughout most of the season.

The main point is that producers had the information they needed to make the decision NOT to spray a fungicide. A significant lack of this information, or dissemination of inaccurate information, could have led to a free-for-all with the potential for millions of soybean acres to be sprayed unnecessarily in North America.

Soybean producers now have access to a variety of educational and informational resources on soybean rust and its management. The IPM-PIPE (Pest Information Platform for Extension and Education) soybean rust website (www.sbrusa.net) is a primary repository for current soybean rust activity maps, state-specific commentaries and recommendations, and links to essential resources having to do with soybean rust (Figure 2.11). In addition, many land-grant universities, companies, commodity organizations, and governmental agencies have developed an array of informational and educational products and resources that allow anyone with an interest in soybean rust to stay on the leading edge of soybean rust awareness.

We all hope that a large-scale epidemic of soybean rust will never occur in North America. However, most soybean pathologists agree that it is not a question of if an epidemic will occur, but when and how often. At some point in the near or distant future, soybean producers in the Soybean Belt will probably be confronted with an epidemic of soybean rust. When this scenario materializes, it will be essential for everyone involved in the soybean industry to be tuned in to the most accurate and timely information sources available. These resources are now in place, and we are prepared to meet the soybean rust challenge into the future.

Figure 2.11. Ed Sikora (left), Auburn University; Arcenio Gutierrez-Estrada, University of Chiapas (center); and Donald Hershman (right), University of Kentucky, scouting for soybean rust for the IPM-PIPE database.
Correct assessment of the risk of soybean rust is key to making effective and economical fungicide applications. Like corn and wheat rusts, soybean rust spreads from south to north during the growing season. Thus, it is possible to assess progressive risk of soybean rust over a growing season and use this information to make informed fungicide-use decisions.

Three factors are key in determining the risk of soybean rust movement into more northern soybean production regions:

- The extent of soybean rust during the spring and early summer in the Gulf Coast area, which determines the amount of spores available to blow northward.
- The July-August weather that determines how favorable local conditions are for soybean rust development.
- Forecasted or observed northward movement of soybean rust spores in weather systems and rust observations in sentinel plots.

Producers in many soybean production areas in North America may be able to assess the risk of seasonal outbreaks using the following steps throughout the year:

- March
  Monitor information (Figure 3.1 and Figure 3.2) on the occurrence of soybean rust in the Gulf Coast states (Alabama, Florida, Louisiana, Mississippi, and Texas) and Georgia. This will be an early indication of the likelihood of rust spore movement into more northern production areas as the season progresses.

- April, May, and June
  Closely monitor reports on soybean rust occurrence in Alabama, Louisiana, Mississippi, and Texas. These states comprise the region that might act as a rust pathway to the north. Georgia is also a state to watch, but has less predictive impact than the other states. If outbreaks occur on soybean plants or kudzu in any of these states during this period, the spores are likely to reach northern soybean regions as early as July.

A network of sentinel plots stretching from the Gulf Coast and into the upper Midwest and Canada provides critical ground-truth information on the actual occurrence and progress of soybean rust in North America (see Chapter 4). Check the USDA public soybean rust web site (www.sbrusa.net) to monitor the northward movement of this disease and to gain access to state-
Factors to Consider in Determining Risk

The decision to spray or not to spray fungicides for control of soybean rust is complex. Fungicides are highly effective at controlling soybean rust, but there are several factors to consider in making spray decisions to manage soybean rust. It still is expected that although soybean rust could affect soybean production throughout North America, it will be endemic in the southeastern states and seasonal in northern states. Disease epidemics are also likely to vary from season to season. Thus, spray decisions (i.e., determining the need to spray, when to spray, and the number of sprays) will be different from region to region and season to season. Generally, a fungicide should not be applied for soybean rust control until the risk of infection is high.

These criteria are the basis of soybean rust risk assessment:

1. Crop Stage

Data from the southeastern United States indicates that the most critical period for soybean rust management is from beginning flowering (R1) through full seed (R6). In other
words, fungicide sprays before beginning flowering or after full seed may not produce an economical return. However, there are limited data from Brazil showing that fungicide applications made during the vegetative stages are occasionally economical. The same is true for fungicide applications at R6 in the southern United States.

### 2. Output from Soybean Rust Forecasting Systems

Outbreaks of disease are highly associated with rain and especially above-normal rainfall patterns. Forecasting systems can be effective decision-making tools for managing soybean rust. These systems can be simple, with disease forecasts being based on observations from sentinel plots, or with forecasts being based on complex computer models, rust spore movement, and current and predicted weather. Computer models have been developed for soybean rust forecasting and are currently being applied. (See Chapter 5 for more information on soybean rust modeling efforts.)

### 3. Results of Scouting, Detection, and Diagnostic Activities

The sentinel plot system has been used effectively in the southeastern United States to indicate when fungicide application is necessary. Spray warnings are given once soybean rust is found in sentinel plots. Because soybean rust is usually first observed on plants of more advanced growth (beginning flowering [R1] or later), the sentinel plantings have provided an opportunity to observe the first signs of the disease BEFORE the disease gets a foothold in neighboring production fields. In addition, sentinel plot data from the Southeast has been very useful to soybean producers in the Mid-South, Midwest, Northeast, and Canada who are attempting to establish their soybean rust risk.

For those producers who would rather wait for local rust disease development before deciding to apply a fungicide for soybean rust control, field scouting can be done, but great care must be taken. It is very easy to miss the early stages of soybean rust in a field, and there is significant risk that by the time you see the disease, it may be too late to get complete control. To determine if soybean rust is present and at what level, a thorough visual examination of soybean plants in fields, over time, is crucial. When walking through fields, periodically stop and closely examine the soybean plants. Look down into the lower plant canopy because this is where initial soybean rust pustules usually first develop. Closely examine the undersides of leaves for tell-tale pustules of soybean rust. Be sure to examine several sites throughout each field; do not restrict scouting activities to the edges of fields.
Since rust fungi, in general, require free moisture and/or high humidity to germinate and infect leaves, focus on shaded areas of the field, low spots, or areas of poor air circulation. If there are places in a field with a distinct yellowing or browning, these areas should be targeted in addition to the standard scouting pattern being used. If soybean rust is suspected, collect samples and carry or overnight them to your state’s plant disease diagnostic laboratory. Alternatively, report the location to your local Extension office immediately. The earlier rust is detected, the more likely it is that fungicide applications will be effective.

Be aware that several other foliar diseases are easily confused with soybean rust, especially when rust is in the early stages of pustule formation. (See Chapter 12 on Similar Looking Diseases.)

4. Single vs. Multiple Fungicide Applications

The number of fungicide sprays required to achieve acceptable control of soybean rust will depend on five main factors:

• The stage of crop development when the disease first appears.
• The incidence and severity of infection as determined by crop scouting.
• Current and forecasted weather conditions.
• Price of soybeans.
• Cost of application.

The earlier in the growing season soybean rust is detected, the more sprays may be needed to achieve acceptable disease control. More than one application may be needed if the first application is made at or before beginning flowering (R1), and the weather continues to favor rust development. However, if growing conditions are hot with less than normal rainfall, soybean rust is unlikely to develop to damaging levels, and fungicide applications may not be needed at all. To avoid mistakes and possible crop failures, producers should discuss spray options with someone who is familiar with local farm operations and also familiar with soybean rust biology and the range of fungicide control options.

5. Timing of Fungicide Applications

When it comes to timing of application, there are two obvious mistakes, both of which can be very costly. Soybean rust can spread very quickly, and poor timing of fungicide sprays would be followed by disease-control failure. Spraying too early can result in the fungicide wearing off by the time infection occurs. Conversely, waiting until the disease has progressed too far to spray will not stop the disease. The ideal time to make the first fungicide application for soybean rust control is when the risk of
infection is high, but before infection occurs; this is the purpose of sentinel plots and disease forecasting.

**A word of caution:** Each fungicide has a unique preharvest interval indicated on the product label (see Table 3.1 and Appendix Table B.2 for a full list). If a fungicide spray is needed for soybean rust control late in the season, this preharvest interval, which varies from as short as 14 days to as long as 42 days, may have a great impact on which fungicide you may legally apply. For some fungicides, the specific growth stage is listed — the number of days that a variety is at a specific growth stage will also vary from year to year and region to region. To avoid problems, it is prudent to ascertain a product’s preharvest interval BEFORE making an application.

### Table 3.1. Preharvest intervals for soybean rust fungicides.

<table>
<thead>
<tr>
<th>Fungicide Class</th>
<th>Product</th>
<th>Preharvest Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloronitrile</td>
<td>Bravo, Echo</td>
<td>42</td>
</tr>
<tr>
<td>Strobilurins</td>
<td>Quadris Headline</td>
<td>14, 21</td>
</tr>
<tr>
<td>Triazoles</td>
<td>Caramba, Topguard</td>
<td>21, 30</td>
</tr>
<tr>
<td></td>
<td>Folicur</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alto, Punch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bumper, Domark</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Laredo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Propimax</td>
<td></td>
</tr>
<tr>
<td>Strobilurin &amp; Triazole</td>
<td>Quadris Xtra</td>
<td>30</td>
</tr>
</tbody>
</table>

**6. Information Reliability**

We are exposed to information from a wide range of sources — from the corner coffee shop to the Internet, to publications and newscasts. It is important that growers base fungicide spray decisions on information from unbiased, reputable sources. These include university cooperative extension services, government, industry or commodity group web sites, and newsletters or news releases from these organizations.

**7. Understanding Risks Associated With Fungicide Spray Decisions**

It is imperative that growers follow spray guidelines and adhere to the labeled rates for each fungicide. As previously mentioned, the method of
fungicide application is very important — fungicides must cover the whole plant and get into the canopy to be effective. If the correct equipment (nozzle type, pressure, adjuvants, and timing) is not used, there is considerable risk of failure. Failure to adequately control soybean rust will also occur when poor fungicide decisions are acted on, or when otherwise good decisions are not implemented properly. Either situation is likely to result in reduced economic returns.

Spray decisions may also have an effect on crop insurance claims filed. Therefore, it is essential to keep complete records of what was done and how spray decisions were made.

To be in compliance with the law, growers must have a copy of the Section 18/Emergency Use label in their possession when the product is applied. Long-range weather predictions made in April and May, indicating that July and August weather conditions may favor rust outbreaks in the north, should be considered in risk assessment for soybean rust. The current disease models use the weather predictions (precipitation and temperature) to calculate the risk of soybean rust. However, it must be understood that the predictions are subject to error. Thus, the most reliable way to establish the need to spray fungicides for soybean rust control continues to be early disease detection.
Chapter 4

The Sentinel Plot System: Monitoring Movement of an Invasive Pathogen

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Layla Sconyers, University of Georgia

Sentinel Plots in the United States

Sentinel plots are used to monitor airborne pathogens in other parts of the world, and disease-tracking systems are used to monitor other diseases in the United States. Soybean rust (SBR) sentinel plots are monitored in Brazil to predict risk. In the United States, cereal rusts and blue mold of tobacco are tracked each season. As part of the USDA-APHIS, the United Soybean Board (USB), the North Central Soybean Research Program (NCSRP), and state (or local) soybean check-offs, the progress of soybean rust development was monitored during 2005, 2006, and 2007 and will be monitored in 2008 with a total of 574 sites in 35 states. Five Canadian provinces are also involved in the monitoring effort in 2007. A single soybean rust monitoring protocol has been developed for all sentinel plots included in this system.

The sentinel program for monitoring SBR in North America has three objectives. The primary objective is to serve as a warning network for tracking the spread of the disease in North America. For this reason, and because the pathogen can only over-winter in subtropical regions, southern and Mississippi Valley states have more sentinel plots relative to their soybean acreages than states in other regions. The second objective is to quantify the timing and amount of spore production in over-wintering and growing-season source areas, an important input for the SBR aerobiology prediction system. A third objective of the sentinel plot system is to collect data for epidemiological research. For this reason, sentinel plots should be maintained after first detection unless other considerations dictate otherwise. The decision to destroy sentinel plots after detection is left to each state.

In each participating state or province, multiple locations are planted to one acre or less of several maturity groups up to approximately one month prior to commercial soybean planting (Figure 4.1). The greatest risk for disease development is during the reproductive stages of soybean development (first bloom to pod fill), and scouting should be intensified during this time. Monitoring of sentinel locations is year-round in the southern United States. During the winter months, kudzu (Figure 4.2) and other legumes are also monitored for SBR development. After SBR is detected, the decision to continue to monitor disease development in the sentinel plot is left to the individual state.
Sentinel plot monitoring in many states is being done by each state’s county Extension educators/agents. These individuals have been trained on how to identify soybean rust and other common diseases of soybean (Figure 4.3). Due to the difficulty of detecting SBR at low incidence and severity, many states have their cooperators mail leaf samples to a central diagnostic lab where the leaves are incubated prior to observation with microscopy.

Data from all sentinel plots are uploaded to the USDA’s SBR-
Pest Information Platform for Extension and Education (PIPE) web site. In each state, the monitoring program is supervised by the state Extension soybean pathologist. Soybean rust data are entered into a database as part of the PIPE program. Data entered into this system are used for refining disease-forecasting models. Counties that have been scouted with no soybean rust detected are colored green, while counties where rust has been detected are colored red. All detections, including samples from diagnostic clinics, are also entered into this database. This system provides a real-time representation of soybean rust and scouting efforts. The data are used by the state Extension specialists in making recommendations for fungicide applications.

Utilization of Spore Traps in Predicting Soybean Rust Spread

As part of a study conducted by Syngenta Crop Protection and the University of Arkansas, spore traps (Figure 4.4) have been placed (in 2005, 2006, and 2007) in sentinel plots throughout participating soybean-producing states. The traps are used to collect rust spores onto a petroleum-jelly-coated microscope slide. The purpose of this study is to determine if these spore traps could be used to provide an additional warning tool for soybean rust by detecting the presence of rust spores that may lead to the development of the disease. The implication of finding spores in these traps is unknown at this time in the United States because
spores of soybean rust cannot be reliably distinguished from spores of some other fungi by visual examination only. The decision to release information pertaining to spore detection has been left up to each state specialist. Even when we can confirm that the spores are soybean rust, we are uncertain of the viability of the spores found in the traps. Research has shown that there are lethal effects of ultraviolet radiation and desiccation while spores are transported in the air; these will vary significantly as a result of weather.

Currently, the spore traps provide an indication that soybean rust spores may be in the area. This does not necessarily mean that soybean rust will develop. In 2005, “soybean rust-like” spores were detected as far north as Minnesota and Canada, yet soybean rust never developed north of Kentucky. In 2006, “soybean rust spores” were detected across the Great Plains into the Dakotas, and rust did not develop. At present, researchers are trying to improve their ability to identify the correct species of the spores that are recovered in these traps. Since this disease has the potential to spread quickly, there is a need for a quick field diagnosis. Researchers are currently working on the development of more rapid field diagnostic tests (e.g., ELISA quick strips).

**Figure 4.4. A Syngenta spore trap.**
Chapter 5

Sentinel Plots in the United States: Modeling the Seasonal Spread of Soybean Rust in North America

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The goal of soybean rust modeling is to provide state plant pathology Extension specialists with an unprecedented level of support for tracking the spread of the disease during each growing season. In turn, these specialists interpret the model predictions in light of current disease distribution and intensity to help growers make informed scouting and fungicide application decisions for soybean rust control.

The modeling team tracks soybean rust much the same way that the National Hurricane Center tracks tropical cyclones. The modelers use what is known as an ensemble approach to follow the movement and development of soybean rust across the continent. In this approach, outputs from multiple computer models are merged to give a single disease prediction that is then used by Extension specialists to inform clientele about soybean rust risk and the potential for epidemics. The ensemble approach was adopted for soybean rust because it achieves reliable forecasts at a greatly reduced cost in time and effort. In addition, the interpretation of model predictions by a trained meteorologist results in the desired human-machine mix, thereby minimizing the limitations of individual models and maximizing their strengths.

Three very different types of computer models are used to track soybean rust in North America. The Integrated Aerobiology Modeling System (IAMS), developed by Pennsylvania State University and ZedX, Inc., scientists, follows the disease development cycle that can lead to the geographic spread of soybean rust. The IAMS uses observations from the sentinel plot network and mobile scouting to estimate the production of spores at locations known to be infected with soybean rust. A transport component predicts aerial movement of spores, their survival during transport, and likely areas of spore deposition. Following deposition in an area, additional model components provide information on when soybean rust symptoms are likely to be expressed and on disease severity.

A second model, the HYPSLIT atmospheric transport model maintained by the NOAA Air Resources Laboratory, uses real time and forecast meteorological data to predict long-range transport, dispersion, and deposition of soybean rust spores from specific locations over subsequent days. A third soybean rust model, constructed by researchers from Iowa State University and St. Louis University, uses a climate model to predict which areas of the country are most likely to be at risk from soybean rust over subsequent weeks and months.
Like the meteorologists in the National Hurricane Center, the soybean rust forecasting team provides integrated, timely, easy-to-understand maps, drawn from the best information available. The job of interpreting the ensemble forecast maps is left to Extension specialists who are familiar with the people and the situation in their respective states.

Figure 5.1. National Weather Service terms for severe weather risk are used on maps depicting risk from soybean rust. The ensemble forecasting team provides this information to the state plant pathology Extension specialists on a regular basis.

Forecasting the Risk from Soybean Rust

Ensemble meteorological forecasts combine output from different types of models to create a realistic picture of what weather we should expect in the next few days. In the case of soybean rust, the ensemble forecasts assess the probability that a spore transport event, and subsequent spread of soybean rust, will happen in the near future.

Overall risk from soybean rust is communicated to the public on the SBR-PIPE public web site (www.sbrusa.net) as three text forecasts: a summary of current conditions, a one- to three-day forecast, and a forecast of the risk three to five days into the future. Soybean rust risk for a specific state is communicated to the public by state Extension specialists. Their risk assessment is based upon a range of ensemble map and text forecasts provided to them by the soybean rust forecasting team.
**Chapter 6**

**Soybean Growth and Development**

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Shawn Conley, Department of Agronomy, University of Wisconsin

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**Soybean Morphology**

Two stem types — indeterminate and determinate — of soybean are grown in the United States. Growth of both types is similar during the vegetative growth phase, and at the time of flowering (R1), plants have less than 50 percent of the total leaf area they will eventually amass. Once flower initiation occurs, indeterminate and determinate plants differ dramatically in stem growth habit. Indeterminate plants continue to develop leaves on the main stem and branches throughout the flowering period, which can last as long as 40 days. In contrast, determinate plants cease growth on the main stem at R1, but leaves continue to develop on branches (which will hold most of the yield) until the beginning seed (R5) growth stage.

The importance of new leaf development and expansion comes into play following a fungicide application. For example, once an indeterminate plant reaches R1 (or just prior to that) a new trifoliolate leaf is initiated every three to five days, depending on temperature and the soil moisture. This means that 3.5 to 7 new untreated trifoliolates will develop over the 14- to 28-day efficacy period of many fungicides. These untreated leaves would be completely unprotected against new soybean rust infections. Thus, the need to re-treat rust-infected crops with a second fungicide application must consider an assessment of plant growth since the last application, as well as post-application development of soybean rust in the crop.

**Soybean Development**

The impact of soybean rust on soybean is dependent on the developmental stage when infections occur. Soybean development can be separated into two major developmental phases — vegetative and reproductive. The duration of these phases is controlled by genetics, temperature, and day length. Soybean producers influence the duration of these phases through variety selection (genetics), the location of the farm (day length and temperature), and planting date (day length and temperature). Despite these variables, the duration of developmental stages falls within a rather predictable range (Table 6.1).
Both the vegetative and reproductive phases of development are subdivided into a number of growth stages. A specific vegetative or reproductive growth stage for a field of soybean is first reached when 50 percent of the plants in the field have reached that specific growth stage.

### Vegetative Phase

Vegetative stages are described from the time the plant emerges from the soil. Apart from the earliest two stages, each vegetative stage is designated with a V followed by a number. This number represents the number of nodes on the main stem with a fully developed leaf, beginning with the unifoliolate node. A fully developed leaf is defined as a leaf that has a leaf above whose leaflets have unrolled sufficiently such that the two edges of each leaflet are not touching. As an example, V1 refers to the stage at which the unifoliolate node has a fully developed leaf, meaning that the leaf above is unrolled.

### Reproductive Phase

Crop physiologists generally agree that the reproductive phase is the most important for yield determination. Stages R1 to R5 are important in determining seed number, and stages R5 to R7 are critical for determining seed number and seed size (Table 6.1).

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**Table 6.1. Soybean Reproductive Stages as Defined by Fehr and Caviness (1977).**

<table>
<thead>
<tr>
<th>Stage ID</th>
<th>Description of Developmental Stage (abbreviated stage title in bold)</th>
<th>Duration of Growth Stage (days) †</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td><strong>Beginning bloom</strong> — One open flower at any node on the main stem.</td>
<td>R1 through R4 20 – 45</td>
</tr>
<tr>
<td>R2</td>
<td><strong>Full bloom</strong> — An open flower at one of the two uppermost nodes on the main stem with a fully developed leaf.</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td><strong>Beginning pod</strong> — Pods are 3/16 inch (5 mm) at one of the four uppermost nodes on the main stem with a fully developed leaf.</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td><strong>Full pod</strong> — Pods are 3/4 inch (2 cm) at one of the four uppermost nodes on the main stem with a fully developed leaf.</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td><strong>Beginning seed</strong> — Pod at one of the four uppermost nodes on the main stem contains seeds that are 1/8 inch (3 mm) long.</td>
<td>R5 through R6 25 – 45</td>
</tr>
<tr>
<td>R6</td>
<td><strong>Full seed</strong> — Pod at one of the four uppermost nodes on the main stem contains green seeds that fill the pod cavity.</td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td><strong>Beginning maturity</strong> — One normal pod on the main stem has reached its mature pod color.</td>
<td>R7 to R8 7-18</td>
</tr>
<tr>
<td>R8</td>
<td><strong>Full maturity</strong> — 95 percent of the pods have reached their full mature color.</td>
<td></td>
</tr>
</tbody>
</table>

† Data are compiled from Board and Settimmi, 1986; Egli, 1994; Egli and Bruening, 2000; Kumudini, 1999 on MGs 00-VII. The duration of a growth stage is dependent on variety/maturity group (MG), latitude, planting date, and temperature. The durations are shorter for early MGs, later planting, and higher temperatures.
The reproductive phase begins when a single flower opens anywhere on the main stem of 50 percent of the plants in a field. The time and the location of the first flower depend on genetics, temperature, and day length. Generally, the first flower for an indeterminate soybean cultivar appears in the lower to mid-canopy position. For determinate soybeans, the first flower usually appears at the fourth or fifth main stem node down from the apex. Flowering then proceeds both up and down the main stem and spreads along the branches.

The earliest formed flowers will be fertilized first and will form the first pods. Once formed, pods go through a rapid expansion process. Once pods have expanded to their maximum size, seed growth accelerates, and seeds begin to fill the pod cavity. Seed growth continues until the plant reaches physiological maturity. Therefore, depending on when the first flowers formed, a single soybean plant may have some nodes that have flowers and other nodes that have pods. Thus, pods may vary in size and maturity based on when their flowers were formed and fertilized.

Physiological maturity (R7) signals the end of pod and seed development throughout the entire plant. Physiological maturity corresponds to a point when one normal pod on the main stem has reached its mature pod color (usually tan or brown) (Table 6.1).

**Development and Yield**

Final crop yield is a function of the number and size of seeds. The period from R1 (flower initiation) to R6 (full seed) is critical for yield determination, because this is when both pod and seed number are determined. Seed size can also be influenced during this period because R3 to R6 is when the cotyledonary cell number (very important for final seed size) is determined. Stresses occurring during the R1 to R6 period have a greater impact on number of pods and seeds than on seed size. The period between R5 (beginning seed) and onset of R7 (physiological maturity) is critical for seed growth and is also important in setting seed size.

Because pod development begins at R3 and seed growth ends at R7, conditions that limit growth during this period can impact yield by limiting seed number, seed size, or both. As explained earlier, a single plant that is not yet at R7 may have a number of different organs (flowers, pods, and seeds) at various developmental stages at the same time. Table 6.1 outlines general development and timing of the reproductive periods, but does not specify exactly when, and by how much, the different growth stages overlap.
Stresses and How They Impact Yield

From an agronomic perspective, stress is usually defined as an external factor that adversely affects crop yield. Stresses may be biotic or abiotic. Biotic stresses are those associated with a living organism such as weeds, insects, and diseases. Abiotic stresses are caused by environmental factors, such as light, water, soil minerals, soil pH, and wind. Soybean rust is a biotic stress. Yield losses caused by soybean rust result either from impaired photosynthetic function of infected leaves or actual defoliation of the leaves. The relative contribution of each to yield loss is not known.

Limited research has indicated that yield loss associated with soybean rust is strongly correlated with green leaf area. This is the total leaf area remaining in a healthy, green state. However, researchers familiar with the disease report that yield loss appears to be more related to defoliation than to the unhealthy effects associated with lesions prior to defoliation. Because of its ability to cause leaf drop within three weeks after infection, defoliation potentially is the greater factor affecting final yield. For this reason, understanding how defoliation affects yield will ultimately help us understand how rust affects yield. This information, in turn, is vital for fine tuning good farming practices to prevent yield loss in soybean due to soybean rust.

Leaf area must be maintained at critical levels during the seed-filling period to avoid yield loss. Leaf area during the early and mid seed-filling periods should be great enough to intercept about 95 percent of sunlight. The main effect of defoliation on yield is caused by decreased canopy light interception, which decreases the crop’s cumulative photosynthetic activity. This impairs crop growth rate (ability of the crop to produce dry matter) and results in a yield loss.

The effect of defoliation on yield differs markedly with developmental stage and the level of defoliation. Investigators have determined that defoliation at the start of the seed-filling period (R5) has the greatest effect on yield. Leaf growth ends at this time and regrowth potential is very limited compared with earlier developmental periods. Furthermore, pod and seed number per area are still being determined. Thus, a significant reduction in leaf area and light interception at the start of seed fill can result in serious yield reduction by reducing pod number, as well as decreasing seed number and seed size. This is why soybean producers are warned to protect their fields with fungicides when soybeans are in the early reproductive stages and the risk of soybean rust is high.
By the time the R5 (beginning seed) growth stage is reached, vegetative dry weight has approached a maximum and final pod and seed number are nearly determined. Leaf area index also reaches its maximum level at R5. This level is maintained, even with minor defoliation, unless stresses occur during the R5 to R7 period. Soybeans become increasingly more tolerant to defoliation as the seed-filling period progresses. However, complete defoliation must be avoided during most of the R5 to R7 period to maintain optimal yield potential. Eventually, normal plant senescence results in rapid defoliation in the last week or so of the seed-filling period.

References


Summary

- The need to re-treat rust-infected crops with a second fungicide application must consider an assessment of plant growth since the last application.

- Growth of indeterminate and determinate soybean is similar during the vegetative growth phase, and at the time of flowering (R1), plants have less than 50 percent of the total leaf area they will amass.

- A fully developed leaf is defined as a leaf that has a leaf above that has unrolled sufficiently such that the two edges of each leaflet are not touching.

- The reproductive phase begins when a single flower opens anywhere on the main stem of 50 percent of the plants in a field.

- Yield losses caused by soybean rust result from both impaired photosynthetic function of infected leaves and from defoliation.

- Rust infections that cause leaf defoliation and/or lesions on the mid to top canopy between R1 and R7 have the greatest effect on yield.
Growth Stage R3
Pod is 5 mm (3/16 inch) long at one of four uppermost nodes on the main stem with a fully developed trifoliate leaf node.

Photo used with permission from the Iowa State University publication Soybean Growth and Development (PM 1945)

Growth Stage R4
Pod is 2 cm (3/4 inch) long at one of the four uppermost nodes on the main stem with a fully developed trifoliate leaf node.

Photo used with permission from the Iowa State University publication Soybean Growth and Development (PM 1945)
Growth Stage R5
Seed is 3 mm (1/8 inch) long in the pod at one of the four uppermost nodes on the main stem with a fully developed trifoliate leaf node.

Photo used with permission from the Iowa State University publication Soybean Growth and Development (PM 1945)

Growth Stage R6
Pod containing a green seed that fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed trifoliate leaf node.

Photo used with permission from the Iowa State University publication Soybean Growth and Development (PM 1945)
Chapter 7

Fungicide Basics

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Various fungicides are available, either through Section 3 or Section 18 labels or under an Emergency Use (or label registration in Canada), to manage soybean rust in the United States and Canada. Each product is unique in regards to plant uptake, redistribution of active ingredient on or in host tissue, mode of action, efficacy, length of residual activity, phytotoxicity, and resistance potential. The specific characteristics of each fungicide determine how that product is used in a soybean rust management program. Soybean rust fungicides are classified as protective (functional only pre-infection) or curative (functional early post-infection), (Figure 7.1).

Protectant (Pre-Infection) Fungicides

Protectant fungicides prevent fungi from successfully penetrating host tissue. Of the available soybean rust fungicides, chlorothalonil is an example of a product that is only active against spore germination. If this fungicide is applied after spores have germinated and the fungus has grown into (infected) the plant tissue, it will be ineffective. The strobilurin class of fungicides (azoxystrobin, pyraclostrobin, trifloxystrobin, etc.) has the ability to stop both spore germination and host penetration, but has little or no effect once the fungus has successfully penetrated or colonized host plant tissue.

Curative (Early Post-Infection) Fungicides

Curative fungicides have the ability to inhibit or stop the development of infections that have already started. With some fungicides, this includes a degree of anti-sporulant activity that helps to slow disease development by limiting the reproductive potential of the fungus. Of the available soybean rust fungicides, only triazoles (see the tables in

Figure 7.1. Schematic representation of fungicide activity in relation to soybean rust development.
USING FOLIAR FUNGICIDES TO MANAGE SOYBEAN RUST

the Appendix) have curative activity. It is this post-infection activity that makes triazoles the fungicide of choice if soybean rust is established at low levels in a field (Figure 7.2). If chlorothalonil or one of the strobilurin fungicides is applied post-infection, existing infections will continue to develop. It is very important to remember that triazoles do not have unlimited curative activity. As can be seen in Figure 7.3, triazole-based fungicides have reduced activity once infections begin to produce spores. This is the main reason why fungicides are less effective once soybean rust has become even moderately established in a field.

Figure 7.2. The blue color represents fungicide following application (A) and distribution of protectant (B) fungicides. Stobilurin and triazoles have limited systemic movement in the plants as shown (C, D).
Combination Products or On-Farm Mixing of Fungicides

A few soybean rust fungicides are marketed as a premix or co-pack of a strobilurin plus a triazole (see the tables in the Appendix). In addition, the label for Headline (pyraclostrobin, a strobilurin [BASF]) specifically recommends that a non-strobilurin, curative mixing partner be applied with Headline if soybean rust exists at any level. Both premixes and label-sanctioned tank mixes of a strobilurin + triazole are effective against spore germination, host penetration, and initial tissue colonization.

Check with fungicide manufacturers for compatibility before on-farm mixing of fungicides, insecticides, or herbicides.

Uptake and Movement in Plants

Fungicide use directions indicated on the product labels are based on unique uptake and movement characteristics for each fungicide. The main point to remember in all of this is that different fungicides, even those in the same chemical class, are not necessarily equal when it comes to uptake by plants and movement in plants. Some fungicides, such as chlorothalonil, remain on the leaf surface (not taken up by the plant) and therefore need to be applied more frequently as environmental conditions can decrease residual activity. These non-systemic protective (contact) fungicides remain on the treated leaves and are NOT present on the new growth that emerges after application.

In contrast, the systemic fungicides, such as the strobilurins and triazoles (and premixes of the two), are taken up by plants and redistributed in tissues to varying degrees. Although most fungicides currently labeled for soybean rust are either systemic or

Integrated Pest Management

The use of Integrated Pest Management (IPM) concepts with soybean rust may be significantly different than what we have come to accept with insect or weed pests. While insecticides and herbicides can offer good rescue treatments, fungicide performance is best when applied pre-infection or very early in the infection cycle. IPM practices for soybean rust will focus on the prediction of threat to the crop in a given area. Disease forecasting will rely on the use of field observations and weather patterns. The goal of these systems will be to alert growers to the potential for soybean rust in a timely enough manner to allow scheduling of fungicide applications to optimize product efficacy. Perhaps the greatest problem experienced by producers using fungicides against soybean rust worldwide has been early detection and treatment before the disease is out of control. This will also be a major challenge to North American soybean producers.
locally systemic within plants, none are as highly systemic as some commonly used insecticides and herbicides. This is another reason why coverage and canopy penetration are so important when it comes to managing soybean rust using fungicides (see Chapters 9 and 10). In addition, fungicides vary as to how quickly, and to what extent, they are taken up by the plant. This is one reason fungicide manufacturers often recommend the use of adjuvants with certain fungicides.

All strobilurin fungicides move into the plant and are locally systemic (translaminar), but differences in systemic movement have been observed among the various products. For example, pyraclostrobin is a locally systemic strobilurin that is taken up by the plant, but does not move far beyond the point of uptake. In contrast, the strobilurin azoxystrobin is taken up by the plant and is also systemic to a limited extent beyond the point of uptake. Regardless of strobilurin product, leaves produced after application are NOT protected.

Triazole fungicides have greater systemic activity and, as a group, tend to be absorbed and redistributed more quickly within the leaf and upward to new developing leaves than the strobilurins. Be aware that systemicity is not necessarily related to efficacy; therefore, refer to fungicide trial results for product performance. Label rates and product instructions reflect these differences in uptake, movement, and residual activity among the various fungicides used to manage soybean rust.

It is very important not to exceed the recommended interval between applications. Towards the end of the application interval, the fungicide active ingredient is sufficiently diluted, bound up, or degraded that tissue, especially new growth, will be mostly or completely unprotected. In general, strobilurin and triazole fungicides at labeled rates provide 14 to 21 days of protection whereas chlorothalonil provides seven to 14 days. The interval indicated on the label reflects both product breakdown over time AND new (untreated) leaves that have formed since the last application. For more details, see Chapter 6.

**Fungicide Mode of Action**

Fungicides available for soybean rust management have diverse modes of action. Chlorothalonil attacks fungal cells at several sites, inhibiting sulfur-containing enzymes and disrupting energy production in the fungus. Chlorothalonil is considered to be a broad-spectrum fungicide because it is efficacious against a range of fungal pathogens, including *Phakopsora pachyrhizi.*
Strobilurins are broad-spectrum fungicides that inhibit fungal cell respiration, which prevents energy production and leads to rapid cell death. Strobilurins are referred to as “QoI” or Group II fungicides, which is simply a reference to their unique mode of action. Some labels specifically mention QoI fungicides. While it may not be critical to know how strobilurins work, it is important to recognize the QoI designation and be aware that all strobilurins have the same mode of action.

Triazole fungicides inhibit biosynthesis of sterols, which are important structural components of fungal cell membranes. Triazoles are referred to as “DMI” or Group 3 fungicides, which is a reference to their unique mode of action. As mentioned previously, it is not essential to know how triazoles work, but it is important to recognize the DMI designation and be aware that all triazoles have the same mode of action.

**Fungicide Resistance Concerns**

A major concern associated with strobilurin fungicides, and to lesser extent the triazoles, is the potential for resistance to develop among populations of *Phakopsora pachyrhizi* exposed to these fungicides. Resistance concerns are based on the unique modes of action represented by the strobilurins and triazoles. Multi-site mode of action fungicides, such as chlorothalonil, have a very low risk of resistance development. In addition, rust fungi are thought to be less likely to become resistant than many other kinds of fungi. Resistance to QoI fungicides has developed in other pathogens throughout the world, including North America.

Although fungicide resistance has yet to be observed in populations of the soybean rust fungus, it is important to take steps to reduce the risk of resistance to the strobilurins and, to a lesser degree, the triazoles. These fungicides are the main line of defense against soybean rust. Thus, it is imperative that we protect these very effective groups of fungicides.

Refer to Chapter 8 for more details on fungicide resistance management.
A single fungicide application may be adequate for economical disease control if the initial disease outbreak occurs late in the season, or where disease development is significantly slowed by an unfavorable environment. Experience in the southern United States would suggest that a third application would be a rare occurrence or not economically beneficial.

**Fungicide Use Strategies for Soybean Rust Management**

These scenarios have been developed to assist in making fungicide-use decisions for soybean rust management.

The tables in the Appendix list the various fungicides available for soybean rust management in the United States and Canada. Be certain to read and precisely follow all pesticide label instructions and restrictions. Remember that pesticide labels are legal documents. Information presented on the label takes precedence over the guidelines and information presented in this document.

Follow the movement of soybean rust (www.sbrusa.net) to address the risk for...
fields in your region. Read the state/provincial commentary to see what the predicted risk is for your area. Scout for other soybean foliar diseases to choose the appropriate fungicide mode of action and timing to optimize these treatments.

The data from U.S. studies indicate that the maximum benefit from fungicide applications for management of soybean rust occurs when fungicides are applied from beginning flowering (R1) through full pod (R6) and before rust is actually established in the field. Applications made before R1 or after R6 may not produce an economic result. Spraying a fungicide when soybean rust can easily be found in the canopy of a crop may not provide satisfactory or economical disease control. The crop may not respond to treatment at this advanced stage of disease development in many environments. If treating at this stage, triazole type compounds provide the best hope of control.

The presence of other diseases may significantly impact fungicide selection and use decisions. Consult local soybean disease guidelines where management of other foliar, pod, and stem diseases is a consideration. For more details, see Chapter 11 on late-season soybeans diseases from a Southern perspective and Chapter 12 on diseases similar to soybean rust.

Fungicide applications can be based on the risk of whether rust will reach a field:

- At an early enough growth stage (early reproductive stages).
- At a high enough inoculum level.
- At an early enough time for inoculum to increase to economically impact yields.

Soybean rust risk depends on where rust is present and how severe it is there, the likelihood that winds will carry spores from the source to the field, that rain will scrub airborne spores down to foliage, and the growth stage of the crop. State or provincial plant pathology specialists will determine risk for their respective jurisdictions.

The three examples of soybean rust risk presented here are not all inclusive. In fact, there are shades of each of these examples, ranging from extremely low risk to extremely high risk, with everything in between. In addition, there are many other scenarios that would trigger a low-, medium-, or high-risk situation other than what is indicated in the examples:

**Scenarios**

Low Risk — An example of a low-risk scenario would be one that is similar to the 2006 soybean rust situation in which dry conditions in the Gulf...
Coast states prevented build-up of soybean rust spores early enough to impact the crop in the North, including Canada.

**Moderate Risk** — An example of a moderate risk might be a scenario in which soybean rust has been found on soybeans in a neighboring state or region but has yet to be detected in your area. Another situation would be if soybean rust was widespread on kudzu and soybean in the Mississippi Delta and a storm from the Gulf was predicted to move up the Mississippi Valley, and the crop in Kentucky, Missouri, Illinois, and Indiana was still in the mid-reproductive stages of growth. Fields in those states would be at risk.

**High Risk** — An example of a high-risk scenario might be when soybean rust has been identified in a sentinel plot, commercial soybean, or kudzu in your state/province/parish, and weather conditions are predicted to favor rust development.

A single fungicide application may be adequate for economical disease control if initial disease outbreak occurs late in the season, or where disease development is significantly slowed by an unfavorable environment. Experience in South America suggests that a third application may be a rare occurrence.

Applying fungicides to a crop that exceeds 10% incidence of soybean rust in the lower to mid canopy may result in poor disease control.

Scouting for early detection and assessment of disease progress to choose appropriate fungicide modes of action is critical for optimized response to treatment.
## Soybean Rust Fungicide Decision Guidelines

### Table 7.4. Fungicide Decision Table — Fungicide Chemistries for Optimum Management of Soybean Rust.

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>SOYBEAN RUST STATUS (Risk determined by national, regional, and local activity and disease forecasts)</th>
<th>RUST ABSENT</th>
<th>RUST PRESENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soybean Rust Risk&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Barely detectable in lower canopy&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Easy to detect in mid to upper canopy</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td><strong>FUNGICIDE APPLICATION</strong></td>
<td>1st Application</td>
<td>2nd Application (if needed)</td>
</tr>
<tr>
<td>Vegetative (stages before flowering)</td>
<td><strong>NOT RECOMMENDED FOR SOYBEAN RUST CONTROL.</strong></td>
<td>Do not spray</td>
<td>Premix, Tank-mix, Co-pack or Triazole</td>
</tr>
<tr>
<td>R1 (beginning of flowering) through R5 (beginning seed)</td>
<td>Do not spray</td>
<td>Strobilurin Triazole</td>
<td>Premix, Tank-mix, Co-pack</td>
</tr>
<tr>
<td>R6 (full seed) to R8 (full maturity)</td>
<td>Generally, fungicide application not recommended. Yield responses beyond R6 are uncertain, and many fungicide labels specify that applications be made prior to R6. Check with local Extension specialists for specific state/province recommendations.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Determine risk by staying current with information from Extension specialists, trusted industry and/or crop consultants for the region and state. View the Soybean Rust PIPE web site (www.sbrusa.net) frequently for updates and commentary.

<sup>b</sup> Soybean rust incidence less than 10 percent.

<sup>c</sup> Premix, tank-mix, or co-pack fungicide should contain the full rate of the triazole fungicide component.

<sup>d</sup> Application of a fungicide at this level of disease may protect newly emerging leaves, but may not result in a yield benefit. Check with local Extension specialists for specific state/province recommendations.
Chapter 8

Fungicide Resistance Management in Soybean

Carl A. Bradley, University of Illinois

Fungicide Resistance

Development of resistance in fungi to fungicides is a concern for the world-wide agricultural industry. Unfortunately, this phenomenon has occurred in many fungi, especially when fungicides have been used intensively on crops. Producers of several crops in the United States, including potato, sugar beet, sunflower, and others, have dealt with fungicide failure due to the rise of fungicide resistant or insensitive pathogen populations.

How Fungicide Resistance Develops

Fungicide resistance can occur when a selection pressure is placed on the fungal pathogen population. Characteristics of both the fungicide and the pathogen play a role in the magnitude of the selection pressure and the risk of resistance occurring. Fungicides that have a single site of action tend to be more at risk for resistance developing compared to those that have multi-site activity. Fungal pathogens that regularly undergo sexual reproduction are more likely to have greater variability in the population, which increases the chances of developing a strain that is less sensitive to a fungicide. When diseases have a repeating stage (polycyclic disease), such as soybean rust, the fungal pathogen may also be more likely to develop resistance to a fungicide partially due to the high number of spores that are produced within a season.

The fungicide user has control over selection pressure, but the variability of the pathogen is out of the applicator’s hands. Managing selection pressure is key to reducing the risk of fungicide resistance.

Fungicide Resistance Action Committee (FRAC)

An organization known as the Fungicide Resistance Action Committee (FRAC) was developed to address the issue of fungicide resistance. This is an international group that provides guidelines and recommendations to manage the development of fungicide resistance. This organization developed a code of numbers and letters that can be used to distinguish the different fungicide groups based on their mode of action. The mode of action of a fungicide is the means by which it poisons the fungus (e.g., inhibiting metabolic pathways, disrupting cell membranes). This code is known as the FRAC Code and is now included on fungicide labels. A fungus that becomes resistant to a specific fungicide may be resistant to many or all of the fungicides within that fungicide’s FRAC Code, a phenomenon referred to as cross-resistance. Table 8.1 includes the FRAC codes for the
Table 8.1. Fungicide Groups That Can Be Applied on Soybean in the United States. (Note: Not all are registered for control of soybean rust.)

<table>
<thead>
<tr>
<th>FRAC Code</th>
<th>Chemical Group</th>
<th>Example</th>
<th>Risk of Fungicide Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Methyl Benzimidazole Carbamates (MBC)</td>
<td>T ops in M</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>Demethylation inhibitors (DMI; includes triazoles)</td>
<td>Folicur</td>
<td>Medium</td>
</tr>
<tr>
<td>11</td>
<td>Quinone outside inhibitors (QoI; includes strobilurins)</td>
<td>Headline</td>
<td>High</td>
</tr>
<tr>
<td>M</td>
<td>Chloronitriles; inorganics</td>
<td>Bravo</td>
<td>Low</td>
</tr>
</tbody>
</table>

fungicide groups that currently can be applied to soybean in the United States. More information is available at the FRAC website: (http://www.frac.info).

Fungicide Resistance Management Practices

Different practices are available to minimize the risk that a fungus will become resistant to a fungicide. The best fungicide resistance management program utilizes all available practices to prolong the effectiveness and the life of the fungicides.

Monitoring Programs

One of the first steps in a fungicide resistance management program is the development of baseline levels of sensitivity using laboratory analysis. A baseline is the dosage of the fungicide that is able to effectively control a fungal plant pathogen population that has never been exposed to the fungicide. Another way to look at it is how sensitive the pathogen population is to the fungicide when it is first used. Once the baseline is established, a monitoring program can be implemented to determine if the pathogen population is becoming less sensitive over time. Generally, monitoring programs consist of collecting populations of the pathogen and testing them for sensitivity to the fungicide in laboratory analysis every season.

Whenever a fungicide is applied to a field, the field should be monitored for how well the fungicide worked and for signs of any failure. Although there are different reasons why a fungicide might fail, it is important to contact the chemical company representative or Extension personnel to determine if fungicide resistance could be a factor.

IPM Practices

Scouting fields and monitoring the development and movement of soybean rust in the United States and applying a fungicide when the disease is present or when there is a high risk for disease is part of an Integrated Pest Management (IPM) program. Applying a fungicide only when it is necessary is important for prolonging...
the effective life span of the product. Many of the fungicide products (or similar products with the same mode of action) that can be applied to soybean are also registered on many other crops that are grown in rotation with soybean. Applying a fungicide unnecessarily to a soybean field in the absence of soybean rust could result in undesirable effects on pathogens of rotational crops.

Example: A strobilurin (QoI; FRAC Group 11) fungicide was applied to soybean for reasons other than disease control. This soybean field was planted in ground where sugar beet was part of the rotation, and common lambsquarters and pigweed were prevalent. The common lambsquarters and pigweed in the field were infected with the Cercospora leaf spot fungus that also attacks sugar beet. In this scenario, a selection pressure is placed on the Cercospora leaf spot fungus in a year that sugar beet is not even grown in the field.

Conserving the fungicide groups that are available is extremely important, because there are few other groups that are effective on certain pathogens. Using IPM practices will help conserve these products for management of soybean rust as well as other disease problems on soybean and other crops.

### Fungicide Mixtures and Rotation

Applying mixtures of fungicides with different modes of action can help reduce the selection pressure placed on the pathogen population compared to using only a single product. This helps reduce the risk of fungicide resistance because, should a mutant spore arise that is resistant to one fungicide, the other is there to poison it. This is only effective if both of the fungicides control the target disease, however. For example, tank-mixing of Folicur plus Topsis M would not be a good fungicide resistance management practice for soybean rust, because Topsis M is not effective against soybean rust.

If more than one application of a fungicide during a season is anticipated, then fungicides with different modes of action should be used. For example, a strobilurin (QoI; FRAC Group 11) fungicide could be applied first followed by a triazole (FRAC Group 3) fungicide. Note, that if a fungicide rotation program is used, each fungicide should be applied at timings that suit the individual fungicide’s inherent activity on the disease being managed; for example, do not apply a preventative fungicide at a time when soybean rust is already in the field.
**Follow Label Recommendations**

Following the label is the law and is another important component of fungicide resistance management. Some fungicides may have restrictions on the number of applications that can be made during a season and restrictions on back-to-back applications. Following fungicide label rates is a key component of disease management as well as fungicide resistance management. When sub-lethal doses of a fungicide are applied, the risk of fungal pathogens becoming more tolerant to the fungicide is increased.

**Summary**

Fungicide resistance management is important in the production of soybean and all crops. You will reduce the risk of a fungal pathogen developing resistance to a fungicide by taking the steps listed here:

- Apply a fungicide only when it is necessary.
- Alternate fungicides that have different modes of action.
- Apply mixtures of fungicides with different modes of action.
- Follow the label. Use recommended rates and obey restrictions.
- If a fungicide is applied, monitor the crop for signs of disease, which may indicate resistance development.
The use of foliar fungicides in soybean production in the northcentral United States is a relatively new practice. Until recently, this practice has been limited to control of late-season diseases in soybean grown in the lower Mississippi River basin. Fungicides have been applied aerially at three to five gallons per acre (GPA) or by tractor-mounted or dedicated ground spray systems with application volumes of 10 to 15 GPA. Successful control of late-season diseases has been based on delivery of fungicides into the upper crop canopy.

Although experience in Brazil and elsewhere suggests that existing spray technology is adequate for managing soybean rust, technology improvements are needed. Soybean producers and custom applicators should do everything possible to make sure that they are applying the amount of fungicide recommended into the proper location of the canopy. Too little fungicide will result in poor control and reduced yields, while too much wastes dollars and increases the risk of phytotoxic effects and/or environmental pollution.

Spraying the proper amount of fungicide on each acre of soybean is not enough to achieve effective soybean rust control. Effective management of soybean rust with fungicides depends on placing fungicides as deeply into the canopy as possible. This is because the disease usually starts in the lower canopy and moves into the middle, then upper, canopy as the crop matures. Nozzle type, spray pressure, application volume, and application speed determine uniformity of deposition and penetration into the canopy. Proper nozzle orientation and overlap are also critical to achieve uniform spray deposition.

Spray technology is available that may help improve coverage of foliage, but it may cost more than conventional technology. Producers may need to modify existing spray equipment to optimize application of fungicides to full-canopy soybean. The cost of equipment modification is likely to vary widely, depending on the extent of modifications needed. For example, cost may be low if only the nozzles are being replaced. On the other hand, modification may be costly if boom reconfiguration is necessary. Some producers will need to purchase new spray equipment. For many good reasons, including economic, producers tend to be conservative when it comes to extensive equipment modifications or purchasing new spray equipment. Soybean rust may help to shift this tendency since the alternative to making the necessary equipment modifications, or purchasing new equipment, may be heavy crop losses — a bigger economic burden to producers.
Which Spray Equipment Configuration Is Likely to Provide the Best Defense Against Soybean Rust?

Even though several research projects have been conducted to learn more about the influence of various application parameters, unfortunately we DO NOT yet have sufficient efficacy data for soybean rust using different spray equipment under U.S. conditions and limitations. However, we DO have spray coverage data from several research projects dealing with other lower canopy soybean diseases, such as Sclerotinia stem rot. An important question in these research projects has been: Does good coverage correlate with efficacy? As it turns out, in most cases, there is a very strong correlation between coverage and efficacy.

How to Achieve the Best Coverage

There are basically two ways to increase coverage — reduce droplet size and increase carrier volume. Ideally, it is best to have as many small droplets hit the target as possible. Nozzles currently used in crop production (herbicide-glyphosate applications) tend to produce a large range of droplet sizes. Large droplets, which will help mitigate spray drift, may not provide good coverage.

Very small droplets lack the momentum needed to push into the canopy, and many have the potential to evaporate within a few seconds of being released from the nozzle.

Thus, for soybean rust control, everything possible must be done to utilize droplets approximately 200 to 300 microns in diameter. Be aware that droplets in this size range are prone to drift under windy conditions. This is an important consideration since drifting droplets will not have any energy to penetrate into the soybean canopy and, thus, may be wasted. Also many soybean rust fungicides are toxic to aquatic invertebrates and fish, so drift near water should be avoided.

Select a combination of nozzles and spray pressure that can deliver the desired amount of material in the required gallons per acre at the travel speed necessary to produce 200 to 300 micron droplets in a uniform pattern.

Two additional factors that influence canopy coverage are boom height and overlap. If the boom is too high, droplets are more susceptible to movement by wind. Lowering the boom reduces the risk of drift during application, but doing so may also reduce the overlap required to provide adequate uniformity across the target. Overlap is needed to prevent skips between nozzles and to even out non-
uniform spray patterns. With flat-fan nozzles, the outer edges of the spray pattern have reduced volumes. Overlapping adjacent patterns along a boom achieves more uniform coverage. On a broadcast sprayer, nozzle spacing and boom height determine overlap. When the spray boom is raised, overlap increases; when the spray boom is lowered, overlap decreases. Table 9.1 shows recommended minimum mounting heights for common fan angles and nozzle spacing.

### Table 9.1. Suggested minimum spray heights for given angles.

<table>
<thead>
<tr>
<th>Spray Angle</th>
<th>20-inch spacing</th>
<th>30-inch spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 degrees</td>
<td>22 to 24 inches</td>
<td>33 to 35 inches</td>
</tr>
<tr>
<td>80 degrees</td>
<td>17 to 19 inches</td>
<td>26 to 28 inches</td>
</tr>
<tr>
<td>110 degrees</td>
<td>16 to 18 inches</td>
<td>20 to 22 inches</td>
</tr>
<tr>
<td>120 degrees</td>
<td>14 to 16 inches</td>
<td>15 to 17 inches</td>
</tr>
</tbody>
</table>

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**Other Options**

The density of the soybean foliage will definitely affect spray penetration into the canopy. Narrow-row plantings typically create denser canopies, and canopies become more dense during the reproductive stages. The density of the canopy will also be greatly influenced by the environmental conditions during the growing stages of the soybean crop.

If soybean is planted in a row, and there is sufficient clearance between rows at the time of spraying, some producers may opt to take advantage of directed spraying to cover the plant with more than one nozzle from different angles (from top and both sides) or with drop pipes between the soybean rows with a double swivel nozzle to the ends of these pipes, which extend between soybean rows. The spray from each nozzle should then be directed toward a row of soybeans. An additional nozzle can be placed on the boom and positioned directly above the row (Figure 9.1). These options are not always practical in heavy canopied soybean.

### An Alternative to a Conventional Sprayer

In spray coverage tests conducted in Ohio, air-assisted sprayers consistently provided the best coverage of paper targets placed inside the crop canopy. This advantage was even more pronounced when spray deposits were evaluated on the undersides of leaves. Thus, air-assisted sprayer technology may be a viable option in soybean rust management programs. Unfortunately, a commercial-scale sprayer with the air assistance may add from $10,000 to $15,000 to the price of the equipment. Still, this expense may be worth the investment.
USING FOLIAR FUNGICIDES TO MANAGE SOYBEAN RUST

Figure 9.1. Spraying with nozzles attached at different angles to promote thorough coverage.

Figure 9.2. Different spraying systems used for fungicide applications with types of twin-pattern nozzles: Twin jet®, Turbo Duo®, Hypro Twin-cap® and Turbo TwinJet®.

**Droplet Size Will Influence Coverage**

The range of droplets from a nozzle is also affected by liquid flow rate (size of nozzle orifice), liquid pressure, and physical changes to nozzle geometry and operation. To help applicators select nozzles and use them at the most optimum droplet size range for a given situation, the American Society of Agricultural and Biological Engineers (ASABE) has developed a classification system. According to this system, spray quality from a nozzle can be classified as: Very Fine, Fine, Medium, Coarse, Very Coarse, and Extremely Coarse.

Currently, nozzle manufacturers recommend high-fine to mid-medium spray droplets (approximately 200 to 300 microns) for application of fungicides for soybean rust control. Since most nozzle sizes will span a range of droplet sizes dependent on the operating pressure, it is important to select the option that closely matches the high side of the fine category and the low to medium side of the medium category. This should approximate the 200 to 300 micron size recommended.
To achieve this, calibration to determine needed flow rate or orifice size must be done in conjunction with matching pressure, nozzle type, orifice size, and speed to the desired droplet size. This last step, matching the droplet size, is not something familiar to most applicators today. It will be necessary to add this step to the set-up of the sprayer to optimize the fungicide application for increased lower canopy coverage and minimized drift.

Selecting Nozzle Type

Always select the most appropriate nozzle to achieve the desired coverage and penetration. Nozzles producing a cone pattern are not recommended for soybean rust control because they produce a higher portion of very fine (less than 100 micron) droplets than flat fan nozzles at any given pressure. Flat-fan pattern nozzles are generally the best choice, provided the spray from these nozzles is categorized as high-fine to mid-medium.

Determining Desired Droplet Spectra

Consulting the nozzle manufacturer’s droplet sizing charts is ESSENTIAL. Also, web sites and manufacturer’s literature are available to help. Nozzle manufacturer’s charts can help you determine what pressure to use for the nozzle type selected to produce the mid-fine to mid-medium quality spray (see Table 9-2).

A flat-fan nozzle setup with two spray patterns (twin orifice or twin outlet — see Figure 9.1) has been considered a good option to provide better coverage of plants with fully developed canopies. Some manufacturers have nozzles that provide a twin spray pattern from one tip, or special fittings or caps that allow the producers to place two nozzles in the same cap, one pointed forward, and the other one pointed backward.

However, recent research has shown that hitting the target (lower canopy) from

<table>
<thead>
<tr>
<th>Category</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Fine (VF)</td>
<td>red</td>
</tr>
<tr>
<td>Fine (F)</td>
<td>orange</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>yellow</td>
</tr>
<tr>
<td>Coarse (C)</td>
<td>blue</td>
</tr>
<tr>
<td>Very Coarse (VC)</td>
<td>green</td>
</tr>
<tr>
<td>Extra Coarse (EC)</td>
<td>white</td>
</tr>
</tbody>
</table>

Table 9.2. American Society of Agricultural Engineers (ASAE) Standard S-572 Spray Quality Categories.
two different angles, with one forward and one backward spray pattern, has not necessarily provided more effective coverage compared to spraying with just one spray pattern, shooting nearly straight down. In fact, the nozzle configurations with wider angles between the two outlets tended to provide the least amount of spray coverage in the lower canopy when foliage was dense.

**A Calibration Example**

Even though coverage may not be as good in some twin orifice or twin outlet nozzle configurations, the use of two nozzles in one cap gives the applicator more flexibility to achieve the higher application volumes and the droplet spectrum suggested for improved lower canopy coverage. As an example, for a single nozzle application, to achieve 20 GPA at 10 MPH with a 20-inch nozzle spacing, an “06” orifice (i.e., TT11006) would be required to deliver a 0.67 GPM flow rate (20 GPA x 10 MPH x 20-inch nozzle spacing divided by 5,940). The pressure for this orifice scenario (TT11006) would need to be 50 PSI, resulting in a coarse droplet with some nozzle types and a medium droplet with the other options. If a double nozzle cap is used, then two TT11003 nozzles combined would meet the calibrated flow rate with the pressure still at 50 PSI. However, the smaller orifices would produce smaller droplets (see Table 9.2). Again, depending on nozzle type, borderline medium/coarse or borderline medium/fine droplets are possible. The medium/fine option would be very close to the desired specifications for successful coverage in the soybean canopy.

Carefully reviewing the manufacturer’s flow rate and droplet category charts would reveal several other nozzle options acceptable for fungicide applications as long as the 200 to 300 micron size requirement is followed. For instance, in the previous example, the XR11006 nozzle at 50 PSI (0.67 GPM) would deliver a medium-sized droplet. The XR11005 nozzle at 58 PSI (0.67 GPM) would deliver a medium to fine droplet. Both would be possible choices. However, a TT11006 nozzle at 50 PSI (0.67 GPM) would deliver coarse to very coarse droplets. This would not be a good option. A TT11005 nozzle at 58 PSI (0.67 GPM) would also deliver coarse droplets, while a TT11004 nozzle at 95 PSI (0.67 GPM) would produce medium droplets and, thus, is a possible selection, provided the spray system can achieve and maintain operation at this high pressure.

**Benefit of Increasing the Spray Volume**

Studies have shown that 10 to 15 GPA application volumes
and a single outlet flat-fan nozzle can provide adequate canopy coverage as long as proper droplet size and pressure are used. However, as the crop continues to grow and there is more canopy cover, higher spray volumes will be needed. This is illustrated by Figures 9.3 and 9.4, which show two cards that were placed in the canopy during application. These cards, which were placed in the mid-canopy, registered a similar total deposition.

The spray coverage shown on the card in Figure 9.3 resulted from 10 GPA applied with a single turbo flat-fan nozzle, while the soybean plants were in the R2 growth stage. Achieving a similar coverage at the R5 growth stage as shown in the card in Figure 9.4 required 20 GPA. A twin orifice nozzle (TwinJet) was used for this application.

Note that similar coverages were measured at the two spray volumes resulting from using two different nozzle types. Both nozzles, however, produced a similar range of droplet distribution; nearly 90 percent of the spray volume in both cases was delivered in droplets around the optimal 200 to 300 micron droplet size range.

In summary, coverage is critical for effective soybean rust control using fungicides. Spray volumes at 10 GPA may give acceptable results early in the season with less canopy density, but higher spray volumes will be required as the season progresses because the canopy is deeper and denser.
Environmental Conditions Impact Application

Environmental conditions during fungicide application influence the final spray outcome. Applications made when temperatures exceed 90°F and/or when humidity is low (<50 percent) may result in excessive evaporation of smaller droplets as they leave the nozzle. Another concern is the existence of in-crop microinversions. An in-crop microinversion may occur when high ambient temperatures are present.
above the canopy, and cooler temperatures are present in the upper portions of the canopy. The lower temperature in the upper canopy results from the cooling effect of the dense canopy compared to the intense heat of the sunlight above the canopy (the shade effect).

Though not fully documented, some believe the microinversion may prevent smaller spray droplets from entering the canopy, especially from higher application releases. Also, spraying during windy conditions should be avoided due to drift concerns. Finally, foliage should be dry at the time fungicides are applied. Moisture on foliage (dew or rain) could reduce product efficacy due to dilution or runoff.

Serious limitations in individual and system-wide spray capacities may make it necessary to spray some fields during less than ideal conditions. Nonetheless, best control of soybean rust is likely to be achieved when fungicide applications are made as close to ideal conditions as possible.

Summary

- Choose the appropriate size and type of nozzle and operate at a pressure that will allow the creation of high-fine to mid-medium (200 to 300 micron) size droplets.
- When spraying in fields with shorter/less dense canopies, the use of twin nozzle technology — two nozzles angled forward and backward — may work better than single nozzles spraying down. A single pattern flat-fan nozzle calibrated to achieve the proper application volume at a higher pressure may be just as successful or better, especially as the density in the canopy increases.
- Air-assisted spray systems may provide the best coverage and droplet penetration into full-canopied soybean. Energy from the air-assist system tends to move the canopy, exposing lower leaves. To achieve the best results, high pressures may be required.
- Keep spray volumes (application rate) at a minimum of 15 GPA for ground application and 5 GPA for aerial application, especially late in the growing season. Higher volumes may be necessary as the soybean crop density increases.
- Environmental conditions at the time of spraying can have a great influence on final disease control outcome.

To spray fungicides for soybean rust:

- Choose nozzles and adjust pressure to develop hi-fine to mid-medium spray quality (200 to 300 microns).
- Use higher spray pressure to achieve the desired droplet size.
- Flat-fan nozzles work as good or better than cone nozzles with less drift.
- Single pattern flat-fan nozzles work as good or better than double outlet or twin-nozzle configurations, especially in heavier canopy.
Any spray platform should be able to make efficient and efficacious applications for rust control. Aerial application platforms (helicopters and fixed wing) are well suited because of their speed — for timely applications, for their ability to work under wet field conditions, and because they do not compact the soil or disturb the crop. These guidelines should make aerial applications most productive.

All applications must be made uniformly over the entire crop.

- Make sure the aircraft is utilizing the optimum swath width.
- Avoid misses around obstructions.
- Dress headlands to get those areas around trees and power lines.
- Do not plant areas that cannot be effectively treated by aircraft. Work with your applicator to determine where these areas are; plow them up if necessary to avoid hot spots.

Utilize the optimum application height.

- Most turbine aircraft need to be operated with the spray boom 10 to 12 feet above the crop canopy — and very large (660 to 800 gallon capacity) aircraft must operate even higher.
- Both lower and higher release heights may reduce pattern uniformity and increase drift potential.

Don’t spray during the heat of the day if possible.

As more and more energy is absorbed into the canopy, it becomes more difficult for the smaller droplets to pass through the strong micro-inversion layer that forms at the top of the crop.

Utilize nozzles that control droplet spectrums well.

Choose nozzles that make as few droplets as possible below 200 microns.

Years of work in heavy canopies indicate the droplet spectrums should be targeted in the 300 to 400 VMD (volumetric median diameter, where half of the spray volume is that size or larger and half of the spray volume is that size or smaller) range.

- Droplet spectrum may be the most important aspect of these applications and should be carefully adjusted with nozzle selection, operating pressure, and mounting configuration.
- Small changes in droplet diameter make big changes in droplet volume. Example: It takes 1.6 300-micron droplets to equal one 350-micron droplet and 2.4 300-micron droplets to equal one 400-micron droplet.
- There are excellent aerial models available to help

Aircraft speed changes the droplet spectrum.

- The optimum droplet spectrum can generally be developed by selecting the appropriate setup configuration.
- Turbine powered, faster aircraft generally have more uniform patterns.
- It may be more difficult for faster aircraft to work around some obstructions.

Total spray volume per acre will be somewhat dependent on crop canopy structure. The optimum range is 5 to 7 GPA.

There is generally a lot of disagreement on this issue, with a lot of opinions leaning toward more water. Canopy penetration and deposition studies have not indicated a need for more diluent volume.

The use of adjuvants and surfactants may be very beneficial as spreaders and stickers. Care should be taken to avoid major droplet spectrum changes when these products are being utilized.

If multiple applications are made, utilize different travel lanes or go in the opposite direction to move droplets into the canopy at different angles.
Prior to the arrival of soybean rust in North America in late 2004, the use of fungicides to control late-season fungal diseases of soybean in the southern United States was variable. For example, in Alabama and Georgia, where the combined soybean acreage is less than 400,000 acres, fungicides were typically used on less than 5 percent of the acreage. Applications were usually limited to fields with high yield potential, where soybean was grown under irrigation, and/or where frogeye leaf spot was a significant production risk. In contrast, fungicide use in Louisiana and Mississippi, where combined soybean acreage exceeds 2.5 million acres, has been routine for control of a range of late-season fungal diseases.

The occurrence of soybean rust in North America has ushered in an era of heightened interest in the use of foliar fungicides to control not only soybean rust, but other late-season diseases as well. This has complicated matters because the decision to apply a fungicide to manage soybean rust may not result in optimal control of late-season diseases, and vice versa. Soybean producers need fungicide programs that are effective against soybean rust and other late-season fungal diseases.

Fungal diseases other than soybean rust are a common problem in soybean produced in the southern United States. If left unmanaged, these diseases can reduce both grain yield and quality. Cercospora leaf blight, frogeye leaf spot, aerial (web) blight, pod and stem blight, and anthracnose are the predominant foliar diseases affecting soybean in the South. Currently, Cercospora leaf blight is the most prevalent and destructive disease in the Mid-South. Thousands of soybean acres were abandoned in Louisiana in 2006 because of this disease. Cercospora leaf blight not only causes direct yield loss, but it also results in indirect losses associated with green stem syndrome (i.e., pods and seeds mature, but stems remain green). In this situation, producers are forced to use a harvest aid (desiccant) prior to harvest.

Pod and stem diseases also frequent producer fields and can impact seed quality if conditions remain conducive for disease development. Aerial blight is limited to production areas that experience extended periods of high relative humidity and moderate temperatures. Under the right conditions, this disease can be as devastating as soybean rust. The most effective and economical method for managing diseases is genetic resistance; however, agronomically acceptable, disease-resistant soybean varieties are not generally available. Therefore, producers have managed late-season diseases using fungicides and cultural practices.
Fungicides differ both in the range and degree of disease control efficacy, and not all are effective against soybean rust and other late-season diseases. Thus, fungicide use decisions are now more complicated in light of the soybean rust threat. Historically, fungicides in the strobilurin and benzimidazole classes have been used to control late-season fungal diseases in the southern United States. Unfortunately, strobilurins, while excellent for combating late-season diseases, are not the most effective products for managing soybean rust. Moreover, thiophanate-methyl, while being moderately effective against Cercospora leaf blight and other late-season diseases, is ineffective against soybean rust.

Triazole fungicides have proved to be effective for managing soybean rust, but their efficacy against common late-season diseases of soybean in the United States is largely unknown. Thus, triazoles may result in poor control of other diseases unless applied as a mixture with a strobilurin. The current trend is to apply a mix of a strobilurin and a triazole if both soybean rust and other late-season diseases threaten production. Unfortunately, these mixtures are significantly more expensive than products applied by themselves, and under certain circumstances, obtaining acceptable control of late-season diseases may be difficult.

Other concerns are the number and timing of fungicide applications needed for managing late-season diseases on a regular basis and soybean rust, periodically. Prior to soybean rust, a single fungicide application made between R3 and R5 was the most common system used by producers. However, because soybean rust epidemics have the potential to initiate at stages earlier than R3, applications made with late-season disease control as a target may be too late to provide effective control of soybean rust. Conversely, applications made earlier to control soybean rust may result in poor control of late-season diseases because of insufficient residual activity. Thus, multiple applications may be needed if soybean rust develops before the R3 stage.

A real-world situation that illustrates these disease management complexities developed in southern Louisiana early in the 2007 season. Soybeans in this area are typically sprayed with a strobilurin (e.g., Quadris) at R3 for the control of late-season pod and stem diseases. This treatment is very effective for preserving grain quality and yield. In addition, if there is a threat of Cercospora leaf blight, which generally occurs later in the season, thiophanate-methyl (i.e., Tospin M) may be applied at R5. In late May 2007, soybeans were at the R2 stage of development and not showing any symptoms of soybean rust;
kudzu in the immediate area was heavily infected with rust. The question at this juncture was whether or not to spray for the control of rust, which was probably in its latent (pre-symptomatic) phase, and at the same time consider that late-season diseases would need to be controlled.

A strobilurin applied at that time would have protected plants from new rust infections for 21 to 28 days, but it would have been ineffective against existing infections. In addition, the treatment would not have sufficient residual activity to control late-season diseases. A triazole applied at R2 would have activity against existing rust infections and would provide a window of protection against new infections, but like the strobilurin, it would be ineffective against late-season diseases. Applying a strobilurin + triazole at R2 would have slightly increased the effective period for protection against new rust infections compared to triazole alone, and the triazole in the mix would have helped with existing rust infections, but the predicted lack of activity against late-season diseases (due to the early application date) and the considerably higher cost of a mix treatment, made this option unacceptable.

Finally, the risk of waiting until R3 to apply a strobilurin + triazole mixture was deemed to be too great given the explosive nature of rust and the rust-favorable conditions that existed at that time. Therefore, the decision was made to apply a triazole at R2 for soybean rust control, realizing that late-season disease control would be compromised unless a later application of Topsisin-M was made.

This real-world disease management scenario illustrates severe gaps in our knowledge. We must determine if there is an extended latent period following early infection, and if so, how much residual activity can we expect from a fungicide applied at this very early stage of reproductive growth. In addition, we must determine how early various fungicides can be applied and still give acceptable control of late-season diseases. Lastly, we must conduct more studies to determine the effectiveness of properly timed applications of triazoles and strobilurin + triazole mixtures for controlling late-season pod and stem diseases.

While Southern soybean growers are accustomed to applying fungicides for the control of late-season foliar and stem diseases, the need to protect leaves from rust in the lower canopy is a new challenge with many unknowns. Adequate control of both soybean rust and late-season diseases may necessitate the use of higher volumes of water and possibly different spray boom and nozzle configurations. Aerial
application of pesticides, including fungicides, with two to five gallons of water per acre is currently very popular in the South. However, this technology needs to be thoroughly evaluated under heavy soybean rust pressure, in combination with different row spacings, to determine if current fungicide application technology is acceptable or if modifications to the system are in order.
### Table 11-1. Comparisons of Chemical Classes of Fungicides with Regard to Management of Soybean Rust (SBR), Cercospora Leaf Blight (CLB), and Other Diseases.

<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Examples</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td>Bravo, Echo, Equus</td>
<td>Extensively tested in 1970s and 1980s. Not very effective against most diseases and probably will not play a role in the Mid-South.</td>
</tr>
<tr>
<td>Strobilurins (QoI)</td>
<td>Azoxystrobin (Quadris)</td>
<td>This is a core fungicide for Mid-South producers. Efficacious against aerial blight, anthracnose, and pod and stem blight; suppresses Cercospora leaf blight and frogeye; not very effective against soybean rust. Will not be recommended as a stand-alone product for soybean rust, but it does have a place as a tank mix with a triazole.</td>
</tr>
<tr>
<td></td>
<td>Pyraclostrobin (Headline)</td>
<td>Similar to Quadris in its activity against diseases other than soybean rust, although it is more efficacious against CLB. However, it is very effective against soybean rust when applied prior to infection. It probably will not be recommended as a stand-alone material, but it is a core fungicide in the Mid-South when tank mixed with a triazole.</td>
</tr>
<tr>
<td>Triazoles</td>
<td>Cyproconazole (Alto)</td>
<td>In general, these materials are very effective against soybean rust, but there are limited data with regard to control of Cercospora leaf blight, aerial blight, frogeye leaf spot, and pod and stem diseases. More research is needed on this class of fungicides with regard to timing, rates, concentrations, and combinations with other fungicide classes.</td>
</tr>
<tr>
<td></td>
<td>Flusilazole (Punch)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flutriafol (TopGuard)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metconazole (Caramba)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Myclobutanil (Laredo)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tebuconazole (Folicur and others)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tetraconazole (Domark)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Propiconazole (Tilt and others)</td>
<td>Not as effective as the other triazoles against soybean rust.</td>
</tr>
<tr>
<td>Triazoles + QoI Fungicides</td>
<td>Cyproconazole + azoxystrobin (Quadris Xtra)</td>
<td>In general, these materials offer the best option for managing soybean rust and other foliar and pod and stem diseases in the South. Additional research is needed on application timing and rates with regard to managing soybean rust as compared to other diseases.</td>
</tr>
<tr>
<td></td>
<td>Flusilazole + famoxadone (Charisma)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metconazole + pyraclostrobin (Headline Caramba copack)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Propiconazole + trifloxystrobin (Stratego)</td>
<td>These materials are not as effective as the other combination products against soybean rust, but they may have a place for managing other diseases.</td>
</tr>
<tr>
<td></td>
<td>Propiconazole + azoxystrobin (Quilt)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tebuconazole + trifloxystrobin (Absolute)</td>
<td>There is not enough information on this material to substantiate recommendations.</td>
</tr>
</tbody>
</table>
Table 11.2. Estimation of Effectiveness of Fungicides on Rust and Other Diseases of Soybeans. Rust Ratings Are Based Upon Limited Testing During 2006 and 2007 and Are Subject to Change.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Trade Names</th>
<th>Soybean Rust</th>
<th>Frogeye Leaf Spot</th>
<th>Cercospora Leaf Blight</th>
</tr>
</thead>
<tbody>
<tr>
<td>chlorothalonil</td>
<td>Echo, Bravo, Equus</td>
<td>P</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>azoxystrobin</td>
<td>Quadris</td>
<td>F</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>pyraclostrobin</td>
<td>Headline</td>
<td>G/F</td>
<td>G</td>
<td>F</td>
</tr>
<tr>
<td>cyproconazole</td>
<td>Alto</td>
<td>G</td>
<td>P</td>
<td>F</td>
</tr>
<tr>
<td>flutriafol</td>
<td>Topguard</td>
<td>G</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>metconazole</td>
<td>Caramba</td>
<td>G</td>
<td>P</td>
<td>F</td>
</tr>
<tr>
<td>myclobutanil</td>
<td>Laredo</td>
<td>G</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>propiconazole</td>
<td>Tilt, PropiMax, Bumper</td>
<td>G</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>tebuconazole</td>
<td>Folicur, Orius, Uppercut</td>
<td>G</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>tetraconazole</td>
<td>Domark</td>
<td>G</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>trifloxistrobin</td>
<td>Absolute</td>
<td>G</td>
<td>G/F</td>
<td>P</td>
</tr>
<tr>
<td>flusizole</td>
<td>Punch</td>
<td>G</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>prothiconazole</td>
<td>Proline</td>
<td>G</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>flusizole</td>
<td>Charisma</td>
<td>G</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Thiophanate methyl</td>
<td>Topsin M</td>
<td>P</td>
<td>G</td>
<td>F</td>
</tr>
</tbody>
</table>

P = Poor; little to no activity.
F = Fair; some activity but does not provide complete control.
G = Good; good activity, timing of fungicide application is critical for success.

Note: These ratings are based upon one or two applications. Trials were conducted in southern states — Dr. Mel Newman, University of Tennessee; Dr. Raymond Schneider, Louisiana State University-Ag Center; Dr. Boyd Padgett, Louisiana State University. Cooperative Extension publications in each state should be consulted for specific recommendations. Reference to commercial products or trade names is made with the understanding that no discrimination is intended for those products that may not be listed and no endorsement of particular products is implied.
Chapter 12

Similar Looking Diseases

Loren Giesler, University of Nebraska-Lincoln

Bacterial Blight

- Affects mid-to-upper leaves.
- Angular lesions, reddish-brown to black centers.
- Initial angular water-soaked lesions with yellow halo.

**Difference from Soybean Rust:** Water soaking; angular lesions; lesions on leaf underside are not raised.

Bacterial Pustule

- Affects mid-to-upper leaves.
- Lesions — small spots to large irregular shapes without water soaking.
- Lesions associate with main veins; pustules form in lesion centers on leaf underside. (10X)

**Difference from Soybean Rust:** Pustules not always with each lesion; pustules do not have spores in openings; openings are cracks instead of circular pores.
**Downy Mildew**
- Affects upper leaves.
- Spots on surface enlarge into yellow lesions.
- Older lesions turn brown with yellow-green margins; size varies with age of leaf affected.
- Fuzzy fungal gray tufts on leaf underside (20X).

*Difference from Soybean Rust:* Lesions larger than rust lesions; no raised pustules on underside; fuzzy fungal growth on underside.

**Cercospora Blight**
- Blight affects upper leaves exposed to sun after seed set.
- Blight starts as light purple areas on upper leaf surface which expands to cover surface; leaves leathery and dark reddish purple on upper surface only.
- As blight develops, necrotic tissue appears on the upper and lower leaf surfaces.

*Difference from Soybean Rust:* Blight — overall leaf area is discolored on upper surface only.
Brown Spot

- Affects lower leaves first.
- Irregular-shaped dark-brown lesions on both leaf surfaces; size — small spots to large areas; adjacent lesions can form irregular shaped blotches.
- Infected leaves quickly yellow and drop.

**Difference from Soybean Rust:** No raised areas (on leaf) underside; angular lesions; if dark lesions, lack of uredia is key symptom; first symptoms can look like rust; has same canopy distribution as rust.

Frogeye Leaf Spot

- Frogeye lesions start as dark, water-soaked spots; can have light centers; circular to angular brown spots with dark red-brown margins.

**Difference from Soybean Rust:** Frogeye — discrete lesions larger than rust with defined lesion margins; no pustules evident on underside.
Chapter 13

Alternatives for Organic Soybean Production

A. Gevens, D. Wright, A. Blount, R. Mizell, R. Sprenkel, C. Mackowiak, S. Olson, J. A. Smith, J. Marois, and L. Datnoff, University of Florida

Organic Management of Soybean Rust

Although only 0.1 percent of the total current U.S. soybean acreage is organically produced, the demand for organic soybeans is gradually increasing due to a growing demand for soy-based food products, such as soy milk and tofu. Additionally, there is a growing consumer interest in organic livestock that has, in turn, increased the need for a greater supply of organically produced feed.

Managing disease on an organic farm can be challenging, especially when environmental conditions are favorable for disease, and there is little or no host resistance. Studies by the USDA have indicated that virtually all of the commercially grown soybean varieties are susceptible to soybean rust (SBR). Additionally, soybean plants are susceptible at any stage of growth, although first infections are typically observed on lower leaves of plants that are flowering or post-flowering. Several synthetic fungicides have been shown to be effective in managing SBR; however, these fungicides are not acceptable in organic production.

Studies were undertaken in 2005 and 2006 to identify organic-approved materials that may be effective in managing SBR. The research was conducted at the North Florida Research and Education Center (NFREC) in Quincy, Florida. A two-acre transitional organic field was used for the studies because its southern border was in close proximity to naturalized kudzu (Figure 13.1) with probable overwintered SBR infections.

Figure 13.1. The organic soybean rust management study at the North Florida Research and Education Center at Quincy, Florida. Note the blue color on some plots due to products containing copper. Photo by Jim Marois. Used with permission.
Organic fungicides were applied at flowering and included these products: Champion WP (NuFarm Americas, Inc.), Ballad (AgraQuest, Inc.), Electrified Water, Oxidate (Biosafe Systems, Inc.), Agricoat Natural II (Agricoat LLC), Basic Copper Sulfate (Old Bridge Chemicals, Inc.), MicroAF (TerraMax, Inc.), and Caprylic Acid.

During the course of the study, insect pests, namely the southern green stinkbug (*Nezara viridula*), became problematic. For this reason, in the second year of research, a trap cropping study was initiated outside the main study area to both limit the insect pests in the SBR study area and to develop a season-long insect trap cropping system for soybean that would be organic-approved.

Under heavy soybean rust pressure, organic-approved copper fungicides, such as Champion WP and Basic Copper Sulfate, controlled SBR significantly better than products that did not contain copper. Soybean plants treated with copper products had significantly less SBR on all rating dates and produced seed with significantly higher yield, size, and quality. Organic-approved non-copper fungicides did limit SBR when compared to the untreated check. However, soybean plants treated with non-copper products did not produce seed with characteristics that were significantly better than the untreated check. Untreated checks were moderately infected at the first rating, and rust progressed rapidly from October 7 to November 3, 2006.
A variety of insects and mites are pests of soybean throughout North America. Many of these pests can become infected with naturally occurring fungi. In some instances, these fungi, called entomopathogenic fungi, are key mortality factors keeping plant-damaging insects and mites from reaching damaging levels. Entomopathogenic fungi can either be specialists, such as *Pandora neoaphidis*, that attack only aphids or generalists, such as *Beauveria bassiana*, that attack a wide range of insect species.

Fungicides applied to soybean put all entomopathogenic fungi at risk. The suppression of entomopathogenic fungi due to application of fungicide can cause a population response in the pest, but this response will depend on environmental conditions and the frequency of fungicide application. Insect and mite pests of soybean that are often infected with entomopathogenic fungi include the two-spotted spider mite, velvetbean caterpillar, green cloverworm, soybean looper, bean leaf beetle, and soybean aphid.

Fungicides have been implicated in the suppression of beneficial fungi in many cropping systems. In potato, where fungicide use is as frequent as every five days, disruption of entomopathogenic fungi can be so severe that aphid populations flare. Although soybean will not be treated with fungicides as frequently as potato, care must be exercised when applying fungicides to any crop where entomopathogenic fungi are known to be a key mortality factor. For example, two-spotted spider mite outbreaks in soybean are usually associated with drought conditions, but when there is sufficient humidity, mite populations are held in check by the entomopathogenic fungus, *Neozygites floridana*. Fungicides used for rust control appear to cause mite populations to flare, resulting in a yield loss.

Recent work in Minnesota has focused on the impact soybean rust fungicides have on the fungal pathogens of soybean aphid. All fungal pathogens found infecting soybean aphids in Minnesota belong to the class Entomophthorales. These fungi require specific environmental conditions of moderate temperatures (60°F to 85°F) and high relative humidity (98 to 100 percent) to infect their hosts — conditions that would also favor development of soybean rust. Typically, soybean aphids are most heavily infected with entomopathogenic fungi late in the growing season, but infected aphids can be isolated during early reproductive plant growth stages when fungicides for soybean rust might first be applied in the north central states.
In 2005, in Lamberton, Minnesota, several rust fungicides, including strobilurin, triazole, and chloronitrile-based fungicides and mixtures of two or more active ingredients, were evaluated for their effect on the prevalence of diseased soybean aphids in replicated field trials. All fungicides tested, which included four different fungicide treatment programs ranging from applying one to three foliar sprays (Table 14.1), lowered incidence of diseased soybean aphids compared to an untreated control (Figure 14.1). On the two sampling dates with the highest disease prevalence (Aug. 30 and Sept. 2), aphids collected from fungicide-treated plots had 89 and 81 percent less infection (Figure 14.1; note: all fungicides reduced prevalence of disease in soybean aphid, and thus data were combined for clarity).

All fungicides tested proved to be detrimental to the entomopathogenic fungi infecting soybean aphid in the field, and this also has been confirmed in laboratory studies. Yet, aphid populations in soybean did not flare up as we have observed in potato. Fungicides were applied to soybean during mid-reproductive stages (R2 to R4), but aphids collected from treated plots late in the growing season, weeks after the last foliar spray, were infected less often (Figure 14.1). We concluded from these limited data that fungicide use in soybean may not always result in an increase in aphid density on soybean, but that the incidence of diseased aphids will be significantly reduced.

Recent research in New York State showed that soybean aphids collected from buckthorn were more likely to be infected with entomopathogenic fungi than those collected in soybean. Our work in Minnesota did find high levels of disease in aphids on soybean, but only late in the growing season at a time of the year when aphids would be leaving soybean and migrating to buckthorn to begin the sexual phase of the aphid’s life cycle. Intense fungicide use across the landscape, which might occur during a soybean rust outbreak, might dramatically lower the incidence of diseased aphids on buckthorn.

Further work is required to confirm these results and to determine how fungicides might affect soybean aphid population dynamics, both on the crop and in the overwintering habitat.

Clearly, fungicides are detrimental to this important group of natural enemies of arthropod pests found in soybean, and unnecessary fungicide applications should be avoided to preserve these beneficial fungi.
Table 14.1: Fungicide Treatments Applied to Small Plots in Lamberton, Minnesota, in 2005. All Applications Were Made at the Labeled Rate.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Active Ingredient</th>
<th>Product Name</th>
<th>Application Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pyraclostrobin + Tebuconazole</td>
<td>Headline SBR®</td>
<td>Growth stage R2</td>
</tr>
<tr>
<td></td>
<td>Pyraclostrobin + Tebuconazole</td>
<td>Headline SBR®</td>
<td>14 DAT*</td>
</tr>
<tr>
<td>2</td>
<td>Pyraclostrobin + Tebuconazole</td>
<td>Headline SBR®</td>
<td>Growth stage R2</td>
</tr>
<tr>
<td></td>
<td>Pyraclostrobin + Tebuconazole</td>
<td>Headline SBR®</td>
<td>14 DAT*</td>
</tr>
<tr>
<td></td>
<td>Chlorothalonil</td>
<td>Bravo Weatherstik®</td>
<td>28 DAT*</td>
</tr>
<tr>
<td>3</td>
<td>Azoxystrobin + Propiconazole</td>
<td>Quilt®</td>
<td>Growth stage R2</td>
</tr>
<tr>
<td>4</td>
<td>Trifloxystrobin + Propiconazole</td>
<td>Stratego®</td>
<td>Growth stage R5</td>
</tr>
</tbody>
</table>

* DAT: Days after application of first treatment.

Figure 14.1: Percent prevalence of disease in soybean aphid in untreated (solid line) and fungicide-treated (dashed line) plots in Lamberton, Minnesota, in 2005. Fungicide treatment lowered the prevalence of disease up to 89 percent when compared to the untreated control. All fungicides tested were detrimental to entomopathogens and thus data were combined for clarity. Courtesy: Karrie Koch (graduate student), David Ragsdale, Professor of Entomology, University of Minnesota, St. Paul, Minn. Used with permission.
Store Fungicides Correctly to Prolong Shelf Life

Growers who purchased fungicides in anticipation of using them for managing soybean rust may have unused product that requires storage. Properly stored fungicides typically have a shelf life of two to three years. General guidelines for proper pesticide storage are summarized in this report. More specific storage requirements for individual products can be found on the pesticide labels or can be obtained by contacting the manufacturer. Products that require protection from freezing or extreme heat should have that information on the label.

Pesticide containers (or packaging) have a batch number and a manufacture or formulation date. They may display a suggested use-by or expiration date. Information about the storage life of a fungicide once the container is opened is rarely found on the label; however, this information should be available from the distributor or manufacturer. Always use opened products first, followed by the oldest products. To make it easier to keep track of what you have in storage, tag or mark the date of purchase on each pesticide container when it is delivered.

For information and regulations related to constructing a new pesticide storage facility or evaluating your current pesticide storage area, consult the Farm-A-Syst program or the Department of Agriculture in your state.

The storage tips presented here apply to all pesticides and are not limited to fungicides.

Prevent Water and Moisture Damage to Pesticides

Water or excess moisture can damage pesticide containers and their contents. Moisture can cause metal containers to rust and paper and cardboard containers to split or crumble. Dry pesticides stored under these conditions may cake or clump. Slow-release products may release their active ingredients. Pesticide labels may smear, peel, or otherwise become unreadable.

To prevent water and moisture damage:

- Keep containers securely closed when not in use.

- Place opened bags of dry formulations (i.e., wettable and soluble powders, dry flowables, and granules) into sealable plastic bags or clear plastic containers. Plastic bags or containers allow the label to be easily identified, while
reducing moisture absorption and preventing spills.

– When storing liquid formulations on shelves (preferably metal shelving, to prevent possible absorption of pesticide by the shelving material), avoid placing liquids above dry materials, where leaking could cause damage.

– A jug containing a liquid formulation may be set inside a plastic pan on the shelf to contain leaks.

• Keep bags off the floor; store on plastic pallets.

– Keep metal drums from direct contact with floors (where they may be more prone to rusting) and place them in a drum rack or on a plastic pallet.

– Avoid locating a pesticide storage facility near an area likely to flood or where runoff water can be a potential problem, such as at the base of a slope.

To prevent damage to pesticides from temperature:

• Water-soluble packages may attract moisture and become brittle when frozen. Store them in a warm, dry location.

• The storage area should be insulated or temperature controlled to prevent freezing and or/overheating.

• Exhaust fans vented to the outside can help reduce temperatures and remove vapors and fumes from the storage area.

• To avoid overheating and degradation of product, pesticide containers should not be stored where they are exposed to direct sunlight.

Control Pesticide Storage Temperatures

Protection from temperature extremes is important because either freezing or excess heat can shorten the shelf life of pesticides and may reduce their effectiveness. The normal temperature range for storing liquid pesticides is usually 40°F to 100°F. Low temperatures may cause the product to break down or separate, or the container may rupture. If a pesticide does freeze, some products may be shaken, rolled, or agitated to re-suspend the contents after thawing. Contact the manufacturer for advice on using specific pesticides that have frozen. Heat expansion of containers may place the contents under pressure, causing the container to overflow or break.

General pesticide storage tips:

• Whether your pesticide storage area is an entire
room or a building, or a closet or a cabinet devoted to pesticide storage, keep it locked to prevent unauthorized entry, vandalism, and theft.

- Post warning signs on doors and windows to let people know that pesticides are stored inside.
- No Smoking signs should also be posted, since many pesticides are flammable.
- Regularly check containers for leaks. The contents of leaking containers should be transferred to a sound container with the exact same formulation and label. Follow label recommendations for disposal of damaged containers.
- Store pesticides in their original containers with the labels intact.
- Put the heaviest containers and liquids on lower shelves; be sure shelves are sturdy enough to handle the load.
- To avoid cross-contamination, store each type of pesticide (fungicides, herbicides, and insecticides) in a separate location or on a separate shelf within the storage unit.
- Store pesticides away from food, pet food, feed, seed, fertilizers, veterinary supplies, and flammable materials.

References


Chapter 16

The Influence of Soybean Rust on Crop Insurance

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Soybean is a widely insured crop, susceptible to many yield-reducing problems. The recent introduction of soybean rust into the United States has raised concern among producers that the disease may seriously reduce crop yields and corresponding financial returns. There is also a concern about how crop insurance will respond to those losses. Federal crop insurance is available in the most common soybean-producing areas of the United States, and soybean rust is considered an insured peril. However, to determine the extent to which crop insurance provides financial protection, it is important to recognize the type of insurance and the level of insurance purchased. This knowledge helps one adequately prepare for a range of financial scenarios related to soybean production.

Not all soybean acres in the United States are insured. Insurance may not be available in some cases because of location (dry area/flood plain) or unusual production practice (such as a double-crop where the crop may not reach full maturity). Other producers may be unwilling to purchase insurance — despite a large premium subsidy. They may deem the cost too high for the coverage available, or the returns too low relative to their expected risk of loss.

For producers with insurance, soybean rust is handled like any other insured peril. Specifically, producers cannot ignore soybean rust and then claim the disease caused a loss. They must follow Good Farming Practices and do what is possible to minimize damage due to the disease. Further, some types of insurance will not cover individual farm-level losses. For example, group products only guard against county-level yield losses. Finally, damage assessments of losses from soybean rust may not be large enough to trigger an indemnity payment. Even with insurance, the financial responsibility may fall entirely on the producer. Accurate documentation of all actions related to soybean rust is critical to any future claim.

Insurance Products

Several insurance products are available, and each has different advantages to the producer. All policies are subject to a purchase deadline. The purchase deadline for soybean insurance is either February 28 or March 15, depending on the state. An insurance product must be purchased by the deadline date for the crop to be covered. Producers pick a product type that matches their financial needs and that is cost effective. The type chosen will vary across locations and over
Common soybean crop insurance options include the following:

- **Yield insurance products**, such as:
  - Multiple Peril Crop Insurance (MPCI)

- **Revenue insurance products**, such as:
  - Revenue Assurance (RA)
  - Crop Revenue Coverage (CRC).

While most crops are insured on an individual basis, as previously mentioned, there are also group policies available that only cover county-level effects. Of these products, Group Risk Protection (GRP) only covers county average yield declines, while Group Risk Income Protection (GRIP) only covers county average declines in revenue. Group Risk Protection (GRP) has increased in use in recent years, especially in Illinois and Indiana.

The different product types may have different price elections used to determine the amount of coverage and indemnity levels in the event of a loss. The prevailing use of revenue insurance products gives additional protection against any potential price risk associated with rust. For example, if soybean rust were to cause significant yield losses at the national level, then the price of soybeans could increase. Producers with revenue insurance can still reasonably forward-price or contract a portion of their crop. Without revenue insurance, lost bushels and higher replacement costs to fulfill any contracts could quickly offset any indemnity payments. With revenue insurance products, indemnity payments are linked to the greater of spring and harvest price levels.

**Level of Coverage**

The coverage level usually refers to the yield election chosen. MPCI is often purchased at the 50 percent level, which is a minimal amount of yield coverage. Another common choice is RA at the 70 percent level. The 70 percent level means that actual yields have to fall below 70 percent of the producer’s historical or proven yields. The producer is responsible for the deductible, which is the remaining 30 percent of the value of the crop.

In these examples, insurable causes of loss (including soybean rust) would have to exceed 50 percent in the MPCI example or 30 percent in the RA example in order to recover any loss caused by soybean rust. If expected yield losses from soybean rust are not above the deductible level (30 percent or 50 percent in this example), the producer would bear the total financial loss, even with insurance. Thus, producers will have to use the current market price, treatment cost, and
soybean rust risk to estimate the cost effectiveness of managing rust. Note: Price declines may trigger payments on the RA example, regardless of yield loss.

Producers have a financial responsibility to try to prevent and control damage from rust and similar problems. The insurance policies typically indicate that in order to maintain coverage, producers must use “Good Farming Practices” and cannot claim “damage due to insufficient or improper application of disease control measures.” Thus, if a reasonable control measure is available, then a producer would need to try to use the method to mitigate any losses.

Producers are encouraged to visit with their insurance agent on any company-specific expectations regarding soybean rust and other perils. Further, record keeping is important in showing that Good Farming Practices have been followed. Producers should keep track of all management actions that have been performed on a crop, what they do (or pay to have done), and when they do it. The producer may be expected to keep receipts, labels, and records should a claim be necessary.

The http://www.sbrusa.net web site hosts a Good Farming Practices Tool (the link to it is in the lower right-hand corner of the screen, labeled GFP Tool) that can help producers document management decisions in concert with the history of soybean rust risk in their state (see Figure 16.1). This tool was developed by the USDA-Risk Management Agency (RMA) with input from state Extension specialists. To be eligible for a claim, producers must record all actions taken to prevent or treat soybean rust in their crop, and this tool aids in the required record keeping.

Figure 16.1. GFP tool for producers.
Determining Loss

Production-based plans of insurance, such as those described earlier, compare the production to count (PTC) to the guarantee. PTC is calculated for crop insurance indemnity purposes using both appraised production and harvested production. For indemnity calculations, PTC is used along with actual production history (APH), acres planted, insurance level of coverage, quality adjustments, uninsured causes of loss, price election, and share in the crop.

To determine production lost due to uninsured causes, the insurance company representatives may talk to the producer to determine what happened and how the producer responded, gather information from agricultural experts to determine Good Farming Practices (GFP), consider recommendations for chemical treatments, and consider what should have happened. The fields in question will also be compared to similar fields in the area where producers followed GFP relative to differences in production practices.

For the following example, we will assume a producer has an APH of 50 bushels per acre, plants 100 acres, elects 60 percent coverage, and has 100 percent share in the crop. In this case, the guarantee calculation is as follows:

\[
50 \text{ bushels per acre} \times 100 \text{ acres} \times 60\% \times 100\% = 3,000 \text{ bushels guarantee}
\]

If the producer harvested 100 percent of the 100-acre crop at 20 bushels per acre, the result was 2,000 bushels of harvested production.

Example No. 1 — No quality adjustment and no uninsured causes of loss:

\[
3,000 \text{ bushels coverage} - 2,000 \text{ bushels PTC} = 1,000 \text{ bushels shortfall.}
\]

The indemnity is based upon 1,000 bushels x price election x 100 percent share. In this case, the shortfall is fully covered at the market price determined by the insurance product or contract.

Example No. 2 — No quality adjustment and uninsured causes of loss:

Producer lost 500 bushels due to some uninsured causes of loss.

\[
2,000 \text{ bushels harvested} + 500 \text{ bushels uninsured causes} = 2,500 \text{ bushels PTC.}
\]

\[
3,000 \text{ bushels coverage} - 2,500 \text{ bushels PTC} = 500 \text{ bushels shortfall.}
\]

The indemnity is based on 500 bushels x price election x 100 percent share. In this case, the shortfall is only partially covered at the market price determined by the insurance product or contract.

Example No. 3 — Quality adjustment and no uninsured causes of loss:

The 2,000 bushels harvested are extremely low quality and quality adjusted from 2,000 bushels to 1,000 bushels PTC using the quality adjustment statements contained in the Special Provision of Insurance (SPOI). These reductions are generally known as discounts.

\[
So for 3,000 \text{ bushels coverage} - 1,000 \text{ bushels PTC} = 2,000 \text{ bushels shortfall is the result.}
\]
Special Provisions of Insurance are part of the insurance contract, modify the crop provisions, exist on a county crop basis, and contain the quality adjustment discount factor (DF) charts. The indemnity is based upon 2,000 bushels x price election x 100 percent share. Quality losses are not likely to be an issue with soybean rust, but under the conditions that favor soybean rust late in the season, other causes of quality loss might occur, such as those caused by seed-infecting fungi. In this case, the shortfall actually exceeds the loss in harvested yield, and coverage will be at the market price determined by the insurance product or contract.

Uninsured causes of loss appear to be the largest single concern for producers dealing with soybean rust insurance issues. Since crop insurance policies list plant disease as a cause of loss, the loss is covered as long as the terms of the agreement are upheld by the producer. The most frequent concern is insufficient or improper application of disease-control measures. This is not an insurable cause of loss. As long as an effective control measure is available, producers are expected to use it to maintain full insurance coverage.

In response to the question, “Must producers spray to prevent/control soybean rust, regardless of cost and regardless of the condition of the crop?” the short answer is “Yes.” If the producer elects, due to economic or other reasons, not to fully protect the crop, then any losses attributed to that management decision are not covered and are considered uninsured causes of loss. As such, the uninsured causes of loss would be added to the PTC value for a field, reducing the indemnity to the producer.

For example, a producer has a 50 bushels per acre APH on his or her soybeans and an appraised production of 20 bushels per acre. Soybean rust then infects the soybean acreage. If the producer chose not to spray, he or she would lose an additional 2 bushels per acre. Thus, sprayed soybeans would yield 20 bushels per acre, and unsprayed soybeans would yield 18 bushels per acre. Even if the costs of spraying were greater than the value of 2 bushels per acre, crop insurance must consider these 2 bushels as lost due to uninsured causes if the producer elected not to spray.

In a situation such as this where the insured loss is already great relative to the insured value, the decision to spray is not a difficult one. Where the decision will be more difficult is when there is only a small difference from the insured value of the crop. Nonetheless, when it is time to make the decision to treat for soybean rust, the decision must be made.

With proper documentation there are some exceptions...
or contingencies to the requirement to treat for soybean rust. If the weather conditions prevent spraying, that is a covered contingency; if the crop is later than R6 when rust is detected, that is a covered contingency; if effective treatments are not available, that is a covered contingency; and if the commercial applicators are not available, that is also a covered contingency.

If producers have questions about their particular crop insurance plans, they should contact their crop insurance provider. It is important that growers understand any restrictions of their particular plan of insurance and the SPOIs involved. In the future, those without insurance may consider purchasing it. Producers may change their choice of product if their current one does not adequately protect farm-level risks and/or revenue. Producers may also want to evaluate their choice of units covered should only portions of their units be particularly susceptible to rust or similar perils.

In the end, soybean rust is an insured cause of loss as long as Good Farming Practices are followed and efforts are made to manage the causes of loss. Documentation of all actions related to soybean rust is critical. Contact your crop insurance agent with questions.

Summary

A range of crop insurance products is available to soybean producers to protect against financial losses caused by soybean rust. The most important point to take away from any discussion of soybean rust and crop insurance is that crop insurance covers losses caused by soybean rust unless the producer did not follow accepted Good Farming Practices. Losses due to uninsured causes include failure to follow Good Farming Practices (often noted as GFP in USDA-RMA and IPM-PIPE documents) such as not spraying when advised by an agriculture expert, inadequate seeding rates, and inappropriate chemical usage such as incorrect chemical used, incorrect chemical application, or incorrect timing. If losses caused by soybean rust are not expected to exceed the deductible applied to the insurance policy, then producers will need to decide the cost-effectiveness of initiating control measures relative to crop price and estimated yield loss.
Chapter 17

Pesticide Basics

Pesticide Labels

A pesticide label is a legal document. Each user is required by law to apply any pesticide only in a manner that is consistent with label directions. If for any reason use rates or application guidelines presented in this publication or other references are not consistent with instructions on the label, users are reminded that the label takes precedence and must be obeyed. It is ILLEGAL to apply pesticides:

- Using less water than the label instructs (increasing the concentration).
- At a higher rate per acre than the label instructs.
- More frequently than the label instructs.

Specified preharvest intervals (minimum number of days between the last application and crop harvest) also must be obeyed.

Pesticide Formulations and Spray Adjuvants

Pesticide products contain at least one active ingredient that is combined with liquid or solid carriers to produce formulations that are safer or more practical to apply than the active ingredient alone. Common formulations include wettable powders, liquid concentrates, emulsifiable concentrates, dry flowable formulations, flowable liquids, soluble powders, dusts, and granules.

Several types of additives are available to improve the effectiveness of spray applications. Collectively, they are known as adjuvants. Do not use an adjuvant with any pesticide without first consulting the specific pesticide label. Improper selection or use can result in crop injury or reduced effectiveness, particularly when adjuvants are mixed with emulsible concentrates.
Glossary of Terms

**Anti-sporulant**: A fungicide that reduces the rate or level of fungal spore development.

**Curative fungicide**: A fungicide capable of arresting the growth of an existing fungal infection in plants.

**Dry flowable (DF)**: Formulations are similar to wettable powders, but the powders (clay particles) are formed into tiny spheres. They do not readily cake together, so they “flow” easily from the product container. Another name for this type of formulation is Water Dispersible Granule (WDG, WG).

**Dusts (D)**: Are usually made by mixing a chemical toxicant with finely ground talc, clay, or dried plant materials.

**Emulsifiable concentrates (EC)**: Contains a pesticide and an emulsifying agent in a solvent. ECs form suspensions when they are diluted with water for application as sprays. They leave much less visible residue than WP formulations, but they are more likely to injure fruit and foliage.

**Eradicative fungicide**: A fungicide capable of arresting the growth of an existing fungal infection during the later stages of plant colonization, but before sporulation. Eradicant fungicides may be anti-sporulants.

**Field severity**: The total amount of disease in a given field. Field severity is the product of Incidence x Severity.

**Flowable (F)**: Formulations are a liquid or viscous concentrate of suspended pesticide in water. They usually cause less injury to fruit and foliage than EC formulations and generally, but not always, are as safe as WP formulations.

**Granules (G)**: Are formed by saturating an inert material such as sand or clay with a pesticide. Particles (granules) range in size from 30 to 60 mesh. Granules are applied as dry material, usually to soil or water.

**Incidence**: The percentage of infected (at any level) plants in a field.

**Infection**: Penetration and colonization of the host by a pathogen.
**Liquid concentrates (L or LC):** Formulations containing toxicants that are water soluble. No emulsifying agents or organic solvents are required. Note: The designations L and LC are sometimes used by formulators on emulsifiable concentrates that are not water soluble.

**Locally systemic:** Describes a fungicide that moves relatively short distances in a plant following application and subsequent movement into plant tissue.

**Mode of action:** The specific mechanism by which a fungicide acts against a target fungus. The physiological processes of the fungus that are inhibited by the fungicide.

**Preventative treatment:** Treatment applied before infection occurs.

**Protectant fungicide:** A fungicide that forms a barrier to infection and prevents spore germination and/or penetration of the plant surface by the fungus, also referred to as a prophylactic fungicide.

**Residue:** The amount of fungicide left in or on the plant. Efficacy, persistence, and tolerances are all determined by the residual activity of a fungicide.

**Sentinel plot:** A small observation area in a crop field that is intensively sampled for the presence of a disease.

**Severity:** The degree of infection on a given plant. Usually represented as a percentage of the plant area diseased.

**Sign:** Visible fungal structures, such as a pustule or a spore.

**Soluble powders (SP):** Powder formulations that dissolve in water. A few pesticides and many fertilizers are prepared as soluble powders.

**Strobilurin:** A fungicide class that was originally derived from a compound called strobilurin A from the fungus *Strobilurus tenecellus*. All of the synthetic fungicides in this class are active at the same site of activity in the fungus, interrupting energy transfer in the mitochondria.

**Symptom:** The host’s response to the infection by a pathogen, such as leaf chlorosis or lesion with necrosis.

**Systemic:** A product that, when applied to the outside of the plant, is absorbed and moved within the plant. Most products move only
with the water stream (xylem), essentially from the base to the tip of the leaf.

**Translaminar:** Diffusion of the fungicide through the leaf from one leaf surface to the other.

**Triazole:** A large class of synthetic fungicides that are active at a single site in the fungus, inhibiting the production of sterols in the fungus. Sterols are important in cell membrane formation.

**Urediniospore:** The wind-dispersed infectious spore of rust fungi.

**Volume median diameter (VMD):** Common term used to describe the droplet spectrum of a nozzle. VMD is the droplet size at which half of the total spray volume coming out of the nozzle is contained in droplets larger and half of the spray volume is contained in droplets smaller. For example, a nozzle with a VMD of 510 μm contains half of its total sprayed volume in droplets with a diameter greater than 510 μm and the other half in droplets smaller than 510 μm. Another way of describing droplet sizes produced by a nozzle is the percentage of spray volume contained in droplets smaller than a specific diameter, usually 150 μm. This method of description directly addresses droplets small enough to be at risk for drift. For instance, a nozzle may be measured to produce 2 percent of its total spray volume in droplets smaller than 150 μm in diameter, which means that only a small portion of the total volume sprayed by this nozzle is contained in droplets at risk for drift.

**Wettable powders (WP):** Dry formulations of pesticides that are to be mixed with water for application. The toxicant is mixed with specific powders; wetting agents are added to make the mixture blend readily with water. Wettable powders form a suspension that must be kept agitated in the spray tank. Sprays prepared from wettable powders are less likely than other sprays to cause injury to fruit or foliage.
Web Sites — Sources for Soybean Rust Information

APS Soybean Rust Symposium — Proceedings for 2006 and 2005
http://www.plantmanagementnetwork.org/infocenter/topic/soybeanrust/2006/

National Plant Diagnostic Network:
http://npdn.ppath.cornell.edu/default.htm

North Central IPM Center:
http://www.ncpmc.org/index.html

Northeast IPM Center:
http://www.northeastipm.org

Ohio State University Soybean Rust Web Site: (updates of this publication)
http://www.oardc.ohio-state.edu/SoyRust/

PIPE platform for tracking and monitoring soybean rust
www.sbrusa.net

Plant Diagnostic Clinics in the United States:
www.apsnet.org/directories/univ_diagnosticians.asp

Plant Health Initiative:
http://www.planthealth.info/

Soybean Rust Information Center
http://www.plantmanagementnetwork.org/infocenter/topic/soybeanrust/

Regional IPM Centers:
http://www.ipmcenters.org/
Selected Articles and Related Publications


### Appendix A

#### Table A.1. Conversion Factors for Weights and Measures: Proportions.

<table>
<thead>
<tr>
<th>Proportions</th>
<th>Metric</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 g/ha</td>
<td>1.4 oz/acre</td>
<td></td>
</tr>
<tr>
<td>1 kg/ha</td>
<td>0.9 lb/acre</td>
<td></td>
</tr>
<tr>
<td>1 ton (metric)/ha</td>
<td>0.446 tons (U.S.)/acre</td>
<td></td>
</tr>
<tr>
<td>1 l/ha</td>
<td>0.4 qt/acre</td>
<td></td>
</tr>
<tr>
<td>1 kg/1000 l</td>
<td>1 lb/100 gal</td>
<td></td>
</tr>
<tr>
<td>g/1000 kg</td>
<td>1 ppm</td>
<td></td>
</tr>
<tr>
<td>1 km/hr</td>
<td>0.6 mph</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 oz/acre</td>
<td>70g/ha</td>
<td></td>
</tr>
<tr>
<td>1 lb/acre</td>
<td>1.12 kg/ha</td>
<td></td>
</tr>
<tr>
<td>1 ton (U.S.)/acre</td>
<td>2.24 tons (metric)/ha</td>
<td></td>
</tr>
<tr>
<td>1 fl. oz/acre</td>
<td>73 ml/ha</td>
<td></td>
</tr>
<tr>
<td>1 gal/acre</td>
<td>9.39 l/ha</td>
<td></td>
</tr>
<tr>
<td>1 lb/100 gal</td>
<td>1 kg/1000 l</td>
<td></td>
</tr>
<tr>
<td>1 ppm</td>
<td>1 g/1000 kg</td>
<td></td>
</tr>
<tr>
<td>1 mph</td>
<td>1.6 km/hr</td>
<td></td>
</tr>
</tbody>
</table>

#### Table A.2. Conversion Factors for Weights and Measures: Temperatures.

<table>
<thead>
<tr>
<th>Temperatures</th>
<th>Celsius (Centigrade)</th>
<th>Fahrenheit</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>-22</td>
<td>-22</td>
</tr>
<tr>
<td>-20</td>
<td>-4</td>
<td>-4</td>
</tr>
<tr>
<td>-10</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>0</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>20</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>30</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>40</td>
<td>104</td>
<td>104</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fahrenheit</th>
<th>Celsius (Centigrade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-18</td>
</tr>
<tr>
<td>10</td>
<td>-12</td>
</tr>
<tr>
<td>20</td>
<td>-7</td>
</tr>
<tr>
<td>30</td>
<td>-1</td>
</tr>
<tr>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>60</td>
<td>16</td>
</tr>
<tr>
<td>70</td>
<td>21</td>
</tr>
<tr>
<td>80</td>
<td>27</td>
</tr>
<tr>
<td>90</td>
<td>32</td>
</tr>
</tbody>
</table>

To convert Celsius to Fahrenheit—multiply by 9/5 (1.8), then add 32.

To convert Fahrenheit to Celsius—subtract 32, then multiply by 5/9 (0.56)
Table A.3. Conversion Factors for Weights and Measures: Equivalents.

<table>
<thead>
<tr>
<th>Common Equivalents</th>
<th>Metric</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 millimeter</td>
<td></td>
<td>0.039 in.</td>
</tr>
<tr>
<td>1 centimeter (10 mm)</td>
<td></td>
<td>0.39 in.</td>
</tr>
<tr>
<td>1 meter (100 cm)</td>
<td></td>
<td>39.4 in.</td>
</tr>
<tr>
<td>1 kilometer (1,000 m)</td>
<td></td>
<td>0.62 mi.</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 square centimeter</td>
<td></td>
<td>0.155 sq. in.</td>
</tr>
<tr>
<td>1 square meter</td>
<td></td>
<td>1.2 sq. yd.</td>
</tr>
<tr>
<td>1 hectare (10,000 sq m)</td>
<td></td>
<td>2.47 acres</td>
</tr>
<tr>
<td>1 sq. kilometer (100 ha)</td>
<td></td>
<td>247 acres</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 gram</td>
<td></td>
<td>0.035 ounces</td>
</tr>
<tr>
<td>1 kilogram (1,000 g)</td>
<td></td>
<td>2.2 pounds</td>
</tr>
<tr>
<td>1 ton (metric) (1,000 kg)</td>
<td></td>
<td>1.1 tons (U.S.)</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 milliliter</td>
<td></td>
<td>0.034 fluid oz.</td>
</tr>
<tr>
<td>1 liter (1,000 ml)</td>
<td></td>
<td>1.056 quarts</td>
</tr>
<tr>
<td>1 cubic meter (1,000 l)</td>
<td></td>
<td>264.17 gal. (U.S.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>U.S.</strong></th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td></td>
</tr>
<tr>
<td>1 inch</td>
<td>2.54 centimeters</td>
</tr>
<tr>
<td>1 foot (12 in.)</td>
<td>30.5 centimeters</td>
</tr>
<tr>
<td>1 yard (3 ft.)</td>
<td>0.91 meters</td>
</tr>
<tr>
<td>1 mile (5,280 ft.)</td>
<td>1.6 kilometers</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td></td>
</tr>
<tr>
<td>1 square inch</td>
<td>6.5 square centimeters</td>
</tr>
<tr>
<td>1 square foot (1.44 sq. in.)</td>
<td>930 square centimeters</td>
</tr>
<tr>
<td>1 square yard (9 sq. ft.)</td>
<td>0.84 square meters</td>
</tr>
<tr>
<td>1 acre (43,560 sq. ft.)</td>
<td>0.405 hectares</td>
</tr>
<tr>
<td>1 square mile (640 acres)</td>
<td>259 hectares</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td></td>
</tr>
<tr>
<td>1 ounce</td>
<td>28.3 grams</td>
</tr>
<tr>
<td>1 pound (16 oz.)</td>
<td>0.454 kilograms</td>
</tr>
<tr>
<td>1 ton (U.S.) (2,000 lb.)</td>
<td>0.907 tons (metric)</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td></td>
</tr>
<tr>
<td>1 tablespoon (3 teaspoons)</td>
<td>14.79 milliliters</td>
</tr>
<tr>
<td>1 fluid ounce (2 tablespoons)</td>
<td>29.6 milliliters</td>
</tr>
<tr>
<td>1 cup (8 fl. oz.)</td>
<td>0.237 liters</td>
</tr>
<tr>
<td>1 pint (2 cups)</td>
<td>0.473 liters</td>
</tr>
<tr>
<td>1 quart (4 cups)</td>
<td>0.946 liters</td>
</tr>
<tr>
<td>1 gallon (us) (4 qts)</td>
<td>3.8 liters</td>
</tr>
<tr>
<td>1 cubic foot</td>
<td>28.3 liters</td>
</tr>
</tbody>
</table>

Metric Abbreviations: mm—millimeter; cm—centimeter; m—meter; km—kilometer; ha—hectare; mg—milligram; g—gram; kg—kilogram; ml—milliliter; l—liter.
### Table A.4. Oral, Dermal, and Inhalation Toxicity Ratings of Pesticides.1

<table>
<thead>
<tr>
<th>Toxicity Rating</th>
<th>Label Signal Words</th>
<th>Oral LD&lt;sub&gt;50&lt;/sub&gt; (mg/kg)</th>
<th>Dermal LD&lt;sub&gt;50&lt;/sub&gt; (mg/kg)</th>
<th>Lethal Oral Dose, 150-pound Man</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Danger-Poison</td>
<td>0-50</td>
<td>0-200</td>
<td>few drops to teaspoon</td>
</tr>
<tr>
<td>Moderate</td>
<td>Warning</td>
<td>50-500</td>
<td>200-2,000</td>
<td>1 teaspoon to 1 ounce (2 tablespoons)</td>
</tr>
<tr>
<td>Low</td>
<td>Caution</td>
<td>500-5,000</td>
<td>2,000-20,000</td>
<td>1 ounce to 1 pint, or 2 pounds</td>
</tr>
<tr>
<td>Very Low</td>
<td>Caution</td>
<td>5,000+</td>
<td>20,000+</td>
<td>1 pint or more, or 2 pounds or more</td>
</tr>
</tbody>
</table>

1 Note that values in these categories indicate LETHAL (deadly) doses; much lower doses may cause severe injury or chronic health effects.

### Table A.5. Soybean Pesticides—Toxicity.

<table>
<thead>
<tr>
<th>Product</th>
<th>Oral LD&lt;sub&gt;50&lt;/sub&gt;</th>
<th>Dermal LD&lt;sub&gt;50&lt;/sub&gt;</th>
<th>Bee Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fungicides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bravo WeatherStik (chlorothalonil)</td>
<td>9,000</td>
<td>&gt;2,000</td>
<td>&gt;181 ug/bee</td>
</tr>
<tr>
<td>Bumper (propiconazole)</td>
<td>&gt;2,000</td>
<td>&gt;5,000</td>
<td>not available</td>
</tr>
<tr>
<td>Domark (tetriconazole)</td>
<td>&gt;5,000</td>
<td>&gt;2,000</td>
<td>not available</td>
</tr>
<tr>
<td>Echo 720 (chlorothalonil)</td>
<td>3,260</td>
<td>&gt;2,000</td>
<td>not available</td>
</tr>
<tr>
<td>Folicur (tebuconazole)</td>
<td>3,776</td>
<td>2,011</td>
<td>not available</td>
</tr>
<tr>
<td>Headline (pyraclostrobin)</td>
<td>&gt;500</td>
<td>&gt;4,000</td>
<td>&gt;100 ug/bee</td>
</tr>
<tr>
<td>Laredo EC (mycobutanil)</td>
<td>2,800</td>
<td>&gt;5,000</td>
<td>&gt;362 ug/bee</td>
</tr>
<tr>
<td>Propimax EC (propiconazole)</td>
<td>not determined</td>
<td>not determined</td>
<td>not available</td>
</tr>
<tr>
<td>Quadris (azoxyystrobin)</td>
<td>&gt;5,000</td>
<td>&gt;4,000</td>
<td>&gt;200 ug/bee</td>
</tr>
<tr>
<td>Quilt (azoxyystrobin + propiconazole)</td>
<td></td>
<td></td>
<td>&gt;200 ug/bee</td>
</tr>
<tr>
<td>Stratego (propiconazole + trifloxystrobin)</td>
<td>4,757</td>
<td>5,050</td>
<td>not available</td>
</tr>
<tr>
<td>Tilt (propiconazole)</td>
<td>1,310</td>
<td>&gt;5,000</td>
<td>&gt;25 ug/bee</td>
</tr>
<tr>
<td><strong>Insecticides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asana (esfenvalerate)</td>
<td>458</td>
<td>&gt;2,000</td>
<td>highly toxic</td>
</tr>
<tr>
<td>Dimethoate (dimethoate)</td>
<td>571</td>
<td>&gt;2,020</td>
<td>highly toxic</td>
</tr>
<tr>
<td>Lorsban (chlorpyrifos)</td>
<td>&gt;5,000</td>
<td>776</td>
<td>highly toxic</td>
</tr>
<tr>
<td>Mustang (zeta-cypermethrin)</td>
<td>234</td>
<td>&gt;2,000</td>
<td>highly toxic</td>
</tr>
<tr>
<td>Warrior (lambda-cyhalothrin)</td>
<td>350</td>
<td>&gt;2,000</td>
<td>0.038 ug/bee</td>
</tr>
</tbody>
</table>
Warning: Azoxystrobin Phytotoxic to Certain Apple Varieties. Field and laboratory tests have shown that azoxystrobin is extremely toxic to certain apple varieties, mainly Macintosh apples and Macintosh-derived varieties. To date, the phytotoxic symptoms include necrosis, leaf drop, and fruit drop. Incidents have been reported on both grapes and apples in the past. Specific apple varieties that have had problems include:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Discovery</th>
<th>McCoun</th>
<th>Stark Gala</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akane</td>
<td>Galaxy</td>
<td>Molly Delicious</td>
<td>Summared</td>
</tr>
<tr>
<td>Asahi</td>
<td>Gala</td>
<td>Macintosh</td>
<td>Starkpur Mac</td>
</tr>
<tr>
<td>Bramley</td>
<td>Galaxy</td>
<td>Mondial Gala</td>
<td>Warabi</td>
</tr>
<tr>
<td>Courtland</td>
<td>Grimes Imperial</td>
<td>Royal Gala</td>
<td></td>
</tr>
<tr>
<td>Cox’s Orange</td>
<td>Kent</td>
<td>Ontario</td>
<td>Worcester</td>
</tr>
<tr>
<td>Pippin</td>
<td>Kizashi</td>
<td>Queen Cox</td>
<td>Pearmain</td>
</tr>
<tr>
<td>Cox</td>
<td>Lurared</td>
<td>Royal Gala</td>
<td></td>
</tr>
<tr>
<td>Celbarestival</td>
<td></td>
<td>Spartan</td>
<td></td>
</tr>
</tbody>
</table>

The most practical means of describing the droplet sizes produced by a nozzle is to categorize the droplet sizes using the entire droplet size spectrum, not just the VMD or the percentage of volume in small droplets. The classification system used in the American Society of Agricultural Engineers (ASAE) standard S-572: Spray Nozzle Classification by Droplet Spectra is an example. This classification system has six categories: very fine (VF), fine (F), medium (M), coarse (C), very coarse (VC), and extra coarse (XC). Using these categories, a nozzle and operating pressure can be selected that produce a specific droplet size spectrum. The droplet size spectrum required for a job is based on the type of pesticide being applied and is often stated on the label. Table A.6 shows the six droplet spectrum categories and their VMD ranges. Keep in mind that even though a VMD range is given for each category, the classification is based on the entire droplet spectrum produced by a nozzle, not just the VMD. The VMD is given for reference.

<table>
<thead>
<tr>
<th>ASAE Standard S-572 Droplet Spectrum Category</th>
<th>Symbol</th>
<th>VMD (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very fine</td>
<td>(VF)</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>Fine</td>
<td>(F)</td>
<td>150-250</td>
</tr>
<tr>
<td>Medium</td>
<td>(M)</td>
<td>250-350</td>
</tr>
<tr>
<td>Coarse</td>
<td>(C)</td>
<td>350-450</td>
</tr>
<tr>
<td>Very coarse</td>
<td>(VC)</td>
<td>450-550</td>
</tr>
<tr>
<td>Extremely coarse</td>
<td>(XC)</td>
<td>&gt;550</td>
</tr>
</tbody>
</table>
### Appendix B

**Soybean Rust Fungicides — Label Status: United States**

Table B.1. Registered Products in the United States for Management of Soybean Rust (Updated: 1/11/08), Daren Mueller, Iowa State University.

<table>
<thead>
<tr>
<th>Product</th>
<th>Trade Name</th>
<th>Manufacturer</th>
<th>Chemical Group</th>
<th>Active Ingredient</th>
<th>Formulation</th>
<th>Rate/Acre</th>
<th>Volume - Ground (GPA)</th>
<th>Volume - Air (GPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REGISTERED PRODUCTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bravo® WeatherStik</td>
<td>Syngenta Crop</td>
<td>Chloronitrile</td>
<td>chlorothalonil</td>
<td>Flowable</td>
<td>1-2 pts (3 appl.)</td>
<td>20-30</td>
<td>High volume spray</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protection Inc</td>
<td></td>
<td></td>
<td></td>
<td>1½ - 2¼ pts (2 appl.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bravo® Ultrex</td>
<td>Syngenta Crop</td>
<td>chlorothalonil</td>
<td>chlorothalonil</td>
<td>Dry flowable</td>
<td>0.9 - 1.4 lbs (3 appl.)</td>
<td>5-10</td>
<td>Low volume spray</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protection Inc</td>
<td></td>
<td></td>
<td></td>
<td>1.4 - 2.2 lbs (2 appl.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echo® 720</td>
<td>Sipcam Agro USA</td>
<td>chlorothalonil</td>
<td>chlorothalonil</td>
<td>Flowable</td>
<td>1-2 pts (3 appl.)</td>
<td>20-150</td>
<td>High volume spray</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1½ - 2¼ pts (2 appl.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echo® 90DF</td>
<td>Sipcam Agro USA</td>
<td>chlorothalonil</td>
<td>chlorothalonil</td>
<td>Dry flowable</td>
<td>7/8 - 1-5/8 lbs (3 appl.)</td>
<td>5-10</td>
<td>Low volume spray</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1¼ - 2 lbs (2 appl.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equus® 720 SST</td>
<td>FarmSaver.com, LLC</td>
<td>chlorothalonil</td>
<td>chlorothalonil</td>
<td>Flowable</td>
<td>1 - 1.6 pts.</td>
<td>5 minimum</td>
<td>Apply in sufficient water to obtain complete coverage, generally 10-20 gallons per acre.</td>
<td></td>
</tr>
<tr>
<td>Equus® DF</td>
<td>FarmSaver.com, LLC</td>
<td>chlorothalonil</td>
<td>chlorothalonil</td>
<td>Dry flowable</td>
<td>1.5 - 2.2 lbs</td>
<td>5 minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadris® 2.08EC</td>
<td>Syngenta Crop</td>
<td>Strobilurin</td>
<td>azoxystrobin</td>
<td>Flowable</td>
<td>6 - 15.5 fl oz</td>
<td>Sufficient water volume for adequate coverage and canopy penetration</td>
<td>10 minimum</td>
<td></td>
</tr>
<tr>
<td>Headline® 2.09EC</td>
<td>BASF Corporation</td>
<td>pyraclostrobin</td>
<td>Emulsifiable concentrate</td>
<td>6 - 12 fl oz</td>
<td>15 minimum</td>
<td>5 minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laredo™ 25EC</td>
<td>Dow AgroSciences</td>
<td>Triazole</td>
<td>myclobutanil</td>
<td>Emulsifiable concentrate</td>
<td>4 - 8 fl oz</td>
<td>Adequate spray volume to achieve good coverage and canopy penetration (normally 15-20)</td>
<td>5 minimum</td>
<td></td>
</tr>
<tr>
<td>Tilt® 250EC</td>
<td>Syngenta Crop</td>
<td>propiconazole</td>
<td>Emulsifiable concentrate</td>
<td>4 - 8 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bumper® 41.8EC</td>
<td>Makhteshim-Agan</td>
<td>propiconazole</td>
<td>Emulsifiable concentrate</td>
<td>4 - 8 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domark® 230ME</td>
<td>Isagro USA</td>
<td>tetraconazole</td>
<td>Micro-encapsulated emulsion</td>
<td>4 - 5 fl oz</td>
<td>10-25</td>
<td>5 minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratego® 250EC</td>
<td>Bayer CropScience</td>
<td>Triazole + strobilurin</td>
<td>propiconazole + trifloxystrobin</td>
<td>Emulsifiable concentrate</td>
<td>5.5 - 10 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
<td></td>
</tr>
<tr>
<td>Quilt™ 1.67SC</td>
<td>Syngenta Crop</td>
<td>propiconazole + azoxystrobin</td>
<td>Emulsifiable concentrate</td>
<td></td>
<td>14 - 20 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
<td></td>
</tr>
</tbody>
</table>
## Soybean Rust Fungicides — Label Status: United States

Table B.1 (continued). Registered Products in the United States for Management of Soybean Rust (Updated: 1/11/08), Daren Mueller, Iowa State University.

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Manufacturer</th>
<th>Chemical Group</th>
<th>Active Ingredient</th>
<th>Formulation</th>
<th>Rate/Acre</th>
<th>Volume - Ground (GPA)</th>
<th>Volume - Air (GPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto® 100SL</td>
<td>Syngenta Crop Protection Inc</td>
<td>Triazole</td>
<td>cyproconazole</td>
<td>Flowable</td>
<td>4 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
</tr>
<tr>
<td>Punch™</td>
<td>DuPont</td>
<td></td>
<td>flusilazole</td>
<td>Emulsifiable concentrate</td>
<td>3 - 4 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
</tr>
<tr>
<td>Topguard™ 125 SC</td>
<td>Cheminova</td>
<td></td>
<td>flutriafol</td>
<td>Suspension concentrate</td>
<td>7 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
</tr>
<tr>
<td>Caramba™</td>
<td>BASF Corporation</td>
<td></td>
<td>metaconazole</td>
<td>Soluble concentrate</td>
<td>8.2–9.6 fl oz</td>
<td>Utilize spray application techniques including sufficient water carrier per acre, pressure and proper nozzle selection that ensure thorough coverage.</td>
<td></td>
</tr>
<tr>
<td>Folicur® 3.6 SCa</td>
<td>Bayer CropScience</td>
<td></td>
<td>tebuconazole</td>
<td>Suspension concentrate</td>
<td>3–4 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
</tr>
<tr>
<td>Orius™ 3.6 SCa</td>
<td>Makhteshim-Agan</td>
<td></td>
<td>tebuconazole</td>
<td>Suspension concentrate</td>
<td>3–4 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
</tr>
<tr>
<td>Uppercut™ a</td>
<td>DuPont</td>
<td></td>
<td>tebuconazole</td>
<td>Suspension concentrate</td>
<td>3–4 fl oz</td>
<td>10 minimum</td>
<td>5 minimum</td>
</tr>
</tbody>
</table>

*Registrars of products expect an EPA decision for renewal of the Section 18 registration in 2008.*
### Soybean Rust Fungicides — Label Status: United States

<table>
<thead>
<tr>
<th>Product</th>
<th>Trade Name/Chemical Group</th>
<th>Active ingredient</th>
<th>Spray Interval (days)</th>
<th>Max Product/Acre per Year</th>
<th>REI (hours)</th>
<th>Preharvest Interval (PHI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil products</td>
<td>Chloronitrile</td>
<td>chlorothalonil</td>
<td>14</td>
<td>5.4 lbs or 6 pts</td>
<td>12</td>
<td>42 days</td>
</tr>
<tr>
<td>Quadris® 2.08EC</td>
<td>Strobilurin</td>
<td>azoxystrobin</td>
<td>21</td>
<td>31 fl oz</td>
<td>4</td>
<td>14 days</td>
</tr>
<tr>
<td>Headline® 2.09EC</td>
<td></td>
<td>pyraclostrobin</td>
<td>7-21</td>
<td>24 fl oz</td>
<td>12</td>
<td>21 days</td>
</tr>
<tr>
<td>Alto® 100SL</td>
<td>Triazole</td>
<td>cyproconazole</td>
<td>14-21</td>
<td>8 fl oz</td>
<td>12</td>
<td>30 days</td>
</tr>
<tr>
<td>Punch™</td>
<td></td>
<td>flusilazole</td>
<td>14-21</td>
<td>8 fl oz</td>
<td>168</td>
<td>30 days</td>
</tr>
<tr>
<td>Topguard™ 125 SC</td>
<td></td>
<td>flutriafol</td>
<td>21</td>
<td>14 fl oz</td>
<td>12</td>
<td>21 days</td>
</tr>
<tr>
<td>Caramba™</td>
<td></td>
<td>metaconazole</td>
<td>10-21</td>
<td>19.2 fl oz</td>
<td>12</td>
<td>30 days</td>
</tr>
<tr>
<td>Laredo™ 25EC</td>
<td></td>
<td>myclobutanil</td>
<td>14-21</td>
<td>16 fl oz</td>
<td>24</td>
<td>28 days</td>
</tr>
<tr>
<td>Tilt® 250EC and Bumper® 41.8EC</td>
<td></td>
<td>propiconazole</td>
<td>14</td>
<td>12 fl oz</td>
<td>24</td>
<td>Not after R5 growth stage</td>
</tr>
<tr>
<td>Folicur® 3.6F and others</td>
<td></td>
<td>tebuconazole</td>
<td>10-21</td>
<td>8 fl oz</td>
<td>12</td>
<td>30 days</td>
</tr>
<tr>
<td>Domark® 230ME</td>
<td></td>
<td>tetraconazole</td>
<td>If necessary, before R6</td>
<td>10 fl oz</td>
<td>12</td>
<td>Not after R5 growth stage</td>
</tr>
<tr>
<td>Quilt™ 1.67SC</td>
<td>Triazole + strobilurin</td>
<td>propiconazole + azoxystrobin</td>
<td>14-21</td>
<td>40 fl oz</td>
<td>24</td>
<td>Not after R5 growth stage</td>
</tr>
<tr>
<td>Stratego® 250 EC</td>
<td>Triazole + trifloxystrobin</td>
<td>propiconazole + trifloxystrobin</td>
<td>10-21</td>
<td>20 fl oz</td>
<td>24</td>
<td>Not after R5 growth stage</td>
</tr>
</tbody>
</table>
## Soybean Rust Fungicides — Label Status: United States

<table>
<thead>
<tr>
<th>Product</th>
<th>Trade Name</th>
<th>Chemical Group</th>
<th>Active Ingredient</th>
<th>Oral LD50 (rats)</th>
<th>Dermal LD50 (rats)</th>
<th>Bee toxicity (µg/bee)</th>
<th>Signal word</th>
<th>FRAC Code</th>
<th>EPA Reg #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bravo® WeatherStik</td>
<td>Chloronitrile</td>
<td>chlorothalonil</td>
<td>2/3 9,000</td>
<td>&gt;2,000</td>
<td>&gt;181</td>
<td>Danger M</td>
<td>50534-188-100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bravo® Ultrex</td>
<td>chlorothalonil</td>
<td>2/3 &gt;5,000</td>
<td>&lt;2,000</td>
<td>&gt;181</td>
<td>Caution M</td>
<td>50534-201-1000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echo® 720</td>
<td>chlorothalonil</td>
<td>2/3 3,260</td>
<td>&gt;2,020</td>
<td>NA</td>
<td>Warning M</td>
<td>60063-7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echo® 90DF</td>
<td>chlorothalonil</td>
<td>2/3 3,260</td>
<td>&gt;2,020</td>
<td>NA</td>
<td>Danger M</td>
<td>60063-10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equus® 720 SST</td>
<td>chlorothalonil</td>
<td>2/3 NA</td>
<td>NA</td>
<td>NA</td>
<td>Warning M</td>
<td>72167-24-73220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equus® DF</td>
<td>chlorothalonil</td>
<td>2/3 NA</td>
<td>NA</td>
<td>NA</td>
<td>Warning M</td>
<td>72167-25-73220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadris® 2.08EC</td>
<td>Strobilurin</td>
<td>azoxystrobin</td>
<td>1/3 &gt;5,000</td>
<td>&gt;4,000</td>
<td>&gt;200</td>
<td>Caution 11</td>
<td>100-1098</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headline® 2.09EC</td>
<td>pyraclostrobin</td>
<td>1/3 &gt;500</td>
<td>&gt;4,000</td>
<td>&gt;100</td>
<td>Warning 11</td>
<td>7969-186</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alto® 100SL</td>
<td>Triazole</td>
<td>cyproconazole</td>
<td>1/2 &gt;2,000</td>
<td>&gt;4,000</td>
<td>NA</td>
<td>Caution 3</td>
<td>100-864</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punch™</td>
<td>flusilazole</td>
<td>-/- 1,696</td>
<td>&gt;2,000</td>
<td>NA</td>
<td>Caution 3</td>
<td>unregistered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topguard™ 125 SC</td>
<td>flutriafol</td>
<td>-/- NA</td>
<td>NA</td>
<td>NA</td>
<td>Danger 3</td>
<td>unregistered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caramba™</td>
<td>metaconazole</td>
<td>1/2 NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>3 unregistered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laredo™ 25EC</td>
<td>myclobutanil</td>
<td>1/2 2,800</td>
<td>&gt;5,000</td>
<td>&gt;362</td>
<td>Danger 3</td>
<td>62719-412</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bumper® 41.8EC</td>
<td>propiconazole</td>
<td>1/2 &gt;2,000</td>
<td>&gt;2,000</td>
<td>not toxic</td>
<td>Warning 3</td>
<td>66222-42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tilt® 250EC</td>
<td>propiconazole</td>
<td>1/2 1,310</td>
<td>&gt;5,000</td>
<td>&gt;25</td>
<td>Warning 3</td>
<td>100-617</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folicur® 3.6F</td>
<td>tebuconazole</td>
<td>1/2 3,776</td>
<td>&gt;2,011</td>
<td>NA</td>
<td>Caution 3</td>
<td>264-752</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orius™ 3.6F</td>
<td>tebuconazole</td>
<td>1/2 &gt;4,000</td>
<td>&gt;5,000</td>
<td>NA</td>
<td>Caution 3</td>
<td>264-752-66222</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uppercut™</td>
<td>tebuconazole</td>
<td>1/2 3,776</td>
<td>&gt;2,011</td>
<td>NA</td>
<td>NA</td>
<td>264-752-352-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domark® 230ME</td>
<td>tetraconazole</td>
<td>-/- &gt;2,000</td>
<td>&gt;5,000</td>
<td>NA</td>
<td>Caution 3</td>
<td>80289-7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quilt™ 1.67SC</td>
<td>Triazole + strobilurin</td>
<td>propiconazole + azoxystrobin</td>
<td>-/- 1,750</td>
<td>&gt;5,000</td>
<td>&gt;25 + &gt;200</td>
<td>Caution 3+11</td>
<td>100-1178</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratego® 250 EC</td>
<td>propiconazole + trifloxystrobin</td>
<td>-/- 4,757</td>
<td>&gt;5,050</td>
<td>NA</td>
<td>Warning 3+11</td>
<td>264-779</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1 = high, 2 = intermediate, 3 = low. These runoff/leaching potential ratings are from the NRCS Win-PST Pesticide Properties Database (www.wcc.nrcs.usda.gov/pestmgt/winpst.html)
### Soybean Rust Fungicides — Label Status: Canada

Table B.4. Fungicides Registered in Canada for management of Soybean Rust (*Phakopsora pachyrhizi*). (As of August 20, 2007.) Albert Tenuta, Ontario Ministry of Agriculture.

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Active Ingredient</th>
<th>Manufacturer</th>
<th>Status</th>
<th>Rate/ Acre (mL/Acre)</th>
<th>Chemical Class</th>
<th>Maximum Number of Applications</th>
<th>PHI (days)</th>
<th>Diseases Controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folicur 432 F</td>
<td>Tebuconazole</td>
<td>Bayer</td>
<td>Emergency Use. Registration needed if required</td>
<td>125 mL/Acre</td>
<td>Triazole</td>
<td>2 Thorough coverage and penetration</td>
<td>21</td>
<td>Asian Soybean Rust</td>
</tr>
<tr>
<td>Headline EC</td>
<td>Pyraclostrobin</td>
<td>BASF</td>
<td>Registered</td>
<td>160 to 240 mL/Acre</td>
<td>Strobilurin</td>
<td>2 Thorough coverage and penetration</td>
<td>21</td>
<td>Asian Soybean Rust, Frog-Eye/Cercospora Leaf Spot (Cercospora sojina)</td>
</tr>
<tr>
<td>Quadris Azoxystrobin</td>
<td>Syngenta</td>
<td>Registered</td>
<td>200 mL/Acre</td>
<td>Strobilurin</td>
<td>2 Thorough coverage and penetration</td>
<td>15</td>
<td>Asian Soybean Rust, Powdery Mildew, Frog-Eye/Cercospora Leaf Spot (Cercospora sojina)</td>
<td></td>
</tr>
<tr>
<td>Tilt 250E Propiconazole</td>
<td>Syngenta</td>
<td>Registered</td>
<td>200 -300 mL/Acre</td>
<td>Triazole</td>
<td>2 Thorough coverage and penetration</td>
<td>30</td>
<td>Asian Soybean Rust, Powdery Mildew*, Frog-Eye/Cercospora Leaf Spot (Cercospora sojina)*</td>
<td></td>
</tr>
<tr>
<td>Quilt (Quadris + Tilt) Azoxystrobin + Propiconazole</td>
<td>Syngenta</td>
<td>Registered</td>
<td>Quadris 120 – 180 mL/ Acre + Tilt 200 – 300 mL/acre</td>
<td>Strobilurin + Triazole</td>
<td>2 Thorough coverage and penetration</td>
<td>30</td>
<td>Asian Soybean Rust</td>
<td></td>
</tr>
</tbody>
</table>