5-2005

Asian Soybean Rust

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Where did soybean rust come from? Will it get to South Dakota?

The virulent form of soybean rust, native to Asia, is making its way around the world largely by riding the wind currents. Its small spores are aerodynamic and can float for long distances.

Originally described in Japan in 1902, Asian soybean rust spread rapidly throughout Southeast Asia in the 1960s. It made a surprise appearance in Hawaii in 1994; there is good evidence that the fungus was deposited in the islands by a tropical storm that passed over Taiwan and 3 days later rained out over Hawaii. Rainfall is often responsible for scrubbing the windborne spores out of the sky.

In 1997, soybean rust was identified in Uganda, again after riding a tropical cyclone across the Indian Ocean. From Uganda it spread west and south to Zimbabwe (1998) and South Africa (2001), becoming established in many nations in West Africa.

It made a major leap in 2001, crossing the Atlantic, settling in southern Paraguay and then adjacent areas of Brazil and Argentina in 2002, eastern Bolivia in 2003, and Columbia in 2004 (Fig 1).

To come to North America in August 2004, soybean rust hitched a ride on the counterclockwise winds of Hurricane Ivan. Ivan came very close to the northern coast of South America and drew spores up into the Gulf South where there were still green soybeans in August. In that year, the disease established in 13 southeastern U.S. states; its most northerly penetration was into the extreme southeast corner of Missouri.

Soybean rust is sensitive to freezing temperatures and it will not survive anywhere that has adequate cold temperatures to kill off all vegetation. As such, it will have to blow into South Dakota each year to cause disease on our soybean crops.

The time that it arrives will determine how serious losses could be. In the tropics, a soybean crop can be reduced by 80%, but estimates for our area are 10-30%.

Also important are two weather issues—winter weather in Louisiana and spring weather in South Dakota. The chances are better than fair that soybean rust will be blown into South Dakota in

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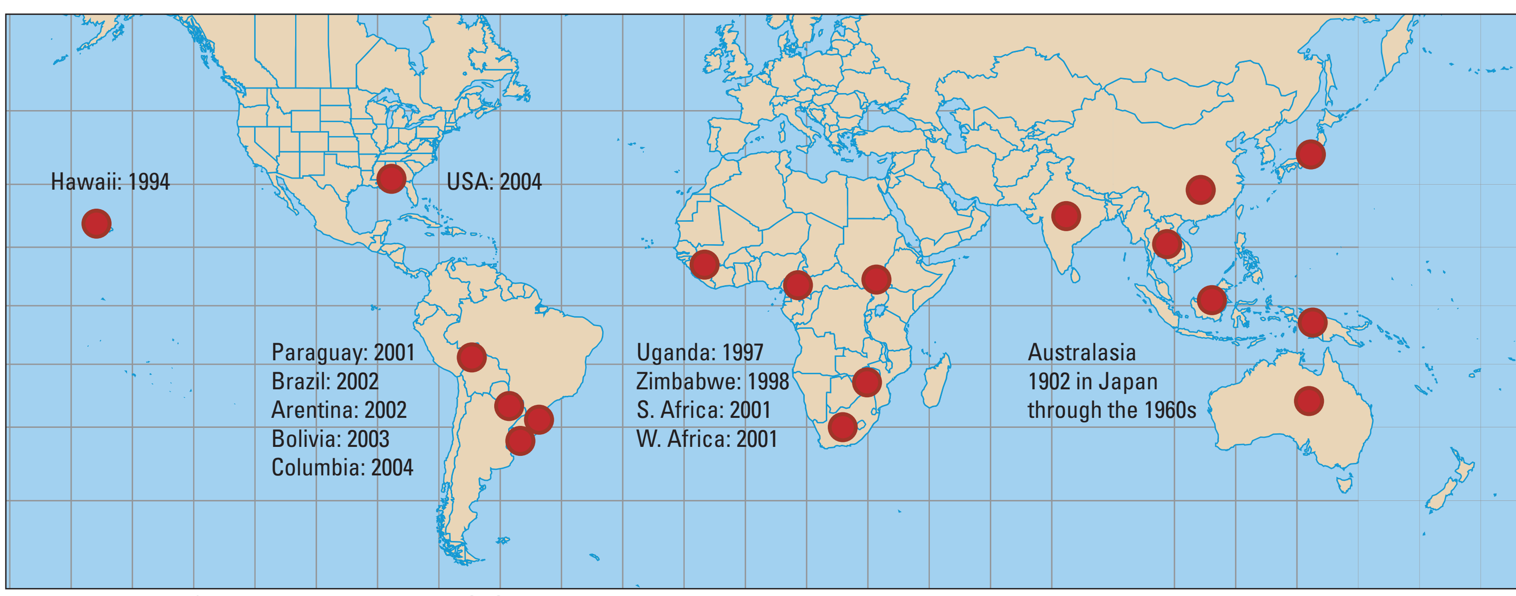

Fig 1. The spread of Asian soybean rust since 1950.

Rust is manageable; we have time to plot its northward flight and to plan our response

Asian soybean rust has existed for over a century on other continents, moving from Asia to Africa to South America. Usually, winds have been the main method of transportation.

Once introduced to South America, making its way to North America was just a matter of time. Whether by accidental introduction on another crop, by land bridge through Central America, or by air, we could only speculate about how or when it would get to the U.S.

In the fall of 2004, in an extremely active hurricane season, Florida was hit by four hurricanes. One of the major ones, Hurricane Ivan, followed a path quite far south within a short distance of the South American coast (Fig 2). Ivan then turned north into the Gulf Coast near Mobile, Ala.

In addition to the typical hurricane damage, Ivan seems to have been the culprit introducing spores of Asian soybean rust from northern South America into North America. Simulating the track of Ivan with computers showed that spores released in South America could be carried onto the Gulf Coast along with the heavy rain and winds that accompany a hurricane. Cloudy conditions extend spore life and allow spores to stay aloft in the hurricane until they rain out over the Gulf Coast.

Positive rust confirmations ranging from southeast Missouri to western Florida followed in areas the model had predicted (Fig 3).

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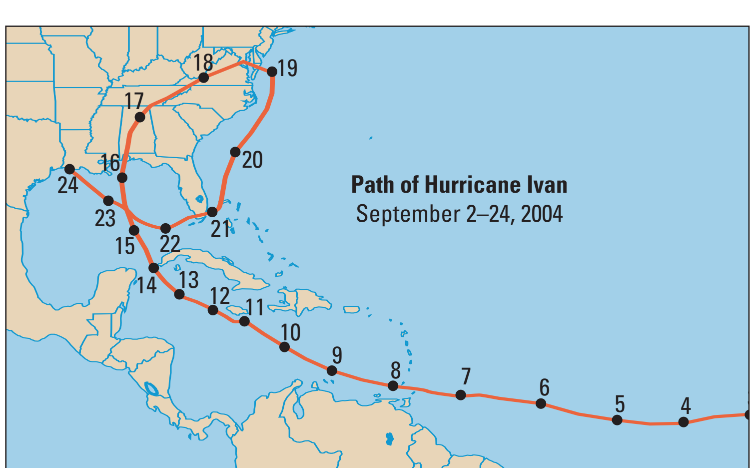


Fig 2. Track of Hurricane Ivan in September 2004. Note the close proximity to South America and eventual land fall near Mobile, Ala.

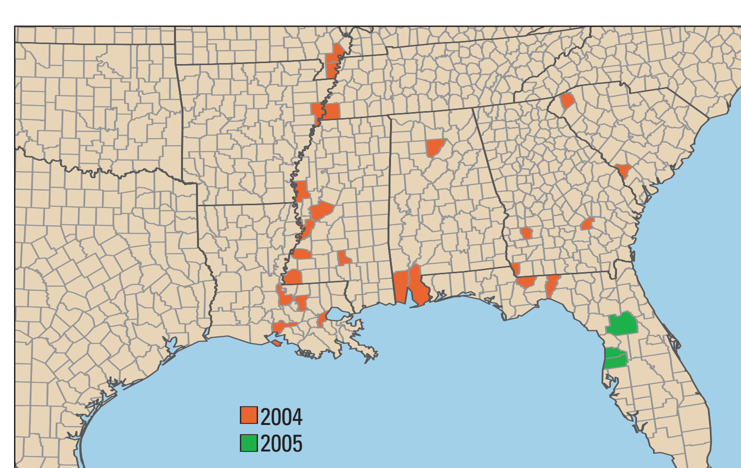
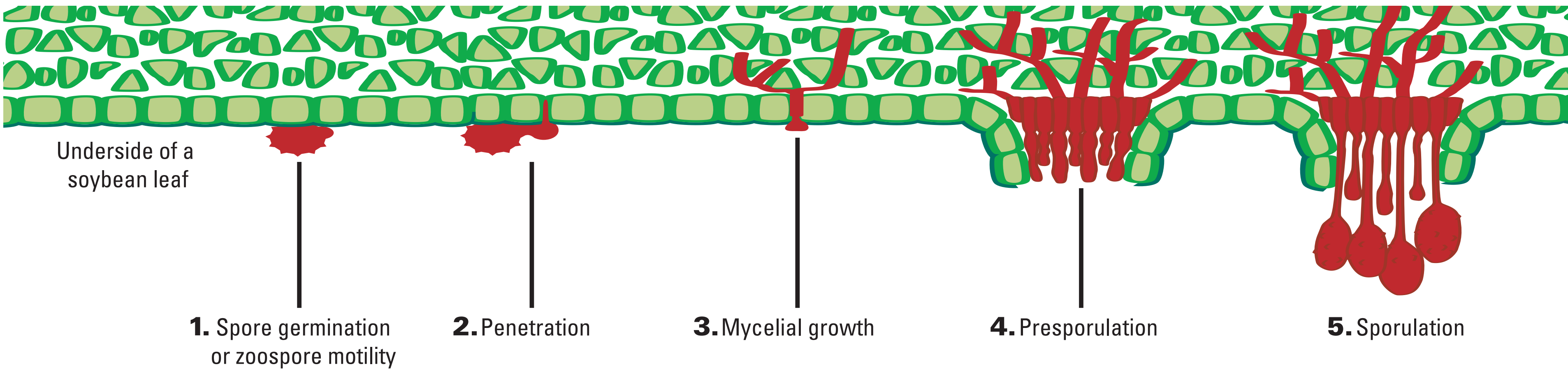


Fig 3. Positive soybean rust locations in Fall 2004 and Spring 2005.



The infection process takes about 10 days from when the spore lands on the leaf, through colonization of the leaf to the production of urediniospores.

2005. If the weather here is hot and dry, infection and disease progress will be reduced. On the other hand, moderate temperatures with overnight dews could lead to rapid increase of the pathogen.

Refresher course in biology: How does soybean rust act?

All rust diseases of plants are caused by specific fungi called obligate parasites. An obligate parasite must have a living (green) plant to survive. The rust fungus will draw all of its nutrition from the green plant, and it cannot survive by consuming dead or dying organic matter.

The Asian soybean rust fungus (*Phakopsora pachyrhizi*) can grow on many legumes in the specific subfamily of legumes that have keeled flowers (the Papillionoideae). This includes peas, common bean (*Phaseolus* spp.), and many forages including sweet clover and red clover but not alfalfa. Worldwide, Asian soybean rust can infect about 90 plant species. We have about 20 of these species in the U.S.

As the spores of the fungus land on a leaf, they germinate and penetrate the leaf tissue (Fig 4), absorbing nutrients through specialized structures called haustoria. All parasitic fungi gain nutrition from compatible host plants by spreading through the cells of the plant and


Fig.4. A germinating urediniospore, 400X. (Courtesy NC 504)

robbing it of the photosynthates the host produces from sunlight. Upon landing on a plant, the fungus must have water films, such as dew, present for at least 6 hours to infect. As the soybean rust fungus colonizes the plant it builds energy and begins to reproduce clonally by producing pustules called uredinia, which contain spores called urediniospores (Fig 5).

The spores can blow long distances to infect new plants. Generally, it takes 9-10 days from the time of infection for pustules to erupt. That means there is a 9-10 day time period where the plant is infected and does not show symptoms.

The fungus thrives in relatively cool temperatures, roughly the 60s and 70s F. It will survive at warmer and cooler temperatures, but spore production may be limited.

At the peak of production, millions of spores may be generated every day from an infected field. A pustule can actively produce urediniospores for about 20 days.

The buildup of the disease in a field is dependent on the frequency of infection periods and the weather. In Brazil, dry spore deposition associated with spores blowing from field to field are not nearly as important as wet deposition associated with rainfall events.


Fig 5. Pustules of *P. pachyrhizi* forcing pale-colored urediniospores out the pore, 80X. (Courtesy NC 504)

Manage for optimal yield. Make educated decisions

Generally, plant diseases are managed by three methods: cultural, genetic (resistance), and chemical.

Cultural methods. Cultural controls include tillage, crop rotations, and plant populations or row spacing. In other parts of the world, these practices have proven useless against this disease, so there is no reason to change row spacing, plant population, or the variety you plant, until research indicates otherwise.

Planting in wide rows may, however, reduce or slow infection if spores are present. Normally, the longer a canopy stays open, the drier the microclimate around the plant leaves will be, cutting off the moisture the spores need to germinate and move into the soybean host. If you find you have to spray late in the season, you may lose 2 to 3% of yield simply by driving over drilled plants. It also will be more difficult to get full coverage of the fungicide on the soybean leaves in narrow rows.

Genetic methods. While four genes have been identified against this pathogen (Rpp 1, Rpp 2, Rpp 3, and Rpp 4), none has proven durable for more than 8 years. Currently the population of this fungus in any part of the world where it occurs is diverse enough to overcome any one of the Rpp genes.

This leaves us looking for a different kind of resistance, one that will allow a certain amount of disease but not allow it to increase very rapidly. This form of resistance is called partial resistance or tolerance.

So far, a few candidate parents have been identified. If they prove durable, it will take 10-15 years to add the genes to adapted, high yielding lines. Resistant varieties are not in our near future.

Chemical methods. The absence of other effective controls leaves the producer with fungicides. They have proven effective and there are many choices. However, not many are being sold in the U.S. for soybean diseases.

In 2003, two fungicides were labeled by EPA for controlling soybean rust: chlorotahlonil (sold as Bravo and Echo) and azoxystrobin (sold as Quadris). Pyraclostrobin (sold as Headline) was labeled in 2004.

Each is a good preventative treatment, meaning it can protect the plant from infection. However, none of these products can arrest an infection that has already occurred. To address this problem, an effort was launched to get special approval (Section 18) for products that are curative. A curative product can kill an infection that has occurred in the previous few days and can also prevent further new infections. Infections that are older than a few days may be slowed and their sporulation may be limited. Approved products are listed in Table 1.

Curative fungicides are generally in the group known as the triazoles. Triazole fungicides disrupt the production of sterols, compounds that are important in the growth of the fungus and its ability to make membranes in its new cells.

Table 1. EPA-approved fungicides for soybean rust.

Product	*Fungicide family*	*Active ingredient*	*Preinfection activity (preventative/protectant)*	*Post infection activity (curative)*
Bravo/Echo	chloronitrile	chlorothalonil	Yes	No
Quadris	strobilurin	azoxystrobin	Yes	No
Headline	strobilurin	pyraclostrobin	Yes	No
Laredo	triazole	myclobutanil	Yes	Yes
Tilt/PropiMax/ Bumper	triazole	propiconazole	Yes	Yes
Folicur	triazole	tebuconazole	Yes	Yes
Domark	triazole	tetraconazole	Yes	Yes
Stratego	strobilurin + triazole	trifloxystrobin + propiconazole	Yes	No*
Quilt**	strobilurin + triazole	azoxystrobin + propiconazole	Yes	Yes
Headline SBR**	strobilurin + triazole	pyraclostrobin + tebuconazole	Yes	Yes

* Rate of propiconazole is too low for effective use with post infection application.
** Submitted to EPA, but pending approval.

The preventative products Bravo and Echo, Quadris and Headline differ in the ways they work.

Bravo and Echo each have the same active ingredient (chlorothalonil) and mode of action (multiple site activity). This product prevents spore germination by depositing a layer of fungicide on the plant surface like paint on a house. Poor coverage and weathering affect the duration of protection. Surfaces that are not covered are not protected.

Chlorothalonil has been on the market for many years and has broad spectrum activity against many fungi and is used in many crops. Chlorothalonil is a true protectant, residing on the outer surface of the leaf and preventing infection.

Quadris and Headline, on the other hand, are locally systemic to systemic, meaning that they are absorbed into the plant and act as internal protectants, preventing infection from inside as the organism tries to penetrate the leaf. The mode of action of these two related fungicides in the strobilurin group is to block a specific step in the energy transport system of the fungus.

The curative triazoles and mobile strobilurins move the same way in the plant. They are absorbed and may move with the water flow to the extremities of the part of the plant they land on. No fungicides for this disease will move to the roots nor will they move in great concentration to new growth. However, products that move in the plant are more forgiving than immobile fungicides.

The right fungicide isn't enough. Timing of use is also critical

For the most part, fungicide products are not highly systemic. If they are applied to indeterminate soybeans (that keep putting on vegetative growth even while flowering), any new growth will not be protected.

Because of the unique properties of specific fungicides, care must be taken to use the proper product to give control.

Chlorothalonil and the strobilurins (Quadris and Headline) should only be used if the disease is not present in the field.

Post-infection, a triazole or product combining a strobilurin and triazole may be used. The combination products include Stratego (propiconazole + trifloxystrobin), Quilt (propiconazole + azoxystrobin) and Headline SBR (tebuconazole + pyraclostrobin in a copack). These products will also work as preventatives before the infection occurs and may have better activity at that timing.

It is hoped that only one fungicide application will be needed in South Dakota.

The ages of soybeans: most vulnerable to Asian soybean rust are R1 through R6

Soybean growers in the Dakotas and Minnesota typically plant varieties that exhibit an indeterminate type of growth (Table 2). This means that following emergence from the soil the seedling will eventually produce, before drying down for harvest:

- new leaves and stems (vegetative or V-stages),
- bloom (R1, beginning flowering, and R2, full flowering reproductive stages),
- pods (R3 beginning pod and R4 full pod stages),
- seeds that increase in size (R5, beginning seed, and R6, full seed stages), and
- attain final maturity (R7, beginning maturity, and R8, full maturity).

An indeterminate variety may exhibit vegetative growth (V-stages) plus one or more of the flowering (R1-2), pod development (R3-4), and seed filling (R5-6) stages at the same time. For example, just after R5 the plant exhibits all of these stages.

The critical stages for growers to recognize are R1 and R6. It is from "beginning flowering" to "full seed" that protection of the plant from soybean rust is most important.

When scouting your soybeans, keep in mind the interval in days and the number of leaves, nodes, and stems may vary among varieties, environments, and years.

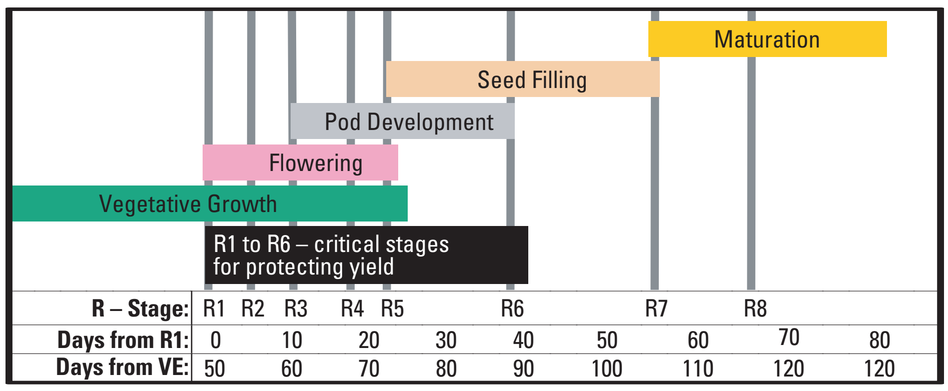
Early varieties tend to develop fewer leaves and mature faster than late varieties. Daily temperatures may cause the stage interval in days to vary a little. Stress to the plant—moisture, temperature, or nutrient deficiencies—tends to lengthen the V-stages and shorten the R-stages. The various R-stages are shown in Table 3.

VE, emergence stage. As the seedling emerges from the soil two cotyledons (thick leaves that store food for the developing seedling), attached opposite one another on the main stem, become evident. The main stem node where these two cotyledons are attached is called the cotyledonary node.

VC, cotyledonary stage. Soon after the cotyledons unfold, the seedling develops two unifoliolate (simple, single) leaves attached opposite one another on the next node above the cotyledonary node. This unifoliolate node is, for growth staging purposes, the main stem reference node or first node.

V1-V (n) stages. After the unifoliolate leaves unfold, the seedling then develops its first trifoliate leaf (Fig 6). All vegetative stages are defined by the presence of fully developed leaves where the leaf margins of the leaflet are no longer touching. For example, at the V2 stage (Fig 7), there are two unfolded trifoliate leaves along with a folded trifoliate leaf and a terminal bud at the top of the stem. Likewise, at V6 there are six unfolded trifoliate leaves, a folded trifoliate leaf, and again a terminal bud (Fig 8). A new V-stage generally appears about every 5 days from VC through V5 stages and about every 3 days thereafter until shortly after the R5 (beginning seed) stage.

Table 2. Reproductive soybean stages from the VE and R1 stages for a maturity group-I soybean variety in South Dakota.*



Source: R.G. Hall. Unpublished data from 2001.

*Maturity group -0, -I, and -II varieties attain the R1 stage about 43, 49, and 49 days after emergence, respectively. Group-0 soybeans reach each R2 – R8 stage about 3 days earlier than Group-I varieties. Group-II varieties attain each R-2 – R8 stage approximately 7 to 8 days later than Group I varieties.

R1, Beginning bloom stage. The first sign of reproductive growth occurs at R1 or beginning bloom when there is an open flower on the main stem (Fig 9) about 50 days after the VE stage. Flowering begins at the 3rd to 6th nodes and continues both up and down the stem. Usually, a few days later, blooms on branches of the main stem begin flowering.

R2, Full bloom stage. At full bloom there is an open flower at one of the four uppermost nodes on the main stem with a fully developed leaf (Fig 10). This stage generally occurs about 54-55 days after the VE stage or about 3 to 6 days after R1. Flowering generally peaks at about R2.5 to R3 and is completed by about R5. At this time the plant has generally attained about 25% of its dry weight and 50% of its total node number and its height.

R3, Beginning pod stage. At beginning pod there is a 3/16-inch-long pod at one of the four uppermost nodes on the main stem with a fully developed leaf (Fig 11). This stage generally occurs about 59-65 days after the VE stage or about 10 days after R1. During R1 to R3 nearly 60 to70% of the flowers will eventually abort, half aborting as flowers and half aborting as pods.

R4, Full pod stage. At full pod there is a 3/4-inch-long pod at one of the four uppermost nodes on the main stem with a fully developed leaf (Fig 12). This stage occurs about 65-70 days after the VE stage or about 17 to 20 days after R1. At this time some of the lower pods on the main stem will approach full size. Pods will attain most of their length and width before the beans begin to grow.

Rapid pod growth (R4) and beginning seed development (R5) make this the most critical stage for yield. Stress (moisture or nutrient deficiencies, frost, or defoliation) from R4.5 to about R5.5 reduces yield more than in any other period of growth. This is because the plant stops flowering and can no longer compensate for earlier losses of flowers or pods. In addition, younger pods and seeds on the plant are more prone to abortion than older pods and seeds.

R5, Beginning seed stage. At beginning seed there is a 1/8-inch-long seed in a pod at one of the four uppermost nodes on the main stem with a fully developed leaf (Fig 13), generally about 70-78 days after the VE stage or 20 to 25 days after R1. This stage is characterized by rapid seed growth and filling. During early growth a white membrane surrounds each developing seed. As the seed enlarges and approaches R6 the membrane will disappear.

During this period there is a high demand for water and nutrients. The growing bean will obtain about 50% of its N, P, and K needs from its leaves and stems and 50% from soil uptake and nitrogen fixation.

At R5 to R5.5 complete defoliation—from hail, for example—will reduce yield about 75%. Likewise, stress at R5.5 to R6 lowers yield significantly by reducing number of pods per plant, beans per pod, and weight of the bean.

R6, Full seed stage. At full seed there is a 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 leaf (Fig 14). This stage generally occurs about 85 to 90 days after the VE stage or 35 to 40 days after R1.

At about R6.1 whole plant growth or maximum dry matter accumulation ceases, while bean growth continues but stops at about R6.6. Beans of various sizes can be found on the plant at R6. Soon after R6, leaf yellowing begins and continues until the leaves drop, beginning at the lower nodes and moving up the stem. Sometimes the lower trifoliolate leaves may drop before the onset of leaf yellowing. The R1 to R6 stages are the most important stages in soybean growth and development for determining yield.

R7, Beginning maturity stage. At beginning maturity one normal pod on the main stem attains its mature pod color, usually brown or tan (Fig 15). This generally occurs about 104-108 days after the VE stage or 54 to 58 days after R1.

A plant at R7 has attained physiological maturity or its maximum dry weight and a seed moisture content of about 60%. The seeds and pods have yellowed and lost all green color. As the pods and seeds mature from about R6.5 to R7 they become less susceptible to abortion; and the total number of pods per plant and beans per pod is set. Stress at this stage has little effect on yield because the larger and older seeds are less apt to abort and the younger seeds are smaller and contribute little to yield anyway.

R8, Full maturity stage. Now 95% of the pods have attained their mature pod color (Fig 16), generally about 114 to 118 days after the VE stage or 64 to 68 days after R1. A mature pod color does not indicate harvest readiness. Often, 5 to 10 days of drying weather are needed after R8 to reduce bean moisture levels to 15% moisture or less.

Yield will equal average number of plants per acre times average number of pods per plant times average number of beans per pod times average weight per bean.

Source of photographs: Ritchie et al. 1994. How a soybean plant develops. Spec rpt 53 (reprint), Iowa State University.

Table 3. Reproductive stages of soybean.

Reproductive stage	
R2	Full bloom
R3	Beginning pod
R4	Full pod
R5	Beginning seed
R6	Full seed
R7	Beginning maturity
R8	Full maturity

Note: In the field plants will not be at the same stage at the same time. Each stage is defined when 50% or more of the plants are at or beyond that stage.


Fig. 6. Folded leaf with curled leaflet margins still touching.


Fig. 7. V2 stage.


Fig. 8. V6 stage.


Fig. 9. R1 stage (Beginning bloom).


Fig. 10. R2 stage (Full bloom).


Fig.11. 4th node at R3 (Beginning pod).


Fig. 12. R4 stage (Full pod).

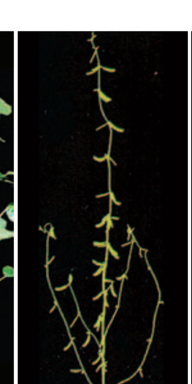


Fig.13. Stem R5 stage (Beginning seed).

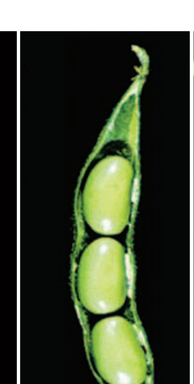


Fig. 14. 4th node pod at R6 stage (Full seed).


Fig. 15. R7 plant (Beginning maturity).

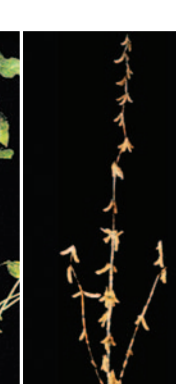


Fig. 16. R8 plant (Full maturity).

Scouting is your first line of defense

Symptoms of Asian soybean rust are not distinctive or unique and it will require a substantial amount of walking the field and looking to differentiate this disease from all of the other foliar diseases that may be occurring in a South Dakota soybean canopy.

Scouting patterns generally call for stopping at five random locations in a field, following an "M" or "W" pattern across the field (Fig 17). This will also be the approach with soybean rust.

However, when scouting for this disease we want to err on the side of detection. Scouting only five locations and only a set number of plants at each site only gives an estimate of the average amount of disease in the field. With this disease we want to do two things: find what is there and, even if low levels are present, treat.

While the "M" or "W" pattern provides random survey sites, for soybean rust it's sometimes better to bias our site selection to favor detection. In our climate that is generally drier than other soybean producing parts of the country, choosing more sites near windbreaks and other features that may favor longer dew periods may be desirable (Fig 18).

While walking between the five sites in each field, watch for stress sites and pick an occasional leaf to check for symptoms. Do not assume that this disease will be uniformly distributed across the field. There will likely be small hotspots.

At each survey site, collect 100 leaves from the lower canopy and mid canopy. Scan the undersides of those leaves for any hint of rust. The number of leaves out of 100 with any level of disease are the disease incidence.

Spray decisions are based on two points: the qualitative assessment—Is there any disease present—and the quantitative assessment—How much disease is present and in what part of the canopy.

No disease present means that any treatment made is a preventative treatment. In the preventative mode we can use any fungicide product. If there is as little as an average of 1 to 10% incidence (1 to 10 leaves out of 100 with any level of disease) in the lower canopy you need an early curative treatment, and strobilurin and chlorothalonil are less desirable choices for treatment.

As the disease begins to move into the middle third of the canopy, the opportunities for successful control and economic response diminish.

Detection of the disease in the mid canopy means that only a triazole product should be used. If a rate range is available on the label, use the higher rate as incidence or severity, the amount of each leaf that can be infected, increases. Be aware that a leaf can only sustain visible rust pustules on about 37% of the total leaf area.

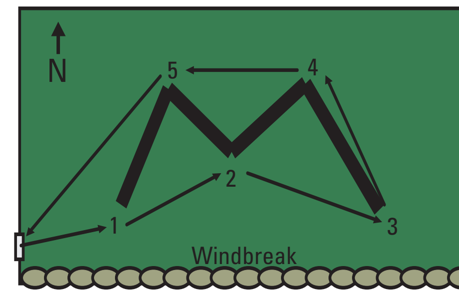


Fig 17. An unbiased standard "M" or "W" scouting pattern to detect uniformly distributed pests.

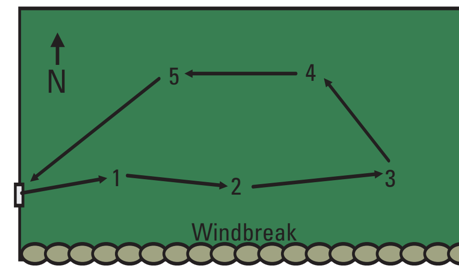


Fig 18. A biased scouting pattern designed to increase the chances of detection of a clustered disease that is influenced by longer dew periods near obstructions.

Biggest issue in spraying fungicides for soybean rust is droplet size

Frequently, pesticide spraying equipment is used for herbicide applications. For glyphosate-tolerant crops, spraying equipment is often set up to reduce herbicide drift to off-target areas while getting enough of the systemic herbicide on the plants to control the weeds.

Fungicide applications require a shift in thinking. Drift is still important, but modifying equipment to provide sufficient coverage of fungicide is crucial to providing adequate control.

Some fungicides are protectants. That means they will not move in the plant, so areas of the leaf that are not covered will not be protected. Other fungicides are systemics. While systemic herbicides can move rapidly throughout the plant, systemic fungicides, however, often move only a short distance, so sufficient coverage of the parts of the plant that must be protected is still very important.

Since soybean rust often starts in the mid to lower leaf canopy, spraying equipment must be adjusted to ensure that the fungicide makes it into the plant canopy with enough drops to get adequate coverage. Two important variables affecting coverage over which the operator has control are quantity of carrier applied (gallons per acre) and quality (size and uniformity) of the spray droplets produced by the nozzle.

Thoroughly read the label of every pesticide product that will be used. Fungicide labels often recommend 10 to 20 gallons per acre (gpa) of spray carrier for treating soybean rust by ground applicator and a minimum of five gpa by aerial application.

If the spray droplet size remains the same, 15 gpa will provide better coverage than 10 gpa, but 20 gpa will be better than 15. Higher application rates require more water and more time spent refilling the sprayer but may result in better control.

Carrier rates depend upon capacities of equipment, acres to cover, and available time. Determining carrier rate and travel speed is the first step in modifying sprayer equipment for treating soybean rust.

Research suggests that a droplet in the medium droplet size provides a good balance of crop canopy penetration and coverage for soybean rust fungicide applications. Choosing nozzles for correct droplet size is now easier with the development of a droplet size category system. The American Society of Agricultural Engineers standard ASAE –S572 provides droplet size categories from very fine through extremely coarse that can be used to determine the nozzle size and pressure required to deliver a particular size droplet.

FLAT FAN 80°	PSI						
	15	20	25	30	40	50	60
FF-01	Medium	Fine	Fine	Fine	Fine	Fine	Fine
FF-015	Medium	Medium	Medium	Fine	Fine	Fine	Fine
FF-02	Medium	Medium	Medium	Medium	Fine	Fine	Fine
FF-03	Medium	Medium	Medium	Medium	Medium	Medium	Fine
FF-04	Coarse	Coarse	Medium	Medium	Medium	Medium	Medium
FF-05	Coarse	Coarse	Coarse	Coarse	Medium	Medium	Medium
FF-06	Coarse	Coarse	Coarse	Coarse	Coarse	Coarse	Coarse

Fig 19. Droplet sizes for various flat-fan nozzles and pressures.

Tank-mixing pesticides appears to be safe for plant; no reduction in control expected

Soybean rust fungicides and insecticides to control aphids and bean leaf beetles can be tank-mixed. At the Southeast Research Farm in 2004, tank-mix applications of commonly used fungicides showed no yield reduction. It is not known if antagonism (reduction in control) will result from tank-mixing, but it is not expected.

Tank-mixing with glyphosate herbicides appears to be safe but is not recommended since the preferred application methods and timing of applications may be different.

To be certain of product compatibility in a tank mix, always check product labels and conduct a small jar compatibility test. For help with this procedure, contact your county Extension educator.

What happens if a larger droplet is used? Doubling a droplet diameter requires 8 times as much liquid per drop, therefore providing 1/8 as many drops. This may not be enough to adequately cover the plant leaves.

What happens if a smaller droplet size is used? A common misconception is that to get good coverage, small nozzles and high pressures are needed to "blast the fungicide deep into the canopy."

Trying to move fine droplets is like trying to blow feathers. Fine aerosol droplets rapidly lose velocity and may evaporate or float above the soybean plant and off the field. This presents two problems. First, the fungicide is not applied where it is needed, and it may drift to a crop where it is not labeled, creating an illegal residue. Second is the matter of economics. The investment in fungicide will not provide a return if it doesn't reach the target.

What is the best nozzle? Choose one that will deliver the carrier rate at the selected speed of travel and still give you the desired droplet size. Fig 19 provides an example of droplet size categories for various nozzle sizes and pressure combinations for a standard flat fan nozzle.

Applying higher carrier rates requires either larger orifice nozzles, higher pressures, or both. As nozzle size increases, so does droplet size for a given pressure. When trying to apply 20 gpa and traveling 12 mph, it is difficult to find a nozzle that will provide a droplet in the medium category at any reasonable pressure.

High carrier volumes can be applied with better quality control by using paired nozzles or nozzles with paired orifices. A single nozzle orifice delivering high volumes tends to lose control of the desired droplet spectrum. Paired nozzles or nozzle orifices may increase canopy penetration, especially in large soybean canopies or late-season applications.

If feasible, use wider angled nozzles (i.e. 110°) and standard spacing (i.e. 20 inches) to reduce boom heights. This reduces the effect of wind and may help maintain some of the momentum of medium sized droplets into the middle and lower canopy where soybean rust starts.

Droplet size may need to be increased slightly (reduce spray pressure) during the heat of the day. Cooler stagnant air in the crop canopy coupled with convection currents above the crop from heating air may reduce the ability of fine droplets to enter the canopy.

An important last step is to calibrate the sprayer equipment. Don't rely on the nozzle charts to assume a certain application rate. Worn gauges, worn nozzles, partially plugged screens, and pressure drops between the gauge and the boom can contribute to significantly different application rates than those expected based on nozzle charts. Make sure equipment is well maintained and in good condition. Calibration procedures can be found in many nozzle catalogs or check with your local Extension office for more information.

Steps to prepare your sprayer for soybean rust

- Read labels of fungicide products
- Determine carrier rate (i.e. 15 gallons per acre)
- Determine speed you intend to travel
- Consult nozzles charts to determine nozzles options
- Consult nozzle droplet category size charts to find nozzles in "medium" category
- Consider dual orifice or two-nozzle adaptors to get to a medium droplet
- Do a thorough calibration with the new nozzle set

You may be dealing with insects, too. Protect your soybeans in early August

We have been growing soybeans in South Dakota long enough that "the honeymoon is over." Most of the diseases and insects of a well-established soybean-producing state have moved in.

Our soybeans can host Septoria brown spot and bacterial blight. Occasionally we see downy mildew. Bacterial pustule and frogeye leaf spot are rare but possible. We have bean pod mottle virus, and aphid pressure increases the risk of soybean mosaic. We have soybean aphids, bean leaf beetles, soybean cyst nematodes.

Obviously these fungi, bacteria, viruses, nematodes, and others don't line up and come one at a time. Symptoms may be magnified—or masked—by multiple organisms, and symptoms also may be altered by weather, plant nutrition, and other factors.

When things get this complicated, and when a new kid on the block—soybean rust— threatens to make an appearance, there tends to be a lack of information.

So far as we know, the black cutworm does **not** spread soybean rust; the spread pattern of soybean rust does not follow the migration path of black cutworm.

We **can** tank-mix fungicides for soybean rust and insecticides for bean leaf beetles and aphids.

Insects hit soybeans same time as soybean rust does, during reproductive stages

Although insects can appear on the field at any given time during the growing season, they are most damaging during the reproductive stages of soybean development. Specifically, insects can be very damaging if they infest the plants from R1 (beginning bloom) through R6 (full seed) stages. In South Dakota, the reproductive stages of soybeans usually occur during the month of August.

The old saying, "Soybean yield is made in August," can therefore be used as a guide to when insects should be controlled on the field to optimize soybean yields. Yield robbing insects such as the soybean aphid and bean leaf beetle must not be allowed to exceed economic threshold levels from mid-July through early-August if we want to harvest optimum yields in October.

Fig 20. Soybean pod infested with soybean aphids in August.

Control of soybean aphids is a 'race against time'

Damage. Soybean aphids feed on the plant's sap and interfere with flowering and pod formation. Soybean plants heavily infested with soybean aphids produce very few pods, and the seeds from whatever few pods that do form are much smaller than normal (Fig 20). Protein and oil contents of the seeds are also severely affected.

Soybean plants with economic numbers of aphids that are then sprayed with an insecticide can have yield increases of up to 13 bushels per acre depending on the brand and rate of insecticide used (see Web site listed at end of page).

Economic thresholds. Soybean aphids can multiply very fast in the summer (about tenfold every week until they reach peak numbers at around R5 or beginning seed stage).

On the other hand, the soybean stages that need to be protected (R1-R5) last merely 21 days. Soybean aphid control, therefore, is a proverbial "race against time" with the weather (wind) being a key deciding factor on when insecticides are ultimately applied on the field.

Again, with soybean aphids, you are dealing with a very damaging insect that multiplies tenfold a week, and you only have less than a month to decide whether to spray or not.

Economic thresholds developed by SDSU Extension entomologists and the USDA-ARS Northern Grain Insects Laboratory, take into account these factors and give South Dakota soybean growers enough lead time to control soybean aphids on the field.

In addition, important variables such as the insecticide-plus-application cost, predicted market value of the soybean crop, and the yield potential of the soybean field are integrated in the economic threshold calculations. SDSU soybean aphid threshold recommendations are therefore both scientific and practical.

An easy-to-follow procedure for calculating the economic thresholds of soybean aphids in South Dakota can be found at the Web site below.

Economic thresholds vary with the predicted market value of soybeans, actual cost of the spray, and yield potential of the field. An economic threshold represents the breakeven point between the cost of the spray and the value of the damage that will be prevented if the field is sprayed.

Biology and scouting. In South Dakota, soybean aphids can show up on soybean plants as early as the V5 (five unfolded trifoliate) stage during the second week of July. Scouting can start in mid-July and should be continued until the R5 (beginning seed) stage.

In July and early August, scouting must be focused on the soybean growing points, as these parts are infested first. Aphids then spread to the leaf undersides and pods as they multiply into numbers much higher than the proposed economic thresholds.

Severe damage has likely already occurred once aphids are detected on the pods, or if shiny or sooty leaves are observed.

Look for aphids from as many sites within the field as possible to properly gauge the representative aphid infestation of the entire field. Soybean aphids usually infest the borders first and then spread into the whole field.

Soybean aphids overwinter as eggs on buckthorns. Eggs hatch in the spring into aphids that then start producing winged forms. Winged aphids migrate from buckthorns to soybeans in July. Both winged and wingless aphids can be found on soybeans as long as plants still have green leaves.

Peak aphid numbers occur at R5 (beginning seed) stage, but decline drastically thereafter. Winged soybean aphids start migrating to buckthorns in September. These winged aphids give birth to aphid forms that will lay eggs on buckthorn buds and twigs. All aphid forms are eventually killed by frost except for the eggs that will again hatch in the spring of the following year.

Insecticides. (PHI is pre-harvest interval):
Asana XL (5.8-9.6 fluid ounces per acre, 21 day PHI)
Baythroid 2 (2.8 fluid ounce per acre, 45 day PHI)
Decis 1.5EC (1.5-1.9 fluid ounces per acre, 21 day PHI)
Dimate (0.50-0.75 fluid ounces per acre, 21 day PHI)
Furadan 4F (0.5 pint per acre, 21 day PHI)
Lorsban 4E (1 to 2 pints per acre, 28 day PHI)
Mustang MAX (2.8-4.0 fluid ounces per acre, 21 day PHI)
Penncap-M (1 to 3 pints per acre, 20 day PHI)
Pounce 3.2EC (4-8 fluid ounces per acre, 60 day PHI)
Proaxis (1.92-3.20 fluid ounces per acre, 45 day PHI)
Warrior (1.92-3.20 fluid ounces per acre, 45 day PHI).

Always read and follow label directions. Consult the label for restricted entry intervals (REI). SDSU research indicates that different insecticides produce different yield advantages. For more information, go to the Web address at end of this page.

Bean leaf beetles are hardy enough to overwinter in South Dakota as adults

Damage. Bean leaf beetles feed directly on the pods and developing seeds of soybeans (Fig 21). Whole pods may fall to the ground as a result of pod clipping.

Leaves and stems are also fed upon by the beetles. Bean leaf beetles are most damaging from R3 (beginning pod) through R6 (green bean) soybean stages.

Spraying economic numbers of bean leaf beetles can result in significant yield increases of up to 9 bushels per acre depending on the brand and rate of insecticide used.

Economic thresholds. The economic thresholds of bean leaf beetles on pod through fill stages can be calculated using a formula that takes into account the chemical-plus-application cost, predicted yield potential, and the expected market value of soybeans. For example, a soybean field planted in 30-inch rows should have an average of six bean leaf beetles per foot of row, or four beetles per sweep of an insect net, for spraying to be cost-effective.

This scenario assumes a yield of 40 bushels per acre, expected soybean market value of $5 per bushel, and a chemical-plus-application cost of $8 per acre.

Economic thresholds vary with the predicted market value of soybeans, actual cost of the spray, and yield potential of the field. Economic threshold represents the breakeven point between the cost of the spray and the value of the damage that will be prevented if the field is sprayed.

Biology and scouting. Bean leaf beetles are about one-quarter inch in length and yellowish in color with four dark spots on the back. They have chewing mouth parts. Bean leaf beetles will continue to feed on soybeans until the pods turn yellow. Scouting must be continued accordingly.

Beetles on the field at harvest time will overwinter in soil litter and shelterbelts and will feed again on next year's soybean seedlings. Bean leaf beetles are native to the U.S. Their host plants include soybeans, edible beans, clover, corn, peanuts, and several leguminous weeds.

Insecticides. (PHI is pre-harvest interval):
Asana XL (5.8-9.6 fluid ounces per acre, 21-day PHI)
Baythroid 2 (1.6-2.8 fluid ounces per acre, 45-day PHI)
Dimethoate 4EC (1 pint per acre, 21-day PHI)
Decis 1.5EC (1.5-1.9 fluid ounces per acre, 21 day PHI)
(Lorsban 4E (1-2 pints per acre, 28-day PHI)
Mustang MAX (2.8-4.0 fluid ounces per acre, 21-day PHI)
Pounce 3.2EC (2-4 fluid ounces per acre, 60-day PHI)
Proaxis (1.92-3.20 fluid ounces per acre, 45 day PHI)
Sevin XLR PLUS (1-2 pints per acre, 21-day PHI)
Warrior (3.2-3.84 fluid ounces per acre, 45-day PHI).

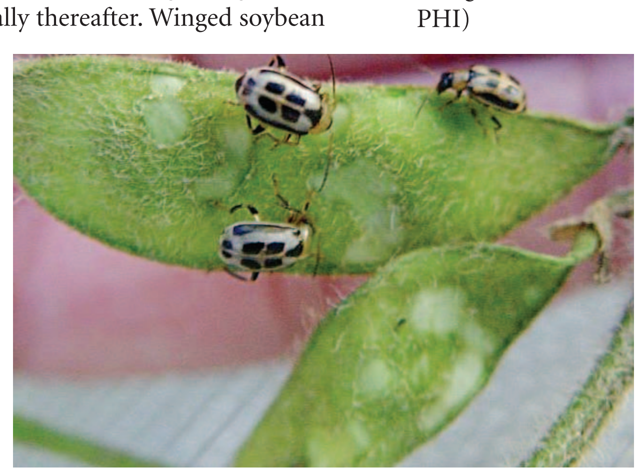


Fig 21. Soybean pods infested with bean leaf beetles in August.

Growers considering treatment later in the season need to be aware of the PHI of the product they intend to use. Always read and follow label directions. Consult the label for restricted entry intervals (REI). SDSU research indicates that different insecticides produce different yield advantages.

For methods of calculating the economic thresholds of soybean aphids and bean leaf beetles and information on various insecticides, visit the SDSU Extension Entomology Web site (http://plantsci.sdstate.edu/ent)

With or without rust in the picture, protect your price … and your revenue

For most of last year, the soybean market had little doubt that soybean rust would eventually find its way into the U.S.; the only question was when. Until its discovery in November of 2004, there was very little consideration of soybean rust in the U.S. in the day-to-day trading of soybean futures.

When the news broke in November 2004 that soybean rust had been found in the U.S., the market reaction was swift and expected; soybean futures gained as much as 40 cents over 7 to 10 days. However, since the rust was discovered so late in the fall, the initial bullish reaction faded rather quickly. As a result, futures prices lost most of their gains by early December 2004.

What then, will be the impact of soybean rust on prices in 2005? Soybean prices will certainly have the potential to rally again this year. How much of an upturn could depend upon the severity and location of the initial infection, the potential for the spread of the disease to larger regions of the country, the uncertainty of yield expectations during the growing season, and, finally, the actual yield losses that may occur. The challenge for the soybean market will be to balance this bullish fundamental factor that could impact 2005 production against a longer-term bearish fundamental factor of carryover supplies of soybeans currently at the highest levels in history.

Since soybean rust is a new peril, the actual implications of this disease on soybean prices are impossible to determine in advance. We could look to South America where rust has been a management concern for a number of years.

South American production keeps rising despite rust

Regardless of the presence of soybean rust in South America, production has consistently grown each year (Fig 22). This is likely due to increased acres, increased yields per acre on non-infected fields, or a combination of both.

Projections for soybean production in January 2005 showed an increase of as much as 15 million metric tons over the previous year. This estimate was revised downward by mid-April due to drier than normal conditions in southern Brazil and northern Argentina in late February and March. The combined production of Brazil and Argentina still is currently projected by the USDA Economic Research Service as of mid-April at 93 million metric tons, an 8.6% increase over production in that region one year ago.

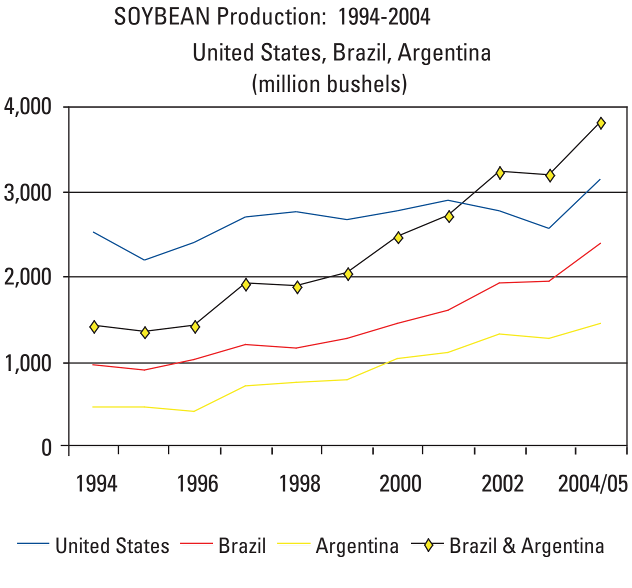


Fig 22. Soybean production, 1994-2004.

Rust may be only one reason for expected decrease in 2005 U.S. soybean acres

The annual Prospective Plantings report of USDA's National Agricultural Statistics Service, issued March 31, 2005, estimated that 73.91 million acres will be planted to soybeans in 2005, a decline of 1.3 million acres from a year ago. It must be noted that this is only a projection of what farmers intend to plant. Actual planted acreage figures will be reported in the 2005 Planted Acreage report released on June 30, 2005.

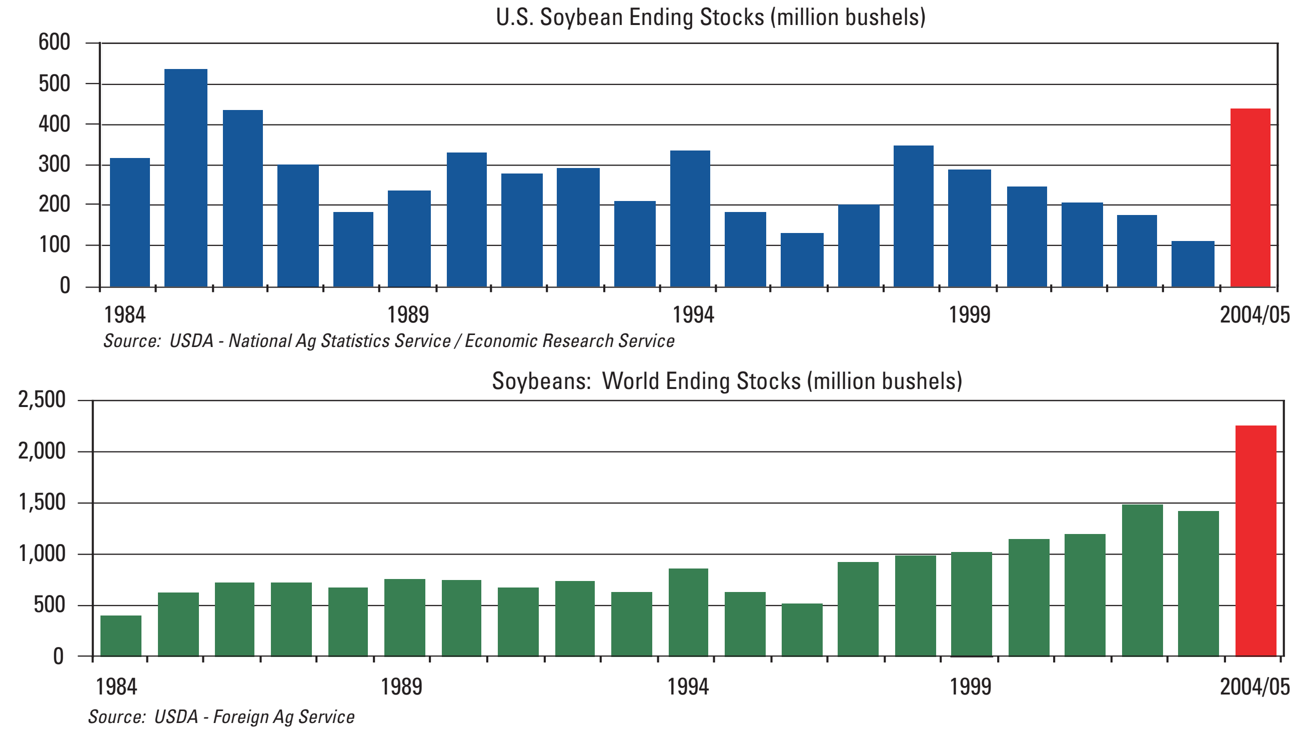


Fig 23. Soybean ending stocks.

Based on this initial acreage estimate and a trend-line national average yield of approximately 39 bushels per acre, production of soybeans in the United States could be approximately 2.85 billion bushels. Assuming demand remains relatively constant, this would not reduce current carryover supplies.

As an added feature to this year's survey, farmers across the nation were asked by USDA whether soybean rust would affect their planting decisions regarding soybeans. The vast majority of growers in the U.S. in this survey were aware of soybean rust and the potential threat it poses. However, only 6% of all farm operators nationwide who were aware of soybean rust reported that the rust issue was a factor in their planting intentions—7% indicated they would increase their acres, 53% said they would plant fewer acres. The remainder indicated rust did not change their planting intentions at all.

Since only 6% of farmers in the U.S. indicated that soybean rust factored into their planting intentions, this means that there are other reasons that may be of more significance to reduced planting intentions than the rust issue alone.

Worldwide carryover 'largest in history'

The carryover supply of soybeans is perhaps the most important bearish fundamental factor in direct opposition to the potentially bullish factor of soybean rust. Current estimates of carryover supplies of soybeans in the U.S. are the largest since 1986. Estimates of worldwide carryover are the largest in history, exceeding the previous record of 2 years ago by almost 34%.

If the U.S. and South America both raise soybean crops that, combined, exceed production of a year ago, world supplies will very possibly continue to grow. This should, in turn, put additional pressure on price (Fig 23).

From a purely fundamental standpoint, the current carryover supplies of soybeans are so large that price pressure would be the normal expectation throughout 2005, especially if both the U.S. and South American harvests in 2005 are sufficient to at least maintain current carryover supplies. However, this expectation was already put to the test in February and March of 2005.

Dry conditions in southern Brazil—not soybean rust—was given as the primary reason for an unexpected rally that lasted well into the month of March. Since futures prices gained as much as $1.20 to $1.80 during this rally, one might reasonably expect that soybean prices will also rally if soybean rust is discovered in the U.S. during the 2005 growing season. If a rust rally occurs, it could be a result of a greater yield impact in other regions of the country, giving South Dakota growers an advantage in making pricing decisions. This advantage may be attributed to South Dakota's location on the disease path, the later season infection period compared to more southern soybean growing states, and the fact that South Dakota farmers will have more forewarning of the disease's potential threat.

Combine the rust factor and large carryover supplies with the other primary element that dictates production—rainfall—and this mix leads to expectations of a volatile market in 2005. This potential volatility will lead to pricing opportunities if rallies occur. Volatility could also lead to missed opportunities if prices decline. It will be critical to evaluate pricing alternatives, crop insurance coverage, and production costs to plan ahead for making sales when, and if, the market offers a profitable price.

Given all 'unknowns,' you need a solid marketing plan

While we can't predict the extent of any bullish or bearish swings in the market, it is still possible for producers to plan ahead by writing a marketing plan and working with brokers, grain elevator managers, Extension educators, and others to make the plan feasible and realistic.

The plan should include production expectations and a working knowledge of crop insurance coverage and the revenue and/or yield protection it provides. Depending upon your insurance coverage, you could realistically forward price a majority of your expected production without any fear of losing gross revenue. The plan should include price levels (price triggers) at which forward sales can be made, possible calendar dates for making sales regardless of price direction, and methods for making sales. Although there is nothing wrong with waiting until harvest is underway to make cash sales of soybeans, a well thought-out, yet simple marketing plan can help you take advantage of profitable pricing opportunities that may be available prior to harvest.

It is also important to create a marketing plan that captures cost of production and profit. It will be important to evaluate forward pricing strategies that will lock in a price, such as a futures hedge or a cash forward contract. These strategies will protect against any price decline after the pricing strategy is employed. If you have committed bushels to one of these strategies and prices begin to rise, you could re-own those committed bushels on paper by purchasing at-the-money or out-of-the-money call options.

Another price protection mechanism is to simply buy put options that lock in a floor price only. In the case of either the call options or the put options, the value of the premium will likely be an issue that determines the purchase of at-the-money or out-of-the money options or whether an option purchase is reasonable or prudent in the first place.

For those bushels yet uncommitted to a pricing strategy, a stepped-up sales plan could be established to make sales at pre-defined price levels.

A marketing plan should also include a strategy for making sales or deferring sales in the event prices decline during the growing season.

With any of these strategies, it will still be important to know the county loan rate value for soybeans. In the event that soybean prices fall, any of these pricing strategies may establish a floor price that is lower than the loan rate.

Insurance backstops against production losses; revenue products allow pricing flexibility

Soybean rust is covered under standard crop insurance products. If a grower takes reasonable steps to control and treat any outbreaks, tries to prevent and control any damage, and still faces sizable yield reductions, then the insurance pays an indemnity on lost bushels.

If enough producers across the U.S. have soybean rust in their fields and if yields drop as a result, soybean prices could increase.

In South Dakota, most producers use relatively high levels of coverage and insure a vast majority of soybean acres, 96% in 2004. Understanding the types and levels of coverage producers typically use will tell us how to manage the production and price risks from soybean rust.

The crop insurance purchase deadline was March 15 for soybeans in Midwest states. Producers picked their coverage types and levels by March 15, but do not report acres until after planting. Producers will want to work closely with their crop insurance agents to assure compliance with their policies.

Producers in South Dakota are unlikely to change their insurance decisions because of soybean rust. Under various scenarios with different national outbreaks of rust, they and growers in other Northern Plains states are not likely to shift away from soybean acres.

The map (Fig 24) shows county transition (T) yields in South Dakota. Regular crop insurance policies are only available in the counties with T-yields. The variation in T-yields matches actual production differences among counties.

The important issue is for producers (and their advisors) to understand what insurance coverage was purchased.

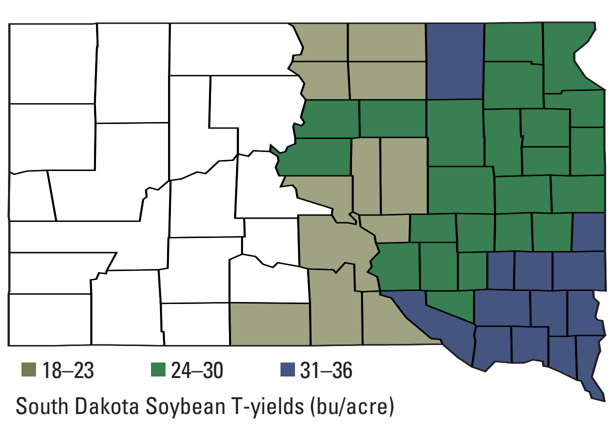


Fig 24. South Dakota soybean T-yields (bu/acre). Source USDA-RMA.

'Ideally, a producer manages against perils such as insects and plant diseases the same way with and without insurance'

The crop insurance policies list plant disease as a cause of loss with the caveat "but not damage due to insufficient or improper application of disease control measures."

Insurance companies are concerned about "moral hazard" where the insured might act in their own self-interest to the detriment of the insurance company in the short run and the insurance product viability in the long run. Ideally, a producer manages against perils, such as insects and plant diseases the same way with and without insurance.

The pie chart (Fig 25) shows the extent and types of coverage purchased by soybean producers in South Dakota in 2004. The National Agricultural Statistics Service reports that South Dakota producers planted 4.15 million acres to soybeans in 2004. The Risk Management Agency, which overseas crop insurance, reports that South Dakota producers purchased insurance on 3.97 million acres of soybeans in 2004. Thus, fewer than 4% of the acres went without insurance (labeled "NI"). In contrast, Iowa producers only insured 86% of planted soybean acres in 2004.

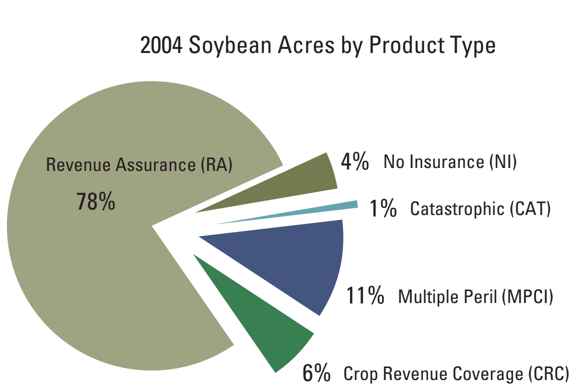


Fig 25. 2004 soybean acres by product type. Sources: USDA-RMA, NASS

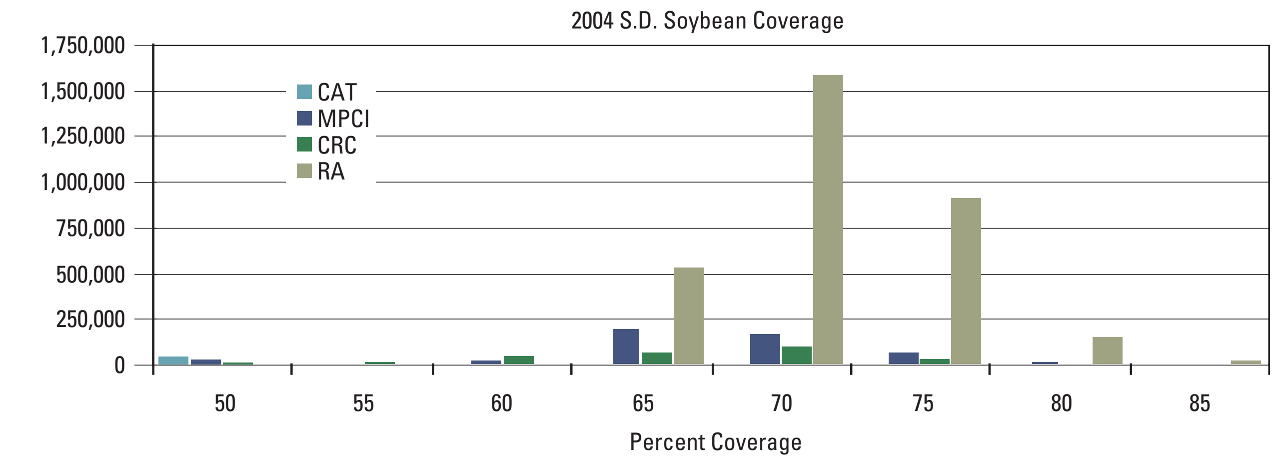


Fig 26. Soybean coverage. Source: USDA-RMA

South Dakota producers covered their acres with one of four farm-level policies: Catastrophic (CAT), Multiple Peril (MPCI), Crop Revenue Coverage (CRC), or Revenue Assurance (RA).

CAT and MPCI are yield insurance products while CRC and RA are revenue insurance products. Two group policies were available in some counties, but producers did not purchase them on South Dakota soybean acres in 2004. Producers bought RA on the largest share of acres because of its favorable price level compared to the yield products and its lower cost relative to CRC.

The trend has been toward more revenue insurance. CRC and RA provide revenue floors for the crop and usually allow producers to more prudently forward price a larger percentage of production without worrying that prices increase by harvest time.

Producers often hesitate to forward price or hedge a large portion of their expected production. In the event of substantial yield loss and higher prices, their hedging loss could exceed any insurance indemnity. RA with the harvest price option and CRC have indemnity payments tied to the greater of spring and harvest price levels. Producers with these coverage types can forward price a percentage of their crops. Then, if prices go up before harvest time and they suffer a yield loss, their indemnity increases to offset any hedging loss.

Most producers purchased soybean policies with yield election levels of 65, 70, or 75% coverage (Fig 26). For 75% coverage, for example, producers insure 75% of their historic or proven yields. Actual yields need to be below that level before the insurance pays any indemnity. If a producer has a proven yield of 40 bushels per acre and buys 75% coverage, he would not receive any indemnity payment unless actual yield was below 30 bushels per acre. The uncovered portion constitutes the insurance deductible.

There are a few implications of the coverage levels typically used on soybeans when considering rust. In the event of a loss with revenue insurance, the indemnity payments could be substantial. Soybean producers in South Dakota tend to purchase a large amount of coverage per acre. The deductible amount, purchasing 75% coverage, means the producer bears the full financial responsibility for the other 25%. If rust becomes enough of a problem to increase soybean prices, the producer would have a large amount of expected revenue to expend on prevention and treatment. The final caveat is the fact that proven yields may not match potential yields for a given insurable unit. In essence, this makes the actual deductible larger than the one on paper.

Insured producers are obligated to use 'good farming practices' to maintain eligibility

Will producers have to spray to prevent/control soybean rust, regardless of cost and regardless of the condition of the crop?

Insured producers are obligated to use "good farming practices" to maintain eligibility. Good farming practices are discussed in the crop policies in a general way and are determined by local agricultural experts.

Moral hazard is the primary concern with good farming practices. A producer with insurance could potentially be better off financially with a low yield and high indemnity payment relative to the cost of managing a peril.

When insurance companies talk about good farming practices they say things like producers should make "good faith efforts" and take "reasonable" measures to reach the insured level of production.

In other words, if an effective control measure were available, then the producer would be expected to use the measure to maintain insurance against loss associated with the peril. In the event that a crop has already been damaged by drought, hail, or other perils the producer could forgo treatment if any additional indemnity does not make treatment look cost effective.

The economics of 'to treat or not to treat'

In evaluating treatment options for soybean rust, the producer should compare the cost of treatment to the expected return of that treatment.

Once the crop is planted and growing, all previous costs become "sunk costs" and are irrelevant to future decisions of treatment or non-treatment.

For example, assume a proven and an expected yield of 36 bushel of soybeans priced at $5.85. If rust becomes a threat, the grower estimates a 9 bushel per acre loss, or 25% yield loss. No treatment would yield 27 bushels at $5.85 or $152.10 (Table 4).

Table 4. Partial budget for rust treatment.

	No treatment, 25% loss	*One application for rust treatment*	*Differential revenue and costs*
Revenue:	$152.10	$210.60	$58.50
Sunk Costs	86.00	86.00	0.00
Additional costs	0.00	16.75	(16.75)
Return to labor, land, machinery	$66.10	$107.85	$41.75 benefit to treatment

The additional cost of treatment is estimated at $16.75, which includes material at $12 an acre and custom application at $4.75 an acre. (Material cost has been estimated at a range of $10 to $15 an acre per treatment.) Application cost is based on *South Dakota 2004 Custom Rates*, with a surcharge for fuel.

In this example treatment results in an estimated $41.75 benefit per acre over non-treatment.

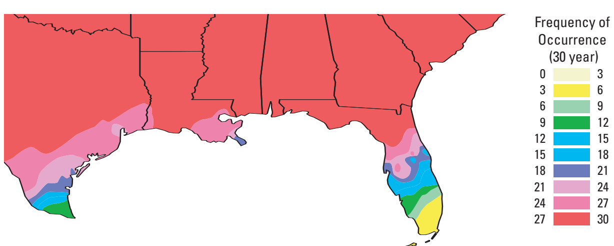
An informative reference by M. Livingston, R. Johansson, S. Daberkow, M. Roberts, M. Ash, and V. Breneman of the USDA Economic Research Service, entitled Economic and policy implications of wind-borne entry of Asian soybean rust into the United States, can be found at www.ers.usda.gov/publications/OCS/Apr04/OCS04D02/OCS04D02.pdf

Soybean rust cannot overwinter in South Dakota; sentinel plots and models will track its progress up from the South

Now that Asian soybean rust has been introduced onto the continent, it is expected to stay here as it can survive on many host plants in areas that do not freeze annually.

It is this freezing that will give soybean producers, especially those in the far northwest part of the soybean growing region, some breathing room and a chance to **track and respond** to the rust. Because freezing temperatures occur for at least a few days each winter all the way to the Gulf of Mexico, the overwintering of rust will be confined to far southern locations, probably southern Texas and Florida (Fig 27). These southern locations remain warm enough to keep host vegetation alive.

Fig 27. Likelihood of overwintering. The number of years out of 30 that soybean rust would be killed off during the winter based on climatic averages. The most likely places for overwintering are the yellow, green, and blue areas in southern Texas and Florida. *Source: Magery et al, USDA APHIS CPHST.*



That doesn't mean midwestern soybean growing areas, South Dakota included, are protected from soybean rust. As insects and spores from rusts on wheat have done before them, soybean rust spores can ride the surface winds of spring, moving northward along with the warmer air and moisture typical of springtime and throughout the summer.

The location of overwintering areas—whether Texas or Florida—is critical to the re-introduction of rust on an annual basis.

Overwintering and infestation occurring in the far southeastern U.S. reduce the risk and delay the potential for re-introduction of rust later into the summer this far north in the soybean area. Prevailing westerly winds across most of the U.S. will slow the westward progress of the rust from the southeast U.S. In such a situation, rapid progress will likely not occur. The rust will be limited to shorter westward jumps as green-up starts to occur in the spring.

Overwintering rust in Texas is another story. A different meteorological effect could operate. A spring and early summer phenomena called the Great Plains Low Level Jet occurs once to twice a week depending on the season. This jet is a rapid current of wind originating in the Southern Plains that typically moves warmer air and moisture northward on winds 400–2000 meters above the surface. The jet could move spores quickly northward.

Because the rust will likely not make big jumps, the main factor here is to watch where soybean rust has been reported, follow its transport, and watch the calendar. (Soybeans are most vulnerable to rust from bloom through pod filling.) Once rust has been identified in the Louisiana, Arkansas, Texas, Oklahoma area, the potential for northward movement into the southeast part of South Dakota is possible.

If rust is found in Kansas or Nebraska our risk increases greatly; producers should begin to watch closely after this point.

Universities and the USDA will be using various meteorological computer models to suggest where potential infestation may occur based on winds moving spores from infected areas northward. These data will be made available through web sites.

Another early warning method consists of a network of sentinel plots scattered throughout the soybean-growing region of the U.S. Agencies and cooperating farmers have planted early soybeans in these plots—early so that the plants will be in reproductive stages and receptive to spores if and when they appear. Surrounding fields of beans, planted later, may still be treated with fungicides. This nationwide network will help give South Dakotans advance notice of the spores' arrival.

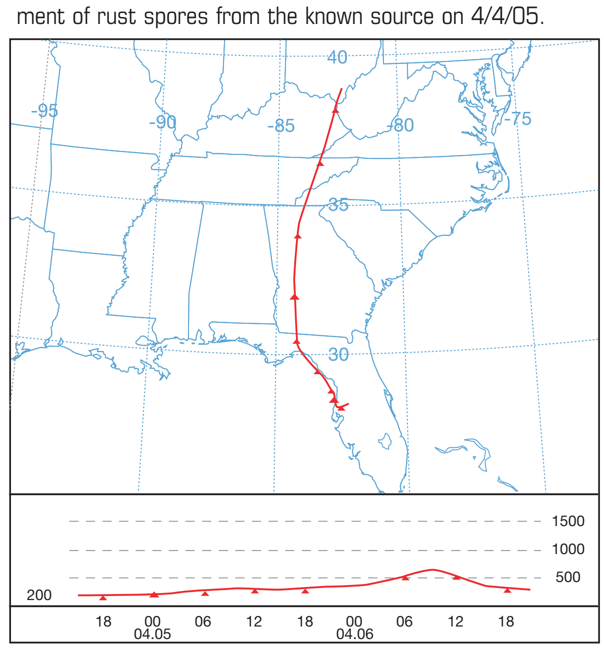
The National Plant Disease Forecast Center at North Carolina State Univeersity will post spore spread maps on a 6-hour update cycle. All of these forecast sites are accessible from the SDSU soybean rust website http://plantsci.sdstate.edu/planthealth See also http://climate.sdstate.edu

We will have time to plan a response because of our northern location

The South Dakota Office of Climate and Weather will also be developing trajectories from National Weather Service computer models. These trajectories will help determine where air masses coming over South Dakota originated (Fig 28). These maps indicate if air passing soybean growing areas of the state has come from infected regions. Other modeling efforts have been used to determine the likelihood of occurrence based purely on temperature and moisture conditions.

So far, the best estimates are that disease epidemics in the eastern part of the state can occur in about one of every 2 years, based on the occurrence of weather conditions conducive to soybean rust. This is again a model estimate because there are a great many unknowns about rust and how readily it will be transported during the year.

Fig 28. Example trajectory model indicating potential movement of rust spores from the known source on 4/4/05.



There do not seem to be any specific temperature conditions within which rust cannot occur, other than below freezing. The most optimal conditions seem to be temperatures between about 60 and 80 F.

Another condition the spore needs is water on the leaf, either from dew or rain, for at least 6 hours. The longer the leaf is wet, the better for the germinating spore and the more likely infestation will result.

This need for water may limit westward spread of soybean rust in the state, where dew formation in the canopy is less likely. An open canopy (soybeans in rows instead of drilled) also reduces the occurrence of dew and makes the free water requirement more difficult to maintain. Lower humidities, common enough in South Dakota dryland farming, can also lead to shorter times that free water will remain on the soybean leaves. Irrigated soybean fields in Nebraska and South Dakota could possibly be sources of inoculum; to test this out, several of the South Dakota sentinel fields are being irrigated. Disease status in these sentinal plots also will be posted on http://plantsci.sdstate.edu/planthealth

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