SOYBEAN RUST MANAGEMENT IN WISCONSIN

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Asian soybean rust is caused by the fungus *Phakospora pachyrhizi*. The soybean rust pathogen has been moving progressively westward from its center of origin in China and has now reach North America. Soybean rust has gained considerable attention in the US since its discovery in nine Southern states this fall. Currently, there is much speculation and apprehension on how soybean rust will develop and impact soybean production in the U.S. The reality of the situation is that soybean rust has been a devastating disease in many parts of the world. Thus, it is prudent that we must respect its potential to reduce yield, and be prepared to manage it starting in 2005. This publication was developed as a resource to acquaint crop advisors and soybean growers with the soybean rust pathogen, soybean rust epidemiology and how this disease can be managed to limit yield loss.

Description of Soybean Rust

Asian soybean rust is a disease caused by the fungus *Phakopsora pachyrhizi*. Like all other fungi that cause rust diseases, the soybean rust pathogen must have a living host to grow and reproduce. Unlike many of the rust pathogens that infect cereal crops, the soybean rust pathogen does not have a spore stage that is dormant during the winter and can resume growth in the spring and infect a living host. *Phakopsora pachyrhizi* infects the foliage of a soybean plant and causes lowered photosynthetic activity and premature defoliation. Infection of foliage can result in reduced pod set and grain development ultimately leading to reduced soybean yield. Symptom severity and yield reduction is dependent on growth stage of host when initial infection occurs, susceptibility of soybean variety and climatic conditions during the growing season. Symptom severity and yield loss will decline as infection is delayed with growth stage.

Identification of Soybean Rust

Symptoms and Signs

Symptoms of soybean rust appear as plants approach the R1 (early flower) growth stage and appear on leaves in the lower canopy (Fig. 1). Accurate and timely diagnosis of soybean rust is critical to achieve control of soybean rust, especially if fungicides are involved in the management plan. Initial symptoms of soybean rust begin on lower leaves, but symptoms and signs can also occur on petioles, stems and pods. Initial symptoms are chlorotic (yellow) areas that that develop into tan or brown angular lesions. Lesions increase in size over time and change color from gray, to tan or reddish-brown. Tan lesions mature to form small pimple-like structures (called pustules) on the lower leaf surface. Pustules contain powdery tan spores that give the leaves the appearance that they have dandruff and are surrounded by slightly discolored necrotic (i.e., dead) tissues. Leaves lower in the canopy are infected first and are difficult to detect. Furthermore, early symptoms are not unique to soybean rust and are easily either missed or confused with symptoms caused by other pathogens. The inexperienced person will likely miss symptoms of soybean rust until infected tissues support sporulation, the formation of pustules. Initially, a hand lens is needed to identify pustules. In time, pustules become abundant and are apparent macroscopically. Early identification is mandatory for successful control with fungicides.

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For a more accurate identification symptoms can be viewed with a hand lens. In the early stages of infection the emerging pustules look like miniature volcanoes topped with a pore. There is no yellow halo surrounding the pustule. Later, the pustules "burst" releasing masses of rust-colored spores. Reddish-brown lesions are composed of primarily necrotic tissue and typically have only a limited number of pustules. As plant canopies close and pods begin to set, the soybean rust pathogen

Figure 1. Symptoms and signs of soybean rust. Signs of the pathogen (A) are gray tufts of spore masses (pustules) that appear on both sides of a leaf. Symptoms are various degrees of chlorosis (yellow) or necrotic (dead) tissues. Symptoms of soybean rust at canopy level may appear as a nutrient or disease caused by several other pathogens of soybean.

can rapidly spread from lower to upper foliage of plants. If not controlled, soybean rust results in premature chlorosis and total defoliation of plants by the R4-6 growth stages. Other diseases of soybean including brown spot, bacterial pustule and particularly downy mildew could potentially be confused with soybean rust. Soybean rust could also be confused with nutrient deficiency problems.

Submission of Leaf Samples for Rust Diagnosis

If you believe you have found soybean rust, getting a high quality, intact leaf sample to the Plant Disease Diagnostic Clinic is critical for verification.

- Select a representative group of leaves (or other plant parts) that exhibit the range of symptoms that you have observed in the field;
- Be sure to collect detailed information on the location where the sample was collected so that the site can be revisited if necessary. If you know the GPS coordinates of the site, please provide these;
- If possible, place the leaves between layers of cardboard and paper towels to keep them flat (i.e., layer the materials as follows – cardboard, paper towel, leaves, paper towel, cardboard, paper towel, leaves, paper towel, cardboard, etc.);
- Place the leaves in a self-sealing plastic bag and seal the bag shut;
- Place this bag inside a second self-sealing plastic bag, being particularly careful that the outside of this second bag does not become contaminated;
- Keep the leaves cool (e.g., by placing them in a cooler or refrigerator) between the time of collection and the time when they are shipped to the PDDC;
- Ship samples to the PDDC by overnight mail whenever possible.
- The PDDC address: Plant Disease Diagnostics Clinic, Department of Plant Pathology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, WI 53706-1598

Epidemiology and Soybean Rust Disease Cycle

Distribution of Soybean Rust Pathogen in the North America

Prior to 2004, the soybean rust pathogen was confined to regions south of the equator in South America not accessible to North Hemisphere weather systems. However, the pathogen moved north of equator in 2004 into Columbia. Thus, the wind transported spores of the pathogen were reached by winds originating in the Caribbean and moved northward by low pressure weather systems. Soybean rust was detected near Baton Rouge, LA on a university research station on November 10, 2004. Spores of the soybean rust pathogen are believed to have been transported into the Southern US on the winds of hurricane Ivan (Fig. 2). This detection activated a general alert and soybean rust was detected soybean plants in eight additional states, plus on kudzu in Florida (Fig. 3).

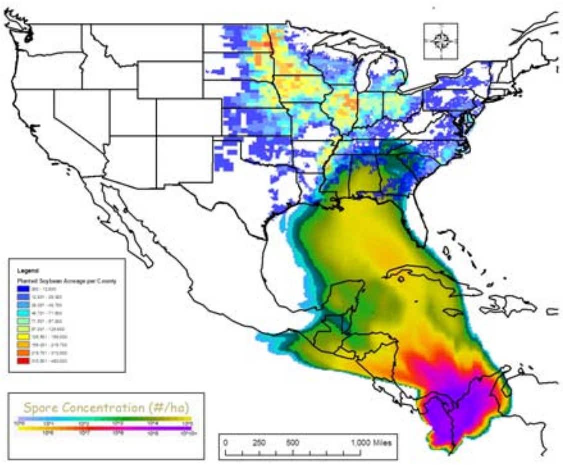

Figure 2. Computer model for the hypothesized transport of the soybean rust pathogen on the winds of hurricane Ivan during September 15-17, 2004. Spores of the pathogen originated in Columbia and were transported northward into North America.

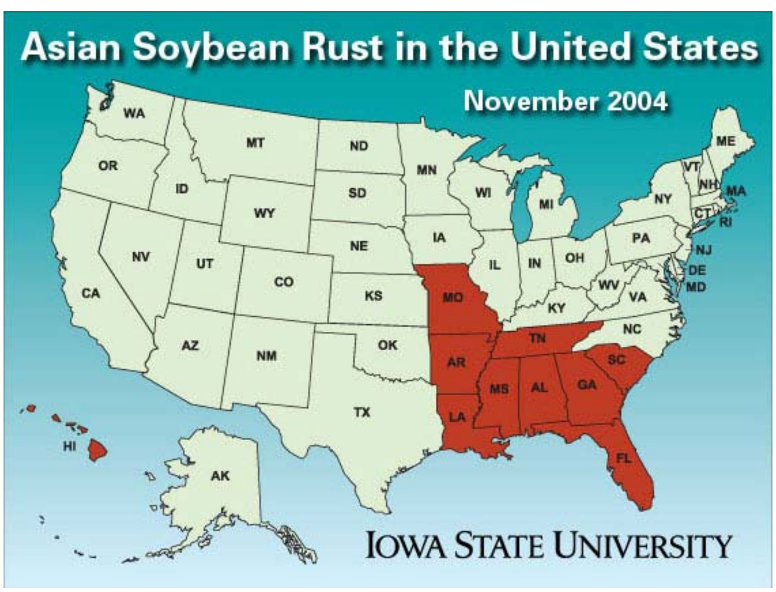

Figure 3. Distribution of soybean rust in the United States as of November 2004. The pathogen was

identified on soybean and on kudzu in Florida.

Sources of Inoculum

Phakospora pachyrhizi is reported to infect 95 plant species of which most are in the legume family. Hosts of most economic importance are soybean and all types of common bean including snap bean and dry edible beans. Host range will play an important role in the epidemiology and economic importance of the soybean rust pathogen in North America. In Wisconsin, other potential hosts are soybean, snap and kidney bean (*Phaseolus vulgaris*), American birdsfoot trefoil (*Lotus unifoliolatus*), crimson clover (*Trifolium incarnatum*), Korean clover (*Kummerowia stipulacea*), white clover (*Trifolium repens*), purple crownvetch (*Coronilla varia*), Chinese lespedeza (*Lespedeza cuneata*), lupine (*Lupinus spp.*), pea (*Pisum sativum*), rattlebox (*Crotalaria spp.*), yellow sweetclover (*Melilotus officinalis*), ticktrefoil (*Desmodium spp.*), and winter vetch (*Vicia villosa*).

In order to survive winter in the absence of a soybean crop, the soybean rust pathogen requires an alternative host that retains living foliage (Fig. 4). Thus, the soybean rust pathogen will only survive in regions of the U.S. in which freezing temperatures do not occur. Kudzu, a widespread perennial leguminous plant in many parts of the U.S., meets these requirements and could serve as an overwintering host for the soybean rust pathogen. It is an alternative host to the soybean rust pathogen, is widespread in the southern U.S. and escapes freezing temperatures and remains green all year regions bordering the Gulf of Mexico (Fig. 5). Yellow sweetclover is a candidate for an overwintering host of the soybean rust pathogen in Wisconsin. However, foliage of perennial host species in Wisconsin are usually killed by freezing temperatures, thus the rust fungus will perish. Unless winter temperatures increase dramatically, the soybean rust pathogen is not expected to survive in Wisconsin during the absence of soybean or bean production.

The lack of an overwintering source of inoculum means the soybean rust pathogen must be reintroduced to Wisconsin each growing season. Spores of the soybean rust pathogen are transported readily by air currents and can be disseminated rapidly hundreds of miles in 2 to 3 days. The severity of soybean rust will be influenced by where the soybean rust pathogen survives during the winter months. Lack of inoculum survival in Wisconsin should contribute to lesser severity of soybean rust. However, the explosive nature of the soybean rust pathogen can overcome factors such as distant sources of primary inoculum if weather conditions are favorable for rust development.

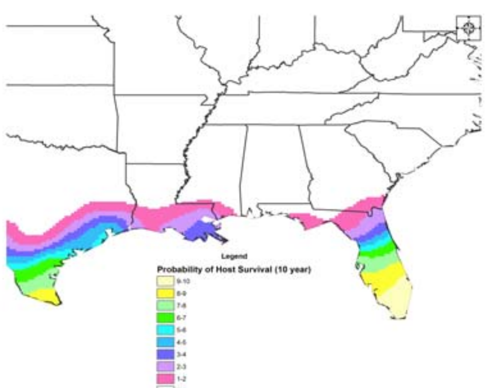

Figure 4. The soybean rust pathogen will survive on leguminous in the southern U.S. Shaded areas represent a range of probability for survival of overwintering hosts based on occurrence of temperatures greater than 28^{o} F in a given year using 10-year daily climate data.

The soybean rust pathogen has not been shown to be moved with soybean seed. Thus, growers should not be reluctant to purchase seed grown in regions where soybean rust developed the previous growing season.

Infection and Disease Development

Soybean rust will develop across a broad range of temperatures common to Wisconsin, but moisture conditions required for spore germination and infection are more restrictive and precise. Key to moisture conditions is the duration of continuous moisture on the leaf surface. Rust spores will germinate between 46°F to 97°F with an optimal range of 61°F and 75°F, but more restrictive is the requirement of 8 hours or more of continuous leaf wetness made possible by relative humidity of >75 to 80% or precipitation. Temperature above 86°F may stop or slow disease development, especially with moisture conditions are limiting. The infection will proceed between 52-82° F with an optimum temperature range of 66-75°F and a minimum of 6 hr of leaf wetness. Spores are produced 10 days after infection and are continually released from lesions if favorable environmental conditions remain.

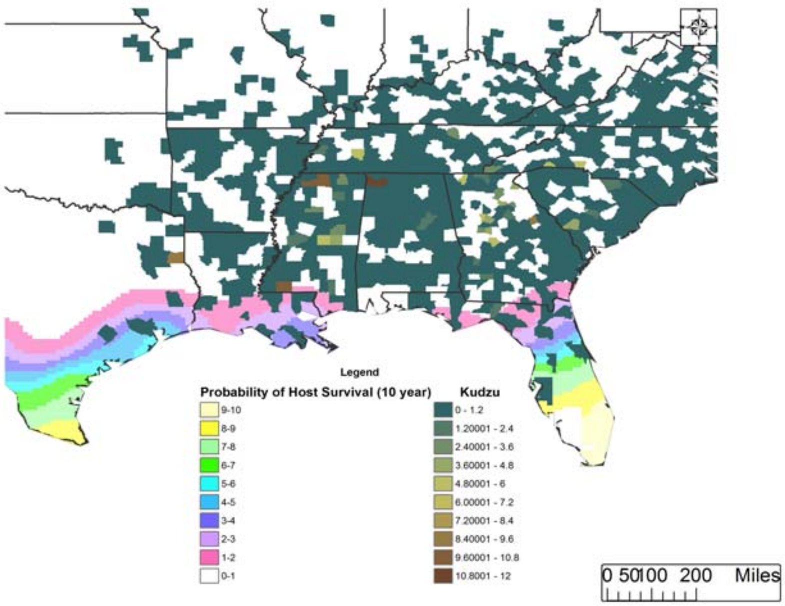

Figure 5. Probability for survival of overwintering hosts based on occurrence of temperatures greater than 28°F in a given year, overlaid with the estimated percentage of kudzu coverage by county.

The environment plays a major role in the incidence and severity of disease. For spore germination and infection to occur the leaf must be wet for an extended period of time. Temperatures need to be between 59° and 86°F, and humidity levels should be in the range of 75-80%. Under these environmental conditions spores are produced within 10-21 days, but in 6-7 days after infection in 72-81°F. An initial infection site normally produces spores for 10-14 days. Within optimal conditions, a plant can go from the first signs of infection to severe defoliation in 1-2 weeks. Knowledge of conditions required for infection and spore production can be applied to the application of fungicides for rust control.

There are three key factors in determining the risk of soybean rust movement into northern soybean production regions: (1) the occurrence of soybean rust during the spring and early summer in the Gulf coast areas. This determines the amount of spores available to blow northward; (2) the July-August climate conditions, which establish where in the U.S. conditions favor soybean rust development, and (3) northward movement of soybean rust spores in weather systems and by "green-bridging". Producers in more northern production areas may be able to assess the risk of seasonal outbreaks using the following steps throughout the year.

Yield Loss

Yield loss from soybean rust will depend on crop stage infected, environmental conditions, amount of inoculum (spores) produced during growing season, soybean variety planted, and whether implemented control tactics were appropriate and correctly implemented during the growing season. Yield loss in other countries has ranged from 10-90%. However, it is difficult to predict yield loss potential in Wisconsin. Soybeans are susceptible to rust infection at all growth stages, however, amount of yield loss will depend on crop stage infected. The most susceptible crop stages are between early flower stage (R1) and mid-seed development stages (R5).

The occurrence of soybean rust declines in regions of China that correspond to latitudes found in Wisconsin (Fig. 6). Although many factors may render this comparison invalid, this information is the best available to make predictions on soybean rust activity in Wisconsin.

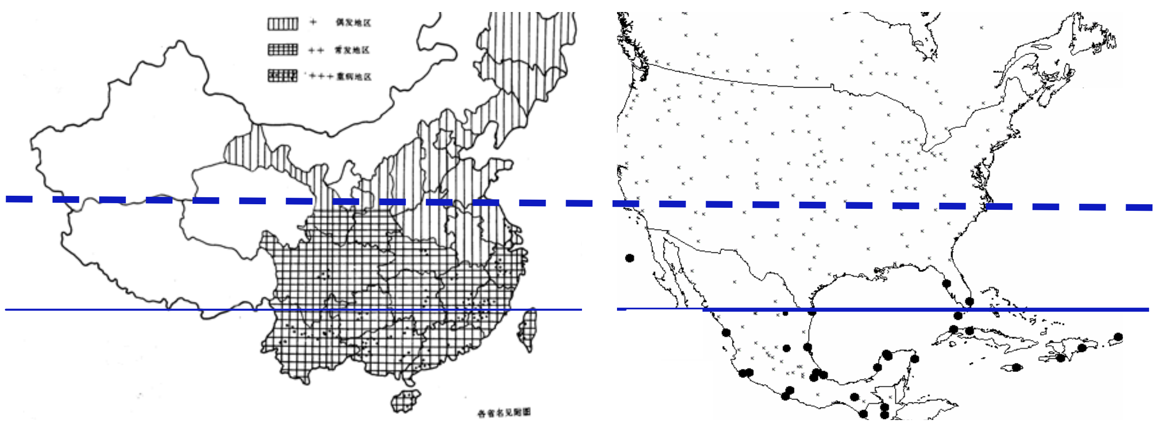

Figure 6. Soybean rust decreases in frequency of occurrence and severity from south to north in China. The map illustrates the intensity of soybean rust in China by latitudes comparable to regions of the United States.

Management of Soybean Rust

Variety Selection

Currently there are no known varieties which are resistant to soybean rust in the Midwest. However, it is likely that varieties will vary in their susceptibility. There are indications that early maturity varieties for a geographic region will escape some degree of the yield-limiting effects of soybean rust. However, early maturity varieties generally have lower potential compared to full-season varieties.

Cultural Practices

Early planting may allow plants to reach advanced growth stages before the arrival of rust inoculum. Other cultural control practices like wider row width and reduced plant populations may reduce the length of time that leaves remain wet and potentially decrease the severity of rust. However, it is not known how big of an impact these methods may have, if at all. The impact of all diseases should be considered before changes in cultural practices are made with the goal of rust suppression. For example, early planting increases the potential of white mold throughout Wisconsin, for yield-limiting levels of *Bean pod mottle virus* due to intense bean beetle activity in early planted soybean fields.

Fungicides

Fungicides are the only in-season pest management practice that is effective against soybean rust. Several fungicides are registered (Section 3) for soybean rust and more are likely to be granted Section 18 emergency use labels in the future. Always check label instruction before using any pesticides.

Fungicides for Soybean Rust

Formulations of chlorothalonil (Echo 720 and Bravo Weather Stik), azoxystrobin (Quadris) and pyraclostrobin (Headline) have full registrations (Section 3) for use on soybeans to control soybean rust (Table 1).

Additional fungicides will be available through Emergency Exemption (Section 18) labels for propiconazole (Tilt, Propimax, Bumper), myclobutanil (Laredo), and/or tebuconazole (Folicur). Up to date information will be available at www.ipmcenters.org/newsalerts/soybeanrust/quarantine.cfm. These labels will not be in effect until the Wisconsin Department of Agriculture, Trade and Consumer Protection determines that implementation of one or all of these Section 18s is appropriate.

Predicting the Need for Fungicides

A major decision will be whether the potential for rust merits the application of a fungicide. There are several factors to consider in making a spray decision to manage soybean rust. It is expected that although soybean rust will affect soybean production throughout the continental U.S., it will be endemic in some areas, and seasonal in others. Disease epidemics are also likely to vary from season to season. Thus, decisions will focus on the need to spray, timing of application, and the number of applications required for a specific field. The need for fungicides will likely be different from region to region and season to season.

Growers and advisors have several starting points for the decision making process. The first is to monitor rust activity to the south of Wisconsin. A second approach is to monitor sentinel plots in Wisconsin. Usually sentinel plots involve planting early-maturing soybean varieties about 3 weeks before the commercial crops are planted. Spray warnings are given once soybean rust is found in the sentinel plots. Since soybean rust is usually first observed on plants of more advanced growth (beginning flowering (R1) or later), the sentinel plantings provide an opportunity to observe the first signs of the disease before the disease gets a foothold in production fields.

Timing of Fungicide Applications

Fungicides of all types will provide greater control if applied before rust spores are deposited soybean leaves. Once rust symptoms are visible, fungicides with protectant activity will not be effective, and protectant/curative types will have limited activity. Early detection and proper identi-

Table 1. Fungicides registered (Section 3) for control of soybean rust.

Fungicide Brand Name and Company	Active ingredient,	Chemistry Class	Soybean Diseases	Resistance management
Bravo® (Syngenta)	chlorothalonil	Chloronitrile (substituted benzene)	Soybean rust, Anthracnose, Diaporthe pod and stem blight, frogeye leaf spot, purple seed stain, Septoria brown spot	See guidelines for chlorothalonil
Echo 720 Sipcam Agro Inc	chlorothalonil	chloronitrile	Soybean rust, Anthracnose, Diaporthe pod and stem blight, frogeye leaf spot, purple seed stain, Cercospora seed blight, Septoria brown spot	See guidelines for chlorothalonil
Quadris® (Syngenta)	azoxystrobin	strobilurin (quinone outside inhibitors or QUI)	Soybean rust, Aerial blight, frogeye leaf spot, Anthracnose, Alteraria leaf spot, Septoria leaf spot, Cercospora blight and leaf spot, Pod and stem blight).	See guidelines for strobilurin fungicides
Headline® (BASF)	pyraclostrobin	strobilurin	Not registered for soybean	See guidelines for strobilurin fungicides.

As useful listing of fungicide chemistry classes is at http://www.avcare.org.au – go to "resistance strategies" for the PDF files.

fication of soybean rust will be key to successful management of soybean rust. Reports from Brazil indicate that infections exceeding 20-30% of the soybean canopy cannot be controlled with fungicide applications. At that point fungicides are no longer able protect plants sufficiently from additional infections, or yield reduction is already so great that fungicide application cannot recover treatment cost. 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 different disease control strategies.

When it comes to timing of application, there are two obvious mistakes, both of which can be costly. Soybean rust spreads quickly and poor timing of a fungicide spray will significantly increase the risk of failure. Spray too early and the effects of the fungicide may dissipate by the time spores arrive and infect plants. Conversely, delayed applications will result in applications after initial infection has occurred and the disease may have progressed beyond the point where effective control is possible with fungicides.

Coverage of Foliage and Canopy Penetration

For fungicides to be most effective, choose application techniques which promote through coverage of the leaves, stems and pods. Select nozzles that promote smaller droplets size and deeper penetration. Also increase pressure and carrier rate. Application techniques used for weed control are generally not compatible with fungicide application.

Because soybean rust tends to initially develop in the lower and mid canopy, thorough coverage of foliage, including penetration of spray into the canopy, is essential to achieving a successful soybean rust spray program. Fungicides are best applied at higher gallons per acre, higher pressures and with different nozzles than herbicides. Thus, improvements in spray technology for fungicide effectiveness are being researched and data will also help with delivery of insecticides to soybean.

Websites for Soybean Rust

There are many websites with information on soybean rust.

- www.ncpmc.org/soybeanrust/
- www.planthealth.info/rust/rust.htm
- www.csrees.usda.gov/Extension/index.html
- www.plantpath.iastate.edu/soybeanrust.html
- www.plantpath.wisc.edu/pdd
- www.uwex.edu/ces/ag/
- www.oardc.ohio-state.edu/ohiofieldcropdisease/soybeans/soybean_rust.htm
- www.ppdl.purdue.edu/ppdl/soybean_rust.html
- http://www.ppdl.purdue.edu/ppdl/SBR/SBR_fungicide.htm