Disease Management and Identification

Sam Markell
NDSU Extension Pathologist

Dean Malvick
University of Minnesota Extension Pathologist

Berlin Nelson
NDSU Pathologist

Problematic diseases of soybean in the North Dakota and northern Minnesota region may affect yield and quality of the crop. Accurate identification of the problem is the first step in managing these diseases. Once identified, specific management techniques to address the problem may benefit soybean growers. The information in this chapter is designed to aid in identification, prevention and management of soybean diseases. Pictures can be found in the photo section of this publication. Below are general guidelines for managing soybean diseases.

- **Use high-quality seed.** Certified seed will minimize the introduction of soybean pathogens. Avoid using seed produced on fields with diseases that can be seed-borne.
- **Use crop rotation.** Soybean diseases, especially root and stem diseases and soybean cyst nematodes, build up when soybean crops are grown in close rotations. Lengthening rotations to three or four

years between soybean crops allows natural processes to reduce pathogen populations. Some crops such as dry bean and sugarbeet may be infected by some pathogens that attack soybean. Have diseases accurately identified so you can make sound decisions on the use of rotation crops.

- **Scout fields for disease.** Record the incidence of disease; such information can be used to make good decisions on management practices.
- **Strengthen the soybean plant.** Use good cultivation practices to promote growth of soybean. Provide adequate soil fertility, avoid soil compaction, enhance drainage, control weeds and avoid herbicide damage.

Two websites that provide information on diseases in this region are:

- *www.extension.umn.edu/cropdiseases/soybean/index.html*
- *www.ndsu.edu/pubweb/~bernelso/soydiseases/*

Below Ground

The most significant diseases in our region, such as root rots, and pests, such as soybean cyst nematode, are found underground. An independent section on seed treatments follows discussion of all diseases.

Soybean Cyst Nematode

The soybean cyst nematode (SCN), *Heterodera glycines*, is the most problematic pathogen of soybean in the United States. This nematode is a microscopic

roundworm that infects soybean roots. Extensive losses occur throughout infested areas. Losses greater than 50 percent have been measured in infested fields in North Dakota.

Nematodes easily spread from field to field by equipment contaminated with infested soil, wind-blown soil or overland flooding, or are carried by animals. In addition, SCN can be carried in soil "peds," which are small clumps of soil sometimes found associated with soybean seed. As of 2009, SCN has been confirmed in Cass, Dickey and Richland counties in North Dakota and Becker, Clay, Norman, Otter Tail, Red Lake and Wilkin counties in northwestern Minnesota. However, SCN is suspected in additional counties and likely will spread throughout the growing region.

Symptoms

Infection by SCN often will not result in obvious above-ground symptoms unless plants are stressed or the egg densities are high. Above-ground symptoms include stunting and yellowing, poor stands or just unthrifty plants. The roots can appear dark and decayed, and they have few, if any, nitrogen fixing nodules. A diagnostic characteristic is the presence of white to yellowish lemonshaped female nematode cysts (about 1 millimeter in diameter) on the roots. You can observe these if you carefully remove the plant from the soil with a shovel and gently wash or shake the soil off the roots. The severity of the symptoms is directly related to the amount of SCN

in the soil. Warm, dry growing seasons tend to increase severity of the above-ground symptoms, while cool, wet years tend to decrease severity. Losses from SCN are usually much greater during droughts. Severity also tends to be higher in sandy soils than in heavy-textured soils.

Management

Maintain fields free of SCN by cleaning any equipment that previously was used in an infested area. Reduce the potential spread of SCN from infested fields to adjacent clean fields by reduced-tillage operations and practices that limit wind erosion and movement of soil. Also, use good-quality seed free of soil "peds."

Management begins by confirming the presence of *H. glycines* in the field. Economic thresholds for SCN levels in the soil have not been established for North Dakota or Minnesota. Growing a susceptible soybean in a field with low egg levels is possible, but you always have the chance of some yield loss. Unfortunately, SCN reproduces to high levels in this northern soybean-growing area, thus once a field is infested, growing susceptible cultivars will begin to increase egg levels relatively fast.

Growers can sample the soils in their fields and send the samples to public (for example, the University of Minnesota Southern Research and Outreach Center in Waseca or the NDSU Soil Testing Laboratory in Fargo) or private laboratories where egg counts can

be determined. Soil tests are used to determine if a field is infested, an extended rotation is necessary or a resistant cultivar should be used. Soil testing is highly recommended if a potential for SCN infestation exists. Information on the correct soil-sampling procedures can be found on the websites of many universities or labs that process samples.

If a grower decides to plant a susceptible soybean on land infested with SCN at low egg densities, a fall soil sampling should be conducted to determine the egg density in the field. Those results will indicate the amount of reproduction during that season and can be used to decide if a rotation or use of a resistant cultivar is warranted.

Crop rotation is an effective method to reduce egg densities in soil. Rotation to nonhost crops for three to four years may reduce nematode populations, but many factors affect the reduction in egg densities, thus the results in each field will vary. Data from North Dakota indicates that in heavily infested fields following rotations to nonhost crops for four to five years, egg densities in some fields still were high. Nonhost crops are corn, sugarbeet, alfalfa, potato, small grains and sunflower. Dry edible bean, certain lupines and crambe are hosts of SCN. Consult a list of susceptible crops before growing specialty crops in SCN-infested fields. Weed control is important because SCN will reproduce on a wide variety of weeds.

Resistant cultivars are available to control SCN, but fewer are available in the early maturing varieties adapted to northern areas of North Dakota and Minnesota. Resistance usually is combined with crop rotation to manage SCN. Use cultural practices such as high fertility to help soybean plants become established and grow strongly to reduce the negative effects of SCN.

Phytophthora Root Rot

Phytophthora root rot is a major disease of soybean, especially in areas where soybean has been cultivated for many years. The disease is caused by the fungallike pathogen *Phytophthora sojae*. Yield losses can be substantial; entire fields have been destroyed. The disease is common in the Red River Valley. The pathogen survives in soil as spores called oospores, which are produced in infected plants. When the soil water content is high, the spores germinate and infect the roots. Infection and disease development can occur at any stage of plant development, but are most commonly observed and damaging at the seedling or young plant stage.

Disease is most common in heavy, compacted clay soils and fields subject to flooding. Flooding rains, especially near planting, favor disease development. Reduced tillage, especially notill, is reported to increase damage. The pathogen does not infect other crops grown in this region naturally. Only three *Lupinis* spp. and soybean are natural hosts.

P. sojae has more than 70 races. The most prevalent races in North Dakota are 3 and 4, but many others are found in low frequency. As more acreage is cropped to soybean and more resistance genes are deployed, we expect the race frequency will change.

Symptoms

They include seed rot and pre and postemergence dampingoff and wilting of young plants. These are common in flooded soils and often are misidentified as water damage. On older plants, leaves may become yellow and plants will wilt, with wilted leaves remaining on the plant. The lateral and tap roots are destroyed. A dark brown discoloration often appears on the lower portion of the stem. The disease is usually patchy in the field, often occurring in low or flooded areas.

Management

Planting resistant cultivars is the best method to control Phytophthora root rot. Choose a resistant cultivar that contains a gene that controls races 3 and 4. Because these two races (3 and 4) were found to be the most prevalent races in the last survey. The resistance genes *Rps1k* and *Rps6* are commonly available genes and will manage both races. We recommend you rotate these genes in a field (alternate *Rps6* and *Rps1k* in rotation) to avoid the potential increase in races that could overcome one or both genes. Races that can overcome both *Rps1k* and *Rps6* genes are known to exist in our region, and as more acreage is exposed to those genes, other races

will become more common. If a resistant cultivar is dying due to Phytophthora root rot, switch to a cultivar with a different gene the next time soybean is planted in that field.

Some cultivars are reported to have tolerance to Phytophthora root rot. This type of resistance can be effective against all races. These cultivars may not lose yield under low to moderate disease pressure but can be damaged severely under high disease pressure. Crop rotation is not an effective method to reduce disease because the oospores are very long-lived in soil. Metalaxyl and mefenoxam seed treatments will protect seedlings but not older plants.

Rhizoctonia Dampingoff and Root Rot

The fungus *Rhizoctonia solani* causes pre and postemergence dampingoff and root rot of young and adult plants. When soil populations of Rhizoctonia are high, pre and postemergence dampingoff can reduce stands by 50 percent or greater. Generally, Rhizoctonia on soybean is a seedling disease, but damage has been observed on older plants. The pathogen survives in the soil and is common in this region.

Symptoms

They consist of seed decay and brown to reddish lesions on seedling stems and roots just below the soil line. These lesions may girdle stems and kill the plant. On older plants, the pathogen causes a reddish-brown cortical root rot that may extend into the base of the

stem. Plants may appear unthrifty or, less commonly, will die. Root rot can reduce nodulation greatly.

Damage from *Rhizoctonia solani* is observed commonly in areas with a long history of soybean production with close rotations or during weather conditions not favorable for seed germination and rapid growth of seedlings. *R. solani* has various anastomosis groups (AG). AG4 and AG5 are most common on soybean, but AG22 and AG3 are found occasionally. AG3, generally found on potato, is weakly pathogenic on soybean, but AG22 can be highly pathogenic, especially at high temperatures. AG4 and AG22 are common on sugarbeet. Because *R. solani* has a wide host range that includes many crops grown in this region, crop rotation practices may affect the severity of the disease. Disease severity appears greater in plants showing iron chlorosis.

Management

Crop rotation to nonsusceptible hosts such as small grains will reduce populations of *Rhizoctonia* in the soil. Avoid close rotations with sugarbeet if you see evidence of *Rhizoctonia* in the field. Close rotations with dry beans also may increase incidence of disease. Protective seed treatments and good seedbed preparation can reduce dampingoff. Cultivating soil to hill up around stems promotes lateral root growth and may lessen the effect of root rot on older plants.

Fusarium Root Rot

Fusarium root rot caused by *Fusarium solani* and other *Fusarium* species can cause dampingoff of seedlings and root rot on older plants. Infected seedlings can result in poor stands, late emergence or stunted plants. Infected seedling roots will show reddish or dark-brown discoloration and decay. The disease at this stage may be misdiagnosed as Rhizoctonia because symptoms are similar.

Symptoms

On older plants, symptoms consist of reddish-brown lesions on lateral roots and the tap root. In advanced stages of disease, the cortex decays, the roots are black and fissures develop in the dead surface tissues of the tap root. A few nitrogen-fixing nodules may be on the roots. Plants may appear stunted or unthrifty, and you may see a yellowing of the leaves with the veins remaining green for a short time. The leaves eventually become completely yellow, then die from the edges inward and fall from the petioles.

Fusarium root rot often has been observed in association with stressed plants, such as in drought conditions or with herbicide damage. High populations of the pathogen in the soil, however, may result in disease development under good growing conditions. The pathogen may interact with other pathogens, such as *Rhizoctonia* or the soybean cyst nematode, to cause disease. Disease severity may be greater in plants showing iron chlorosis.

Management

Crop rotation will lower populations of the pathogen in the soil. When you see evidence of this disease, avoid dry beans in close rotations because the pathogen can infect dry beans. Most cultivars appear to be susceptible to Fusarium root rot. Fungicide seed treatments can reduce dampingoff by *F. solani*. Damage to seedlings often occurs during weather conditions not conducive to rapid seed germination and plant emergence. Ridging soil around the base of the plants can promote root growth and reduce damage to root rot in older plants. Use high-quality seed; plant in warm, well-drained soils; reduce soil compaction; and provide good fertility.

Sudden Death Syndrome

Sudden death syndrome (SDS) has not been reported in North Dakota or northern Minnesota but may appear in the near future. The disease is caused by *Fusarium virguliforme*. Yield losses from SDS can be severe when symptoms occur early during flowering.

Symptoms

Indications of SDS generally begin on the leaves at or just after flowering. Symptoms at first are scattered circular to irregular-shaped interveinal yellow spots that produce a mottled appearance to the leaves. Eventually the yellow tissue dies and turns brown, and green tissue remains only along the major leaf veins. The upper leaves are the first to defoliate;

complete defoliation can occur when the disease is severe. Flower and pod abortion can occur. Plants showing severe leaf symptoms also will have extensive decay of roots and plants are pulled easily from the soil. The disease usually first appears in patches in fields and expands in subsequent years. Disease development is associated with wet, cool conditions early in the growth of soybean plants and warmer temperatures and heavy rainfalls during and after flowering. Foliar symptoms of SDS can be similar to those caused by brown stem rot.

Management

Cultivar susceptibility to SDS varies, but highly resistant cultivars adapted for North Dakota and northern Minnesota have not been identified yet. If the soybean cyst nematode is present in fields with SDS, control of the nematode will help reduce SDS severity. Some evidence indicates that some crop rotation will reduce populations of the SDS fungus in the soil. Dry bean are a host of the SDS pathogen. Because SDS develops when the soil has excess water content, practices that encourage drainage (including subsurface drainage) will help minimize disease development. Reducing soil compaction can reduce the severity of SDS.

Above-ground Diseases

Many disease threats of soybean, including stem and foliar diseases, exist above ground. A survey of more than 120 fields in 2008 and 2009 identified the most common and/or economically problematic above-ground diseases in North Dakota.

The disease survey was conducted between R3 and R5, so diseases with symptoms that appear later in the season (such as White Mold and Brown Stem Rot) are underestimated significantly. Numerous diseases were identified in both years but disease severity was generally low.

Frequency of fields in North Dakota with diseases between R3 and R5 soybean growth stages in 151 and 121 fields scouted in 2008 and 2009, respectively.

Disease	2008	2009
	—— Percent ——	
Bacterial Blight	100	73
Downy Mildew	23	31
Septoria Brown Spot	54	29
Charcoal Rot	1	9
Stem Canker	1	7
White Mold	2	3
Alternaria Leaf Spot	24	2
Anthracnose	1	1
Powdery Mildew	1	1
Brown Stem Rot	1	1

White Mold (Sclerotinia stem rot)

White mold of soybean is a common disease caused by the fungus *Sclerotinia sclerotiorum*. It can cause seed yield reductions, particularly when soybean is planted in infested soil and you have a dense plant canopy with prolonged periods of wet weather (a major factor in disease development). The disease is observed rarely when dry periods persist in July and August. Besides seed yield reductions, the disease results in reduced seed quality and seed contaminated with the black sclerotia of the fungus. *Sclerotinia* overwinters as sclerotia in soil. The sclerotia germinate to form small mushrooms called apothecia that produce spores termed ascospores. The ascospores utilize senescing flower tissue as a food base and then infect the stems of the plant; the disease is closely tied to flowering.

Symptoms

They usually are observed after the canopy has closed. Dead plants are generally the first symptom observed. An inspection under the canopy will reveal a cottony, white mycelial (fungus threads) growth on stems, leaves or pods. Lesions develop on main stems and side branches. Stems appear bleached and sometimes shredded from advanced decay. Dark sclerotia form in and on diseased tissue. Seeds in diseased pods usually are shriveled and may be infected by the fungus or replaced by sclerotia. When a field with white mold is harvested, the seed almost always is contaminated

with sclerotia. Yield losses usually occur when incidence of disease is 15 percent or greater. In North Dakota, estimated yield loss per 10 percent disease incidence ranges from 1 to 3.4 bushels per acre.

The pathogen has an extensive host range of more than 370 plant species and causes diseases on a wide variety of crops, such as sunflower, dry bean, canola, alfalfa, buckwheat, lupine, mustard, potatoes, Jerusalem artichoke, safflower, lentil, flax, field pea and many vegetables. It also has many common broadleaf weed hosts, such as marsh elder, lambs-quarters, pigweed, Canada thistle and wild mustard.

Management

The most important controls for white mold of soybean are to choose less susceptible cultivars, avoid planting on soils heavily infested with *Sclerotinia* and maintain open rows so air movement through the crop reduces plant wetness. Cultural practices, such as reduced seeding rate and wider row spacing, that reduce environmental conditions favoring disease are helpful. Orienting the rows toward the prevailing wind, for example, may help dry the crop following precipitation. Under very prolonged rainy periods or in protected areas such as along shelterbelts where humidity is higher, disease may develop even in an open canopy. Fungicide applications have been shown to reduce disease in trials.

Soybean fields should be monitored for disease incidence. Check the seed hopper at harvest for the

presence of sclerotia. As disease begins to increase in a field, the rotation time to nonsusceptible crops, such as small grains and corn, should be increased. Crop rotation will reduce populations of sclerotia in soil but will not eliminate the pathogen entirely. We recommend you not plant susceptible crops, such as dry edible bean and sunflower, during the rotation. If you rent land, find out the disease and cropping history before making planting decisions.

Although common soybean cultivars adapted for this region are susceptible to white mold, some cultivars are less susceptible than others. Information on cultivar susceptibility may be available from the NDSU Extension Service and seed companies. Do not use seed from a white mold-infected crop. Seed quality could be low, and sclerotia may be introduced into the field along with the seed. Also, maintain good control of broadleaf weeds because they can be hosts of Sclerotinia and can make the microclimate more favorable for white mold. When growing a susceptible crop under irrigation, avoid practices that favor a dense canopy and free water on the plant during flowering because these will create ideal conditions for disease development.

If fungicides are labeled for management of sclerotinia in the future, the most important aspects of management will be timing and penetration deep into the canopy. Applications must be made preventatively, preferably at the onset of bloom (R1).

Septoria Brown Spot

Septoria brown spot, caused by *Septoria glycines*, is a common leaf disease that may develop throughout the season.

Symptoms

This disease is noticed first as pinpoint brown spots that develop on the leaves on the lower parts of the plants. These spots may remain small or enlarge up to 3/16 inch, becoming irregular and angular in shape and reddish brown to dark brown with age. Severely diseased leaves turn yellow and fall off, with defoliation beginning on the lower leaves and progressing up the plant. Brown, irregularly shaped spots may develop on the stems, petioles and pods. Yield losses of 8 to 15 percent have been reported in other states.

Septoria brown spot develops in warm, humid weather. Hot, dry conditions will arrest disease development, but it may resume if conditions improve. Rainy weather is especially favorable since *Septoria* spreads by splashdispersed spores. Disease development also occurs in areas with poor drainage. The brown spot fungus survives on soybean crop refuse and may be seed-borne.

Management

How frequently economic loss occurs in North Dakota and Minnesota is unclear, but in most of the Midwest, little evidence is available to suggest that Septoria brown spot causes yield loss except under the most extreme circumstances. Given this,

active management of this disease in most years is unnecessary, and management techniques utilized for other diseases (for example, crop rotation) likely are sufficient. Fungicides are available, but disease pressure warranting their use in our area is unlikely. Additionally, bacterial blight is much more common than brown spot (especially in the early part of the season), and the symptoms of both pathogens can be confused. Correct identification of the pathogen is essential.

Bacterial Blight

Bacterial blight was the most commonly found disease in the 2008-09 disease survey. How frequently economic loss occurs from bacterial blight is unclear. Bacterial blight (caused by *Pseudomonas syringae* pv. g*lycinea)* develops in cool, humid weather. The bacteria blight pathogen can be seed-borne and also can survive on soybean crop residue. Bacteria readily enter wounds in the leaf, and rapid spread may occur following late spring or early summer rain storms, hail or cultivation when the plants are wet.

Symptoms

The blight begins as small, greasy, green, angular, watersoaked spots; later they turn yellow and then reddish brown. The spots are surrounded by a narrow yellow border. As the spots coalesce, portions of the leaf tissue fall out, and the leaves become torn and ragged. Infected young leaves may be distorted and stunted. Severely diseased leaves may drop off.

Occasionally, large black spots may develop on stems, petioles and pods. Seeds in infected pods may become slimy. Hot, dry weather will stop the development of bacterial blight.

Management

Do not use seed from a diseased field. Use crop rotation and bury soybean crop residue with tillage. Do not cultivate when the plants are wet. Some cultivars are less susceptible. Because bacterial blight is caused by a *bacterial* pathogen, fungicides are not useful for control.

Downy Mildew

Downy mildew, caused by *Peronospora manshurica,* develops primarily in years with extended periods of cool, humid weather.

Symptoms

They include yellowgreen to yellow spots on the upper leaf surface and a purplish or grayish downy fungal growth on the lower leaf surface opposite the yellowgreen patches on the upper leaf surface. The yellow spots turn brown later in the season. Pod infection may result in seeds that are dull white, cracked or covered with a white crust of overwintering oospores. If these white or encrusted seeds are planted, a small percentage of the emerging seedlings may be infected systemically with the downy mildew fungus, resulting in stunted plants. Leaves of systemically infected plants will have areas of greenyellow tissues along the main veins and the

leaf edges will be curled downward. Downy mildew may cause losses up to 10 to 13 percent.

Management
Use crop rotation and bury infected crop residue by tillage. Use a seed treatment if planting seed from an infected field or the seed has a white crust on it.

Pod and Stem Blight

This disease, caused by *Diaporthe* and *Phomopsis* fungal spp., is common in southern Minnesota but less so in North Dakota and northwestern Minnesota.

Symptoms
They include rows of raised black fruiting bodies that develop on the stem and a random pattern of raised fruiting bodies that develop on the pods. Infected stems often are killed. Infected seeds are shriveled and cracked and may be covered with white fungal growth.

The pod and stem blight fungus survives on infected soybean crop refuse and can be seed-borne. It develops in wet weather and results in crop injury as the crop nears maturity. If infected seeds are planted, plants may die on emergence.

Management
Use crop rotation. Also use tillage to bury infected soybean crop residues. Plant high-quality seed that is nearly free of the pod and stem blight pathogen or use a seed treatment. Harvest promptly at maturity. Maintain adequate potash levels.

Stem Canker

Stem canker is relatively common in southern Minnesota and in South Dakota, but how frequently it occurs in North Dakota and northwestern Minnesota is unclear. Stem canker is caused by two different but related pathogens, each causing a distinct disease: *Diaporthe phaseolorum* var. *caulivora (Northern Stem Canker) and Diaporthe phaseolorum* var. *merdionalis (Southern Stem Canker).*

Symptoms

Early symptoms of stem canker are reddish-brown lesions that appear at the base of the leaf petiole or branches. Lesions may develop into sunken dark-brown cankers with small black raised structures on the surface (perithecia). Plant parts above the lesion may die. Stem canker develops in wet weather, and symptoms most likely may be observed beginning in mid-July following wet springs.

Management

Resistant varieties, tillage, foliar fungicides and crop rotation may be useful to mitigate stem canker where it has been a problem.

Brown Stem Rot

The brown stem rot fungus *Phialophora gregata* was confirmed in North Dakota in 2008. Infection occurs through the roots and develops slowly until pods are filling.

Symptoms

Symptoms usually do not appear until late in the season. The most reliable symptoms develop inside the lower stem. When the stem is split open with a knife, the pith (central tissues) is brown. The internal browning may extend several inches or more above the soil line. Leaf symptoms, which develop sporadically or may not occur, consist of a yellowing followed by browning of tissues between the main veins. The veins remain green. Foliar symptoms can be similar to those caused by sudden death syndrome. The best time to assess for brown stem rot is the R5 to R6 stage, when seeds are beginning to develop in pods at the four uppermost nodes. Any time that a field suddenly turns brown, rather than yellow green, late in the season, the lower stems should be split and examined for brown stem rot.

The brown stem rot fungus survives several years in soybean crop residue. The disease develops during cool or moderate temperatures. The greatest damage occurs when cool and wet weather occurs during the early reproductive stage and is followed by hot and dry weather.

Management

At the time of this printing, resistant varieties with suitable maturity for North Dakota are unavailable. Use crop rotation, planting nonhost crops for three years. Small grains and corn are not hosts. Burying soybean crop residue to hasten its decomposition may reduce brown stem rot.

Charcoal Rot

Charcoal rot is a relatively rare but problematic disease in North Dakota and northwestern Minnesota. Charcoal rot is caused by the fungal pathogen *Macrophomina phaseolina*. The pathogen has a very large host range, which includes corn and sunflower. Yield losses are most likely when plants are under water stress midway to late in the season. Hence, drought, high temperatures and sandy soils lead to the development of charcoal rot. In Iowa in 2003, incidence of charcoal rot ranged from 20 to 90 percent of all surveyed fields and high yield loss was suspected in some fields. This epidemic was correlated to the driest August on record in the state. Charcoal rot often is observed first as a general loss of vigor in maturing soybean plants.

Symptoms

They include a light gray to silver discoloration at the base of the stem. If the epidemis is scraped off at the base of the stem, a fine black line (similar to a marker drawing) containing microsclerotia may be observed. The pathogen survives as microsclerotia.

Management

Crop rotation and planting nonhost crops are important management tools. If irrigating, keep soil water content reasonably high at the end of the season. Encouragement of early canopy closure by increasing planting density may reduce risk of charcoal rot but also may increase risk of other diseases.

Soybean Rust

The pathogen causing soybean rust (*Phakopsora pachyrhizi*) was detected first in the southern United States in the fall of 2004 and is the most significant foliar disease threat to U.S. soybean production. However, at the time of printing, the disease has not reached North Dakota or Minnesota. The annual risk of soybean rust in North Dakota and Minnesota is thought to be low.

The pathogen causing soybean rust has a relatively broad host range, of which the two most important alternative hosts are kudzu and dry edible bean. The soybean rust pathogen cannot survive freezing winter temperatures, so it overwinters in the Gulf Coast states and Mexico, surviving primarily on kudzu. The urediniospores produced by the pathogen are dispersed easily by wind and will cause infection readily on nearby soybean plants.

Conditions optimal for infection include moderately warm temperatures (60 to 75 F) and six hours of free moisture, which includes rain and/or dew, on leaves. Spores can be damaged by sunlight, so overcast skies are critical for pathogen spread, survival and infection. Under optimal conditions, soybean rust can spread rapidly, and in late 2007 infection, it was found as far north as northern Iowa.

For soybean rust to reach North Dakota and northern Minnesota, several events must occur. First, the pathogen must overwinter in Texas and/or Louisiana. Second, conditions must be favorable near

the overwintering site so ample spores are produced. Third, spores must be picked up by wind currents and blown north while skies are overcast. Lastly, the conditions where the spores are deposited must be favorable for infection to take place. Infection possibly could spread from the overwintering site to our region in one storm, but more likely, successive storm and infection events would be needed to bring the pathogen north in a stepwise progression (up to Oklahoma, then to Nebraska and finally to North Dakota or northern Minnesota).

Symptoms

The first symptoms of soybean rust begin as very small brick-red to brown spots on the upper leaf. The spots are very small (less than a leaf hair) and are observed more readily by holding the leaf up to the bright sky. On the underside of the leaf, opposite the brown spots, pustules will form. Pustules resemble miniature volcanoes, with spore masses erupting through the leaf tissue. Seeing these without a hand-held lens or magnifying glass with at least 20x in power is very difficult. The best way to observe the pustules is to roll the leaf around a finger and look through the hand-held lens at an angle perpendicular to the leaf. When pustules become numerous, the leaves will drop prematurely.

Warning

Soybean rust resembles many other soybean diseases, including bacterial pustule, brown spot, bacterial

blight and downy mildew. Accurate confirmation of soybean rust is critical before any management action can be considered.

Management

Rust-resistant varieties will be available in the future, but they likely will not be available in our maturity groups for many years. Rotation and tillage will have no bearing on soybean rust in North Dakota and Minnesota.

Early detection combined with fungicide applications, if necessary, can result in excellent management of soybean rust. Pathologists in southern states routinely scout for soybean rust and post the information online at www.sbrusa.net. Being the most northern soybean-growing region in the country, we benefit by watching the progression of soybean rust to our south. When rust is suspected and weather conditions are favorable for infection and spread, fungicide applications can mitigate potential damage.

Fungicides are most effective at the early stages of an epidemic, and by the time rust is detected *easily*, economic loss may be unavoidable. Data indicate that fungicides applied before R1 and after R6 are unlikely to be economically feasible. For information about specific chemicals and/or timing, consult www.sbrusa.net and the latest version of the "North Dakota Field Crop Fungicide Guide," NDSU Extension Service publication PP-622.

Virus Diseases

Virus diseases have not been a serious problem in this area, but in soybean-producing areas to the south, viruses have become a problem in recent years. The recent introduction of the soybean aphid into this area may result in virus problems because aphids are virus victors. The two most common viruses that have been found in North Dakota and Minnesota are soybean mosaic virus (SMV) and bean pod mottle virus (BPMV). Numerous other viruses can be found in soybean but they have not been detected yet in this northern growing area. Identification of a virus disease requires special techniques. Identifying a virus based on symptoms is very difficult.

Symptoms

Virus symptoms vary greatly but may consist of stunting, fewer pods, leaf mosaic (light and dark green areas), puckering, blistering, distortion, chlorosis or necrosis. Plants can be infected without showing symptoms. Seed mottling can occur, which is detrimental to the quality of food beans.

The severity of the disease and the effect on yield are affected greatly by the plant stage at infection, the environmental conditions and the susceptibility of the cultivar. Yield losses can be substantial under heavy disease pressure. Seed can transmit SMV, and the virus is vectored by aphids (*Aphis glycines*). The vector of BPMV is the bean leaf beetle (*Cerotoma trifurcata*).

Seed Treatment of Soybean

Soybean seeds may be treated with fungicides to improve stand, protect against seedling infection by some pathogens and reduce the spread of diseases that may be carried on or in the seeds. The use of seed treatments may not be necessary if healthy seed is planted under conditions favoring rapid emergence.

When planting into less than ideal conditions, such as cool, poorly drained or notill/reduced-tillage soil, seed treatments sometimes can provide a more uniform stand but often not a yield advantage. Seed treatments containing mefenoxam or metalaxyl are effective against downy mildew and seedling infection by *Phytophthora* and *Pythium*.

However, seasonlong management of *Phytophthora* can be obtained only through the use of resistant varieties. Products that contain carboxin, PCNB, fludioxonil or strobilurins may provide some protection for seeds and seedlings against *Rhizoctonia*. Biological seed treatments that contain spores of the bacteria *Bacillus subtilis* are labeled for suppression of *Fusarium* and *Rhizoctonia* infection. New seed treatment products frequently are being developed and sold. Many resources are available for more information on seed treatment products currently available. Please consult the latest version of the "North Dakota Field Crop Fungicide Guide," NDSU Extension Service publication PP-622, or other reliable sources for product information. Also consult and follow the product label when using any product.

White mold (Sclerotinia stem rot) may be spread through infected seed. Fludioxonil, thiram and captan + PCNB + TBZ have been shown to reduce disease spread by seeds. Avoiding "binrun" seed and planting certified diseasefree seed is most important in managing the spread of white mold through seeds.

Seed Treatment Fungicides and *Bradyrhizobium japonicum* Inoculants

Some seed-treatment fungicides have an adverse effect on *Bradyrhizobium* inoculants. Captan and PCNB severely reduce survival of bacteria on treated seed and reduce nodulation compared with inoculated seed without these fungicides. Therefore, if captan- or PCNB-treated seed is to be planted, using an infurrow inoculant might be best. Carboxin has a moderate effect on *Rhizobium* and could be used if the seed is inoculated immediately before planting. Mefenoxam and metalaxyl have little or no adverse effect on *Rhizobium,* and thiram has no adverse effect.

No-tillage or Minimum-tillage Soybean Production

Minimum or no-till production practices may create an environment favorable for pathogens to damage soybean seeds or young seedlings. The cool, moist soil conditions created by these practices can delay germination, decrease seedling vigor and slow seedling emergence. This is especially true during cool, wet springs and when soybean is planted early. In the first 14 days following planting, soybean plants are susceptible to stress from a variety of factors, such as high or low soil water content and temperatures, crusted soils, compaction, deep planting and reduced seed quality. Pathogens that become active and damage soybean plants in the seedling stages include *Rhizoctonia*, *Fusarium*, *Phytophthora*, *Pythium* and some of the seed-borne fungi. Seed treatments with a broad-spectrum fungicide will protect the crop during the critical seed germination and emergence period.