What is soybean rust?

Soybean rust is a major disease of soybeans in many parts of the world. Affected plants are quickly defoliated, reducing pod set and fill, which results in reduced yields and seed quality.

There are two species of the *Phakopsora* fungus, the pathogen that causes soybean rust. The most significant is *Phakopsora pachyrhizi* (pronounced “fay-KOP-sora PACK-A-ri-zee”; also called the “Asian type” or “Australasian species”). *P. meibomiae* (pronounced “fay-KOP-sora MAY-bom-ee-ay”; also called the “New World” or “American” type) is less aggressive than the Asian type. The Asian type is not limited to Asia—it has been found in Australia, Africa, South America and Hawaii, among other places.

Where is soybean rust found?

As of December 2003, soybean rust has not been found in the continental U.S. The disease appears to have originated in Asia, where it was first characterized in 1902. Today, it occurs on most continents where soybeans are grown:

- Asia, including China, Japan, the Philippines, Taiwan, India and Eastern Russia
- Australia
- Africa, including Uganda, Zimbabwe, Zambia, Rwanda, Nigeria, West Africa, Mozambique, South Africa and Cameroon
- South America, including Paraguay, Brazil, Argentina and Bolivia
- Hawaii
- The Caribbean (*P. meibomiae* only)

How destructive is soybean rust?

Soybean rust has devastated soybean crops in many parts of the world, with reported yield losses as high as 100 percent in some afflicted areas of Africa and South America. In Australian test plots where no fungicides were applied, yield losses reached 60 to 70 percent. In 2003, Brazilian producers lost $1.3 billion to soybean rust, a figure representing lost yield and the cost of fungicides applied to combat further losses.

However, timely detection, good fungicides and optimum application methods can minimize the impact of soybean rust. Dr. Clive Levy of the Commercial Farmers Union in Zimbabwe noted that some areas of his country lost 80 percent of their soybean yields, while fields that had been treated early, with effective fungicides applied at proper intervals, contained any losses.

Farmers in Brazil have also demonstrated the ability to manage soybean rust over the past three years. Brazilian producers already plan for a summer fungicide application to control their late-season fungal disease complex, which includes brown spot, Cercospora leaf spot and frogeye spot. They have long been attuned to the importance of fungicide application around pod set and familiar with soybean fungicides and how to best apply them. As a result, they have been able to stay on top of soybean rust, treating in a timely manner and minimizing yield loss to the disease.

We don’t know how many U.S. acres will be affected by soybean rust when it reaches our shores, or how many applications of fungicide will be needed to manage the disease. However, it is clear that soybean rust will significantly impact the soybean industry here, as it has overseas.
Of course, the size of the U.S. soybean crop amplifies the effect of soybean rust. USDA's worst-case estimates of the economic impact of a U.S. soybean rust outbreak — including the ripple effects on affiliated industries and consumers — range from $7 billion to $11 billion.

What does soybean rust look like on the plant?

Soybean rust is difficult to identify in the early stages of infection, as symptoms are very small, poorly-defined and occur in the lower-middle canopy of the plant, where it is humid. Early symptoms appear as a yellow mosaic discoloration on the upper surfaces of older leaves. As the disease progresses, leaves turn yellow, and brown or reddish pustules appear, generally on the bottom surface of the leaf.

As leaves show symptoms, infection may be mistaken for spider mite damage or foliar diseases such as Septoria brown spot, bacterial blight or bacterial pustule. It is important to note that soybean rust pustules frequently lack the yellow halo associated with bacterial pustule; under a 20x hand-lens, rust pustules also can be seen to have a pore on top rather than a fissure, from which spores are released. Unlike lesions from spot diseases, soybean rust pustules are raised, mainly on the underside of the leaf. Placing an infected leaf in a zip-lock bag with a moist paper towel overnight can create ideal conditions to stimulate sporulation, during which pustules burst and spores become evident.

For positive identification, send infected tissue to an extension specialist for DNA testing.

How does the fungus damage soybeans?

Scientists believe the soybean rust pathogen can have as many as five stages in its life cycle, though only three have been observed. Spore-bearing bodies of those three stages — uredinia, telia and basidia — grow on the underside of infected leaves, below the epidermal layer. Infected leaves take on a brown, stippled look before losing their chlorophyll and dying. Under a powerful lens, fungal bodies look like little, brown volcanoes.

Spores thrive at 59° to 85° F; above that range, experts believe the spores are less active and shorter-lived. The pathogen requires 6 to 12 hours of free moisture to germinate and relative humidity of 75% to 80% to spread once the disease is established, though some field observations indicate that as little as 4 hours may be necessary to

### Crop Loss to Soybean Rust (Infected Fields)

<table>
<thead>
<tr>
<th>Location</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand¹</td>
<td>10-30%</td>
</tr>
<tr>
<td>China¹</td>
<td>10-30%; over 50% in years of severe infection</td>
</tr>
<tr>
<td>Southern Japan¹</td>
<td>15-40%</td>
</tr>
<tr>
<td>Brazil (2002)²</td>
<td>10-50%</td>
</tr>
<tr>
<td>Brazil (2001–02)³</td>
<td>46-70%</td>
</tr>
<tr>
<td>Brazil (2002–03)³</td>
<td>54%</td>
</tr>
<tr>
<td>Paraguay²</td>
<td>63% (CRIA Trial); 50-66% (3 farmers)</td>
</tr>
<tr>
<td>South Africa¹-⁴</td>
<td>10-100%</td>
</tr>
<tr>
<td>Zimbabwe¹</td>
<td>20-80%</td>
</tr>
</tbody>
</table>

² Source: University of Illinois ([http://www.ag.uiuc.edu/cespubs/pest/articles/200213k.html](http://www.ag.uiuc.edu/cespubs/pest/articles/200213k.html))
³ Source: Syngenta (Brazil)
⁴ Source: Cauldwell & Laing, 2002

### Glossary of Pathology Terms

**Uredinia** — Spore-producing bodies that appear as bumps within soybean rust lesions. The spores they produce, urediospores, burst from lesions and spread on air currents.

**Uredinospores** — Microscopic, egg-shaped spores produced by uredinia. Windborne for hundreds or even thousands of miles, these are the principal transport mechanisms of soybean rust.

**Basidia** — A cell in which spores are produced sexually. Their role in the spread of soybean rust is unknown; to date, P. pachyrhizi basidia have only been seen in greenhouse studies.

**Telia** — Spore-producing bodies whose alternate hosts and role in the spread of soybean rust remain unknown. They have been found late in the season on infected plants in Asia, and on infected plants in greenhouses.
stimulate germination. Because they are not winter-hardy, spores are unlikely to overwinter in the nation’s primary soybean-producing areas. However, in southern Florida and South Texas, the pathogen is likely to survive on alternate hosts such as kudzu, commercial legume crops, several species of vetch, and other weed species. Southerly winds will probably carry new spores to the crop in the South and Midwest each spring and summer.

Germinating soybean rust spores can penetrate the cuticle and epidermal layers of healthy leaf, which means the disease is not dependent upon wounds or open stomata to gain a toehold. Infection begins low on the plant, and symptoms are very difficult to spot. The pathogen travels up the plant and defoliates infected plants quickly. A crop can go from the first sign of infection to severe defoliation in five to seven days, by some accounts. Other studies show the rate of infection exploding from five percent to 90 percent within 21 days.

Soybean rust has a very short life cycle – uredinia mature within about a week and spend the next 10 to 11 days releasing urediospores. Secondary uredinia can emerge on the margins of existing infections, spewing out spores for as long as eight weeks. In all, an initial infection site can produce spores for as long as 15 weeks, remaining viable even under dry conditions. That creates many opportunities for infection in a season, and reduces the window of opportunity to control the disease.

Like most plant diseases, soybean rust is more severe some years than others. Australian researchers note that they experience a particularly bad outbreak about every four years, which probably corresponds to local weather cycles. India and Asia experienced epidemic outbreaks in the 1970s and 1990s.

How mobile is soybean rust?

Soybean rust spores can be carried long distances by wind currents. In 1998, they were blown 1,350 miles down Africa from Uganda to Zimbabwe. Between 2001 and 2003, the disease spread more than 1,500 miles, from Paraguay to near the equator, infecting as much as 90 percent of Brazil’s soybean acres on the way.

The leaps were impressive. Between 2001 and 2002, soybean rust jumped about 600 miles, a trip that would be equivalent to the distance between Memphis and the Central Sands of Wisconsin. By 2003, the disease had traveled about 1,500 miles, roughly the distance between Minneapolis and Orlando, Fla. A scale map of Brazil’s infested areas would cover America’s soybean acres.

Other rust pathogens set a similarly sobering precedent. In 1978, sugarcane rust (Puccinia melanocephela) blew into the Dominican Republic via storm systems, probably from West Africa, nearly 5,000 miles away. Within three months, the disease traveled from the Dominican Republic to Puerto Rico and Jamaica. Within eight months, it was in Florida. Wheat stem rust spores travel on wind currents each year from overwintering sites in the southern U.S. to fields as far north as Canada.

Researchers believe soybean rust is similarly mobile. In fact, many believe that soybean rust spread via wind currents from Asia to Africa, then to South America. Plant pathologists believe soybean rust is likely to spread much like wheat stem rust or Southern corn rust when *P. pachyrhizi* reaches North America.

Though tourists, live plant material and mechanical transport on planes or ships could deliver soybean rust spores to the Continental U.S., spores blown in on storm systems are the most likely source of introduction for soybean rust to the U.S. mainland.
What timing will work best for controlling soybean rust?

Research is underway on forecasting soybean rust. The disease is difficult to scout for. Experience in South America, South Africa and Asia indicates that early detection (at 5% infestation or less) and treatment are essential – soybean rust advances in the plant so quickly that it is vital to control it before the pathogen takes hold in the crop.

### Possible Alternate Hosts of Soybean Rust

Soybean rust has been shown to infect nearly 100 species of plants. Some of the most common potential hosts in U.S. soybean producing areas include:

- Dry beans (including kidney, black-eyed peas, cowpea and others)
- Succulent beans (including green beans, lima beans, butter beans and others)
- Hemp sesbania
- Kudzu
- Lupines
- Vetch species
- Medic

Fungicide Application Timing: Brazil

Understanding the growth stages of the soybean plant is a very helpful tool in predicting when the crop is most vulnerable to soybean rust and scheduling fungicide applications. The growth stage chart pictured in this document (and discussed in detail at [http://www.planthealth.info/growthstage.htm](http://www.planthealth.info/growthstage.htm)) applies equally well to determinate and indeterminate varieties. The critical stages when considering soybean rust are:

- **R1** – Beginning bloom
- **R2** – Full bloom/blooms to the top
- **R3** – Beginning pod – a 3/16-inch pod on one of the four upper nodes on the main stem
- **R4** – Full pod – a 1/4-inch pod at any of the above points
- **R5** – Beginning seed – an 1/8-inch seed in one of the above points

Brazilian growers, already accustomed to applying fungicide to soybeans to combat a late-season disease complex, plant early, then apply the first of two preventive applications at around R3 or R4. A second preventive spray is made 14 days later, at approximately R5.1 to R5.3 (see chart). A combination of strobilurin and triazole fungicides offers protection and reliability. Starting applications of curative fungicides after the disease has infected more than 5 percent of the crop has been ineffective – soybean rust is too aggressive to let it get that far and expect to achieve economic control.

![Fungicide Application Timing: Brazil](image-url)
As a result, we expect success from that a program that starts even earlier, like that used in Zimbabwe. According to Dr. Clive Levy of the Commercial Farmers Union in Zimbabwe, growers in Southern Africa begin a three-spray program at the R1 (first flower) stage of soybean development, about 50 days after planting, where risk of infection is high. The remaining applications are applied at 20-day intervals after the first. Where severity is low in marginal areas, Zimbabwean growers do not apply the third spray. With that program, the susceptible stages of reproductive growth are fully protected. Though we anticipate similar timing in the U.S., we will be testing various programs before developing recommendations.

**What does Syngenta offer that can control soybean rust?**

Soybean rust acts by rapidly defoliating infected plants and depriving them of the energy to set and fill pods. Keeping plants green for as long as possible by fighting the disease can minimize yield losses. One Brazilian study on soybean rust determined that each day of dry matter accumulation can increase soybean yield by 1 to 1.5 bushels per acre.

Currently, Syngenta has two fungicides with full federal labels for control of soybean rust: azoxystrobin (Quadris®) and chlorothalonil (Bravo®). Several states may apply for a Section 18 label for Tilt®. When Quilt, a combination of Quadris and Tilt, is registered, it may be an option for rust control as well.

Azoxystrobin was developed in South America for control of other foliar diseases in soybeans (it is called Priori® in Brazil). Azoxystrobin has been shown to delay senescence and defoliation in rust-infected soybean plants in South America, but it is important not to infer too much from efficacy studies of South American products — rates, formulations and adjuvant packages can differ significantly from those in the U.S. Research is underway on rates, intervals, tankmixes, application and other factors to maximize the effectiveness of the Syngenta line of products in the U.S.

In the U.S., azoxystrobin is labeled for soybean rust control at 6.2 to 15.4 ounces per acre. Given the diversity of conditions in which soybeans are grown in the U.S. and the importance of achieving control as quickly as possible, we believe the rate will provide the consistency and length of control required to manage the disease here.

Bravo may also play a role in soybean rust protection programs. Its protectant activity may help reduce infection and serve as a resistance management tool. As Bravo is strictly preventive, timing is critical. It may fit into soybean rust control programs as an initial, protective spray triggered by predictive disease models and/or as a rotation partner for resistance management. Experience in small grains and dry beans in North America indicates that Tilt (propiconazole) is effective on rust diseases, and offers promise in a soybean rust management program. It is also fully registered for use against soybean rust in Zimbabwe and South Africa.

Quilt, a propiconazole/azoxystrobin premix, is also quite promising. In Brazil, triazole/strobilurin mixes have quickly become the favored treatments for soybean rust. The use of two modes of action — combining the combination of the curative activity of the triazole and the preventive activity of the azoxystrobin — make this a highly effective approach. Multiple modes of action also reduce the chance of selecting for resistant strains of the pathogen, though pathologists believe the risk of resistance in soybean rust is relatively low.

We can expect competitive fungicides to be labeled when soybean rust appears in the U.S. We anticipate that they will mostly represent the triazole and strobilurin chemistries, including tebuconazole (Folicur®), tetraconazole (Eminent®), trifloxystrobin+propiconazole (Stratego®), myclobutanil (Nova®) and pyraclostrobin (Headline®).
Are there cultural practices that can reduce yield loss from soybean rust?

It is likely that cultural practices may influence the severity of the disease. However, much of the research on those practices common in the U.S. must be put on hold until the disease occurs here. Certainly, information from South America and other areas will be used to develop best management guidelines, but there is still much to learn. Research needs to include the effects of fertility, irrigation timing, late vs. early-season varieties, application volume and other variables.

However, cultural control is not enough on its own — protecting the crop with fungicides from flowering through pod fill is vital.

No cultivars in commercial production in the U.S. have been found to be resistant to soybean rust. Breeders say that biotech can speed the development of new varieties, but they are still five to seven years from commercial availability.

What sorts of research efforts are underway to help us develop control programs for U.S. growers?

Syngenta's North American staff is working with colleagues around the world to study the efficacy of the company's fungicides on soybean rust under various conditions, and to determine the optimum timing, rotations, or combinations of products to help growers manage the disease. Syngenta trials in China, Brazil, Argentina and other locations will help us find approaches that American growers can employ for dealing with soybean rust.

It is vital for us to test our fungicides with the formulations and rates that will be available here in the U.S. The company is also helping sponsor research efforts by USDA APHIS and other federal and state agencies that are studying the disease overseas. Ongoing research on the fungus itself — its life cycle, alternate hosts, and races within species — is also underway. And scientists at the USDA Foreign Disease-Weed Science Research Unit at Fort Detrick, Md. — as well as seed companies around the world — are screening germplasm for resistance to the disease.

Where can I get more information on soybean rust?

Though many questions remain about soybean rust, a great deal of information is available online.

USDA APHIS:

American Phytopathological Society:
http://www.apsnet.org/online/feature/rust/

North Central Soybean Research Program:
http://www.planthealth.info/rust/rust.htm

University of Illinois:
http://www.ag.uiuc.edu/cespubs/pest/articles/200213k.html

Iowa State University:
http://www.ent.iastate.edu/imagegal/plantpath/soybean/asianrust/

Ohio State University:
http://ohioline.osu.edu/ac-fact/0048.html

For more information on Syngenta's soybean fungicides, visit www.syngentacropprotection.com