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

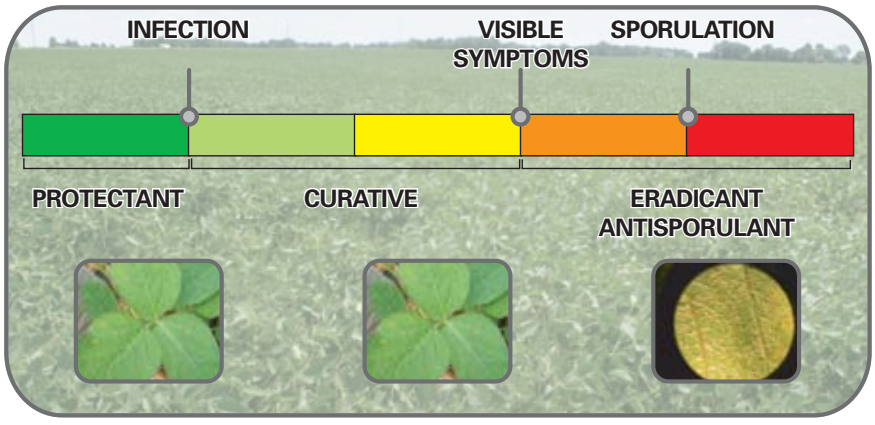
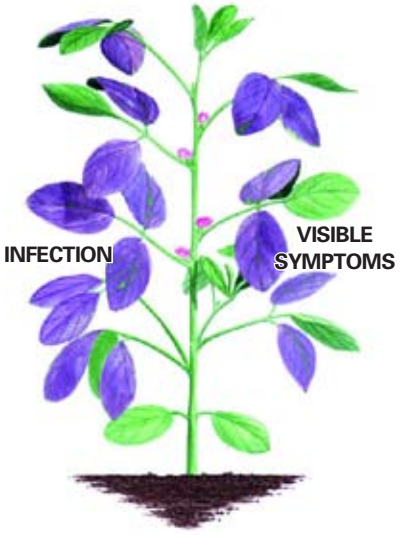


Figure 7.1. Schematic representation of fungicide activity in relation to soybean rust development.

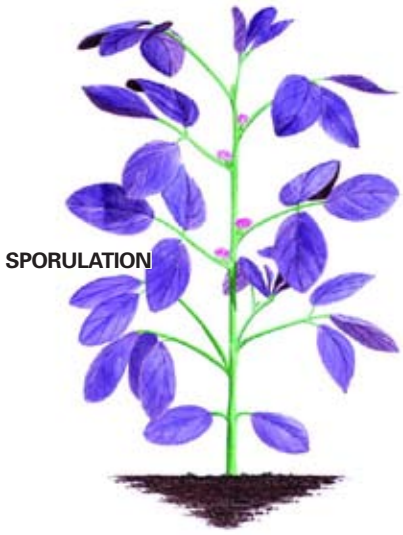
the Appendix) have curative activity. It is this post-infection activity that makes triazoles the fungicide of choice if soybean rust is established at low levels in a field (Figure 7.2). If chlorothalonil or one of the strobilurin fungicides is applied post-infection, existing infections will continue 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.

A. Fungicide Applied

B. Contact Fungicide



C. Strobilurin mobility



D. Triazole mobility

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.

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.

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

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.

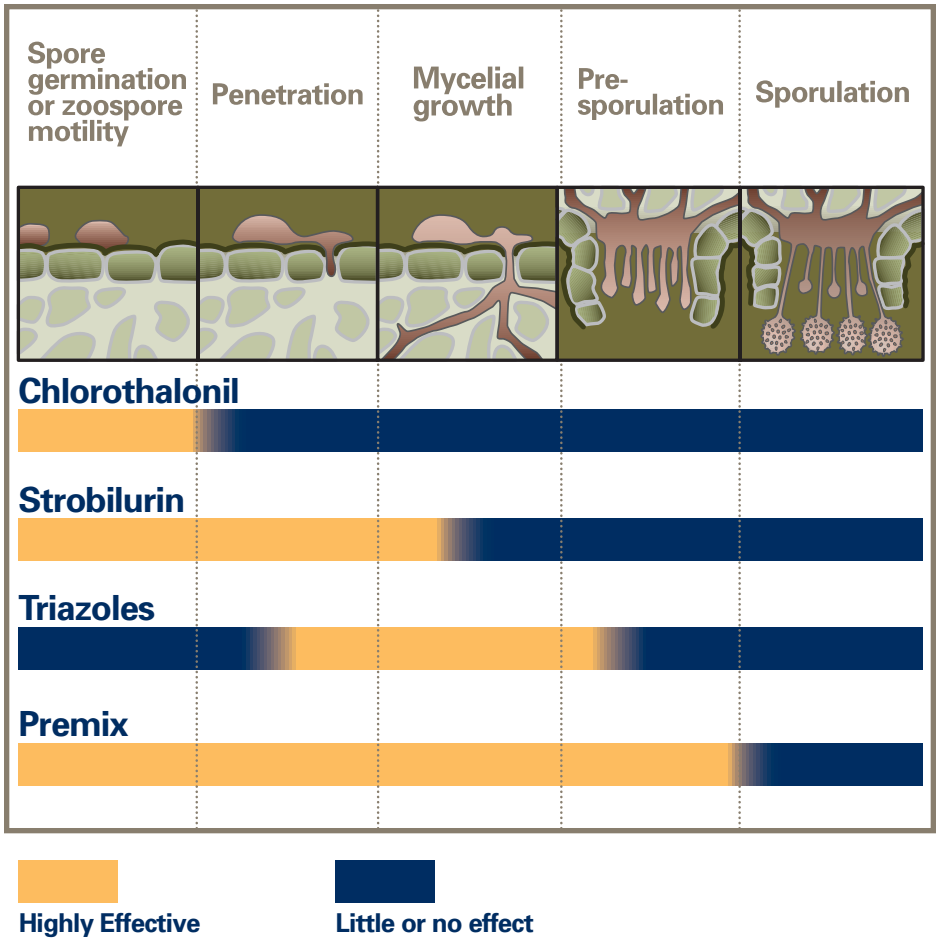


Figure 7.3. Fungicide impact on soybean rust developmental stages.

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>
<tr><th rowspan="4">Crop Stage</th><th colspan="6">SOYBEAN RUST STATUS
(Risk determined by national, regional, and local activity and disease forecasts)</th></tr>
<tr><th colspan="3">RUST ABSENT</th><th colspan="2">RUST PRESENT</th><th></th></tr>
<tr><th colspan="3">Soybean Rust Risk[a]</th><th colspan="2">Barely detectable in lower canopy[b]</th><th>Easy to detect in mid to upper canopy</th></tr>
<tr><th>Low</th><th>Moderate</th><th>High</th><th>1st Application</th><th>2nd Application (if needed)</th><th>Yield benefit from fungicide application is uncertain.

Check with local Extension specialists for specific guidelines.</th></tr>
<tr><td>Vegetative (stages before flowering)</td><td colspan="3">FUNGICIDE APPLICATION NOT RECOMMENDED FOR SOYBEAN RUST CONTROL.</td><td rowspan="2">Premix, Tank -mix, Co-pack

or

Triazole</td><td rowspan="2">Triazole

or

Premix[c], Tank-mix, Co-pack</td><td rowspan="2"></td></tr>
<tr><td>R1 (beginning of flowering) through R5 (beginning seed)</td><td>Do not spray</td><td>Strobilurin

Triazole

Premix, Tank-mix, Co-pack</td><td>Premix, Tank-mix, Co-pack

Triazole</td></tr>
<tr><td>R6 (full seed) to R8 (full maturity)</td><td colspan="6">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></tr>
</table>

[a] 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.
[b] Soybean rust incidence less than 10 percent.
[c] Premix, tank-mix, or co-pack fungicide should contain the full rate of the triazole fungicide component.
[d] 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.

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