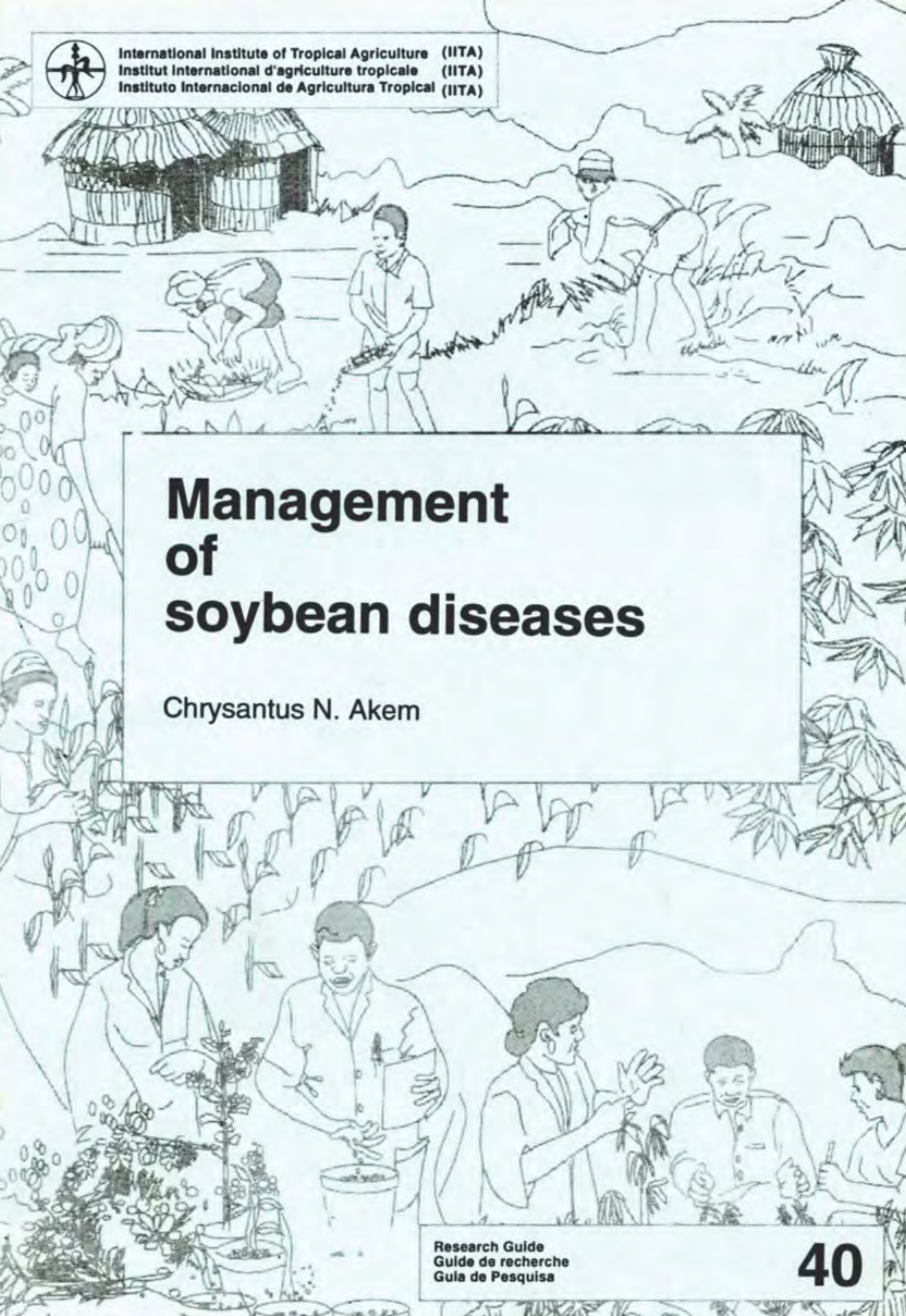

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# Management of soybean diseases

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Research Guide
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Guia de Pesquisa

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IITA Research Guide 40

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# Management of soybean diseases

**Objectives.** This guide is intended to enable you to:

- discuss the importance of soybean disease;
- specify principles of disease management;
- protect soybean crops from diseases;
- describe importance, symptoms, disease cycle, and epidemiology of viral, bacterial, fungal diseases;
- identify disease-causing nematodes;
- control soybean diseases.

## Study materials

- Statistics on importance of diseases.
- Infected and infested plant samples.
- Color slides of disease symptoms.
- Growth media.
- Microscopes.

## Practicals

- Identify diseases in the field.
- Practice and discuss control methods.
- Isolate diseases on growth media.
- Prepare microscopic slides from isolates.
- Demonstrate control methods.

## Questions

1. Where and when did domestication of soybean begin?
2. How many pathogens are of economic importance in soybean?
3. On what factors does severity of soybean diseases depend?
4. To what extent do soybean diseases reduce yield in most production areas?
5. On what principles is a comprehensive disease management program based?
6. On what factors does the choice of a particular control strategy depend?
7. What two possibilities does exclusion include?
8. What are the important soybean diseases whose spread can be limited by exclusion?
9. What methods does eradication involve?
10. What techniques does protection include?
11. Why is race-specific resistance often little effective?
12. Describe integrated pest management.
13. Where is chemical seed treatment **not** needed?
14. What pathogens can you control with soil-applied fungicides?
15. Why should you restrict the use of nematicides?
16. What commercial products are available for biological control of soybean diseases?
17. Why is water management particularly critical for root diseases?
18. What is the importance of soybean mosaic virus?
19. Describe the disease cycle of bacterial blight.
20. Where has bacterial pustule been reported?
21. What is the distribution of frogeye leaf spot?
22. What is the importance of root-knot nematodes?

# Management of soybean diseases



**Abstract.** More than 100 pathogens attack soybean, but only a third of them are of economic importance. Yield reduction varies between 10 % and 30 %. Soybean diseases are caused by viruses, bacteria, fungi, and nematodes. Disease management is based on several control principles that should be combined preferably in an integrated pest management approach.

# 1 Importance of soybean diseases

Domestication of the soybean *(Glycine max* (L.) Merrill) began in China around 1700-1100 B.C. For years, the people of East Asia have depended on soybean for food, animal feed, and medicine. Soybean reached North America in 1765 via London, and Africa through missionaries in the early 19th century.

As the growing area for soybean production expanded throughout the world, soybean diseases increased in number and severity. In 1988, world loss of soybean to diseases was estimated at about 10.5 million tons.

More than 100 pathogens attack soybean, but only a third of them are of economic importance. The extent of yield loss depends on the pathogen, climatic conditions, stage of plant development, severity on individual plants, and number of plants infected.

Many pathogens initiate disease only under specific environmental conditions. The severity of soybean diseases depends on the degree of compatibility between the host and the pathogen, and the influence of the environment on the association.

Nematodes and insects cause wounds on soybean plants while feeding. Wounds provide entry points for pathogens, thus the plant becomes susceptible to root-infecting, wilt-inducing, and seed-decaying organisms.

The epidemiology of most soybean diseases in tropical Africa is poorly understood. More research is needed.

Several pathogen races are suspected. Research is needed to identify the different races so as to breed resistance.

## 2 Principles of disease management

Soybean diseases reduce yields by 10-30 % in most production areas. Losses are often caused by the collective effect of several diseases, rather than by individual diseases. Losses can be reduced by the implementation of a comprehensive disease management program based on the following principles:

- exclusion,
- eradication,
- protection,
- resistance,
- integrated pest management.

The choice of a particular control method depends on an assessment of disease loss potential, cost and benefits, and the long-term environmental impact.

**Exclusion.** Exclusion includes legislation and use of disease-free seed.

Exclusion is useful in an environment presently free of a pathogen and where the pathogen cannot survive between crops. Legislative embargoes, quarantine, or inspection of seeds prevent introduction of plant pathogens and pests into new areas.

Important soybean diseases whose spread can be limited by exclusion include:

- rust,
- bacterial blight,
- frogeye leaf spot,
- soybean cyst nematode,
- anthracnose,
- seedborne viruses.

**Eradication.** Eradication is total elimination of the inoculum. Although this is rarely achieved in practice, reduction of pathogen population densities below economic levels is often possible. Two methods of eradication are *crop rotation* and *tillage*.

*Crop rotation* is a powerful tool for the management of soybean diseases, particularly if it involves members of the grass family, such as maize, sorghum, and wheat. Rotation with resistant cultivars can also be effective in controlling soybean cyst nematode, and rotation with grain sorghum reduces the severity of charcoal rot. When these crops are rotated with soybeans for more than one season, soybean pathogens die out, or their inoculum levels are sharply reduced.

*Tillage* destroys crop residue, and is an effective means of reducing over-seasoning of most foliage- and stem-infecting bacteria and fungi. The majority of these pathogens survive on infested residue. When the residue decays, the pathogens die.

**Protection.** Protection techniques include the use of pesticides and cultural control for disease management. Pesticides include seed treatment, fungicides applied to foliage and nematicides. Cultural control includes maintaining optimum availability of plant nutrients and soil pH, avoiding excess or deficit of water, planting high quality seed, controlling weeds, obtaining optimum soybean population, and harvesting and threshing at maturity. See next section.

**Resistance.** The use of resistant cultivars is the most economical and efficient method of disease control if their yield is better than the yield of local varieties. If yield is lower, resistant cultivars can be used in rotation to reduce the inoculum level. Race-specific resistance is often less effective against soybean cyst nematode, rust and frogeye leaf spot, because numerous races of the pathogens exist. It is therefore important to know the predominant races of pathogens.

**Integrated pest management.** Management of soybean diseases and pests cannot be accomplished in the long term by only one control method. Integrated pest management combines the use of host plant resistance, seed treatment, chemical sprays, and cultural practices within the context of agronomic practices and economic considerations.

Integrated pest management utilizes economic injury levels, economic thresholds, monitoring, record keeping, and pest mapping in a planned approach to crop management that is compatible with local situations.

**Seed treatment.** Chemical seed treatment is not needed where high quality seed is planted at an appropriate seeding rate.

Where seed quality is low because of mechanical damage or physiological factors, chemical seed treatment is useful. Seed treatment is also useful when seed quality is low due to fungal infection, when low seeding rate is used, or when germination is delayed. Seed treatment can effectively reduce losses from seedborne *Pythium* sp. and *Rhizoctonia solani*. Seed treatment is available as dust, liquid, and wettable powder.

**Fungicides.** In general, fungicides applied at growth stages R2 through R5 enhance optimum yield and seed quality by reducing fungal infections. Predictive systems for fungicide use are based on field monitoring, weather data, and planting date. Both systemic and protective fungicides can be used.

Foliage-applied fungicides are commonly used to control diseases such as anthracnose, Cercospora leaf spot, Septoria brown spot and pod and stem blight, which prevail during growth stages R1 through R5. These diseases reduce yield and cause serious seed quality problems.

Systemic fungicides perform better than protective fungicides. Correct application with minimal drift losses and thorough canopy penetration is important for the success of any spray program on soybeans. Both foliage and ground application can be employed. Foliage application is more practical. Soil-applied fungicides are effective for controlling soilborne pathogens, such as Pythium root rot and Rhizoctonia root rot.

**Nematicides.** Nematicides control soybean cyst nematode, root-knot nematode, and other nematode pests of soybean. For economic and environmental reasons, they should be used only when resistant cultivars are not available, or cultural methods such as rotation are ineffective.

**Biological control.** Biocontrol agents applied to the seed or soil are presently the focus of research in many parts of the world. Parasitic soil fungi reduce nematode populations. Presently, no commercial products are available for biological control of soybean diseases.

**Cultural control.** Cultural practices, such as adequate fertilizer application, proper soil pH, adequate water supply, weed control, appropriate plant density, and high quality seed, are effective in reducing damage from many diseases.

Healthy, vigorous plants suffer less from diseases than plants under stress. Water management is particularly critical for root diseases. Saturated soils create favorable conditions for infection by *Pythium* and *Phytophthora*. Water deficit contributes to losses caused by nematodes and charcoal rot.

Optimum soil pH (6.2-7.0) is important for root nodulation. Acid soils increase the damage caused by Sclerotium blight.

Optimum soil fertility, particularly adequate potash and phosphorus nutrition, is important in the management of bacterial blight, bacterial pustule, charcoal rot, Fusarium blight, and soybean cyst nematode. Excessive seeding rates and high plant densities contribute to increased damage from charcoal rot, Sclerotium blight, Rhizoctonia, and Pythium blights. Seeding rates should be adjusted for soil fertility, soil moisture, seed quality, cultural factors, and varietal growth habit.

Other cultural control methods include:

- proper soil cultivation;
- timely weed control (weeds can serve as disease hosts);
- correct choice of herbicide (some herbicides increase disease severity);
- correct row spacing (narrow rows increase disease severity of pathogens);
- consideration of crop growth habit;
- good seedbed conditions;
- correct planting date.

**Soybean mosaic virus** (SMV). SMV is also known as soybean crinkle virus.

Importance. SMV is distributed worldwide and was first reported in the United States in the early 1900s, probably from soybeans from Asia. It can reduce yields by 50 %.

Symptoms. SMV can be seedborne. Infected soybean seedlings are spindly, with crinkled unifoliolate leaves. Plants infected early in the season are stunted, with shortened petioles and internodes. Leaves are reduced in size and generally misshapen and puckered. The youngest and most rapidly growing leaves show the most severe symptoms. SMV can infect several other host species in the *Fabaceae*. It induces systemic symptoms in soybeans.

Disease cycle. SMV is readily sap-transmitted with or without the use of abrasives. The virus is graft-transmissible. A percentage of seeds from infected plants carry the virus, which may remain viable in seeds for at least two years. At least 30 aphid species transmit the virus in a non-persistent manner.

The viruses must multiply in infected cells for translocation and systemic infection to take place. SMV moves up and down in plants and can be detected in all parts of systematically infected plants.

Control:

- use high-quality, virus-free seed;
- eliminate virus-infected plants in the field by rouging;
- use SMV resistant varieties.

**Bacterial blight.** Causal agent: *Pseudomonas syringae* pv. *glycines* (Coerper). Colonies in nutrient agar are white and raised. Optimum temperature for growth is 24-26 °C. The pathogen produces toxins in culture that can result in some symptoms.

Importance. Bacterial blight occurs worldwide. It is the most common bacterial disease of soybean, especially during cool wet weather, and most conspicuous in fields during midseason. Bacteria remain active until checked by hot, dry weather. Bacterial blight is sometimes found in combination with bacterial pustule.

Symptoms. Lesions are conspicuous on leaves but also occur on stems, petioles, and pods. Small, angular, translucent, water-soaked, yellow to light brown spots appear on leaves. Centers dry out and turn dark (reddish brown to black). Older lesions frequently drop out or tear away, giving the leaves a ragged appearance, especially after strong winds and rains. Early defoliation of lower leaves may occur. Seeds become infected and may eventually be covered with a slimy, bacterial growth.

Disease cycle. The pathogen overseasons in surface crop residue and in seeds. Seed infection can occur through pods during the growing season, or through invasion during harvesting. The bacteria spreads during windy rainstorms and during cultivation when foliage is wet. It enters the plant through the stomata and multiplies in intercellular spaces of the mesophyll. Cool rainy weather favors the development of bacterial blight. The disease is seldom devastating to the crop.

Control:

- avoid planting highly susceptible cultivars in areas where the disease is a problem;
- plant pathogen-free seed;
- rotate soybean with crops that are not susceptible to the pathogen, such as maize and sorghum;
- after harvest, bury plant residue completely by plowing the field clean;
- do not cultivate when foliage is wet;
- use resistant varieties.

**Bacterial pustule.** Causal agent: *Xanthomonas campestris* pv. *glycines* (Nakano) Dye. Colonies are pale yellow on nutrient agar, small, circular, and smooth, with an entire margin. Optimum temperature for growth is 30-33 $^{o}$C.

Importance. Bacterial pustule has been reported for most of the soybean-growing areas of the world where warm temperatures and frequent rains prevail during the growing season. Premature defoliation caused by the bacteria results in yield losses. Severe defoliation has been observed in soybean fields in Nigeria.

Symptoms. Early symptoms are minute pale green spots with elevated centers on either or both leaf surfaces. Later, a small, raised, light colored pustule forms in the center, usually in lesions on the underleaf surface. Leaves become ragged when dead areas are torn away by wind. Severe infection often results in some defoliation.

Leaf spots sometimes form without developing pustules. Symptoms of bacterial pustule may resemble those of bacterial blight. However, pustule lesions are not water soaked in the early stages, and usually have minute, raised pustules in the center.

Disease cycle. The bacteria overseason in soybean seed, and in surface crop debris. Some weeds are also alternate hosts. Some strains of *X. campestris* infect beans and cowpea. The bacteria spread via splashing water or windblown rain, and during cultivation when foliage is wet. Bacteria enter the plant through natural openings and wounds. Unlike bacterial blight, bacteria pustule is not checked by high temperatures.

New infections may occur throughout the growing season whenever wet or rainy conditions prevail. The disease can be severe in the tropics.

Control:

- use resistant varieties,
- follow other measures suggested for bacterial blight.

**Frogeye leaf spot.** Frogeye leaf spot is also called Cercospora leaf spot. Causal agent: *Cercospora sojina* K. Hara. *Cercospora sojina* is a highly variable pathogen. Isolates sporulate poorly on most media; best on V-8 juice agar or lima bean agar. Colonies develop on potato dextrose agar as compact light to dark brown mycelial mats.

Importance. Frogeye leaf spot was first reported on soybeans in 1915 in Japan, and now occurs worldwide. It is most common in warmer regions during warm, humid weather. Widespread use of resistant soybean varieties, especially in the major soybean growing regions of the world, has reduced the incidence of the disease and precluded major economic losses.

Yields from susceptible cultivars may be reduced by 20 % or more. In Nigeria, yields have been reduced by up to 50 %. Seed quality is affected by discoloration and reduced germination. In the tropics of Africa, frogeye leaf spot is a problem in Nigeria, Zaire, and Zambia.

Symptoms. Frogeye leaf spot is primarily a disease of the foliage, but stems, pods, and seeds can also be infected. Minute spots that are reddish brown (and circular to angular) first appear on the upper leaf surface. As lesions enlarge and age, the central area becomes ash-gray, surrounded by a narrow border of dark reddish brown. Several spots may coalesce to form larger, irregular spots. When lesions are numerous, leaves wither and fall prematurely.

Stem infections appear late in the season. Pod lesions are circular to elongated, slightly sunken, and red brown.

Disease cycle. *C. sojina* survives as mycelium in infected seeds and infested soybean debris. Germination of infected seeds is slightly reduced. Seeds that germinate may produce weak, stunted seedlings with lesions on the cotyledons. Sporulation on the cotyledon lesions provides inoculum for infecting young leaves. In warm, humid weather, sporulation is profuse in the resulting lesions.

Conidia are carried short distances by air currents and splashing rain. Under favorable conditions, secondary infections of leaves, stems, and pods arise. Seed discoloration is common under heavy infection.

Reactions of different cultivars to *C. sojina* vary from immunity to high susceptibility.

Control:

- grow adapted resistant varieties,
- plant high quality seed, free of the pathogen,
- rotate soybean with other crops (non hosts),
- treat seeds with a fungicide before planting,
- apply fungicides at growth stages R1-R5,
- plow under crop residue at season end.

**Red leaf blotch.** Causal agent: *Dactuliochaeta glycines* (Stewart) Hartman and Sinclair, synonymous with *Pyrenochaeta glycines* Stewart. The sclerotial state of this disease is *Dactuliophora glycines* Leakey. Isolates may differ in colony pigmentation, according to the media used. Corn meal and malt agar are commonly used.

Importance. Red leaf blotch of soybeans was first reported in 1957 in Ethiopia. It has increased with soybean production in southern Africa, particularly Zambia and Zimbabwe. The disease has also been reported in the central and eastern regions of Africa including Cameroon, Malawi, Rwanda, Uganda, Zaire.

Estimated yield losses of 7-37 % in approximately 25 % of the soybean-producing area of Zambia have been reported, along with 10-50 % yield losses in certain provinces of Zimbabwe.

Symptoms. *D. glycines* causes lesions on foliage, petioles, pods, and stems of soybeans throughout the growing season. Lesions are often associated with primary leaf veins. On fully expanded trifoliolate leaves, the lesions are dark red on the upper surface and reddish brown on the lower surface.

The lesions enlarge and coalesce to form large necrotic blotches, up to 2 cm in diameter which may become light brown with a darker center. Heavily diseased plants defoliate and senesce earlier than normal. Early senescence contributes to yield losses. Within older lesions, sclerotia develop primarily on the lower surface of leaves, and pycnidia develop primarily on the upper surface.

Disease cycle. Red leaf blotch frequently develops on soybeans planted on newly cleared land. The source of primary inoculum for such epiphytotics is not known. Primary inoculum may be conidia or sclerotia from infected plants. The disease is generally distributed uniformly throughout an affected field. The pathogen may be dispersed from field to field by sclerotia carried in contaminated soil in routine farm operations.

Control. At present, no commercial procedures have been adopted or recommended for control of red leaf blotch. Fungicides (Fentin acetate) and varietal resistance are under investigation.

**Anthracnose.** Causal agent: *Colletotrichum truncatum* (Schwein.) Andrus and W. D. Moore (synonymous with *C. glycines*. S. Hori). Anthracnose is characterized by crowded, black acervuli. The pathogen grows well on oatmeal agar and potato dextrose agar under alternating 12 hour periods of light and dark at optimum temperature of 25 °C. It produces whitish colonies that eventually turn smoky black with abundant acervuli. Isolates vary greatly in colony characteristics, size of fruiting structures, and pathogenicity.

Importance. First reported in Korea in 1917, anthracnose occurs wherever soybean is grown causing damage in warm, humid areas. The disease reduces stands, seed quality, and yields by 16-26 %, or even 100 % as reported in some cases. There are no reports of epidemics of the pathogen on soybeans in the tropics yet.

Symptoms. Soybean is susceptible to anthracnose at all stages. Symptoms typically appear in the early reproductive stages on stems, pods, and petioles as irregularly shaped brown areas. In advanced stages, usually in late reproductive stages, infected tissues are covered with black fruiting bodies (acervuli) that produce minute black spines (setae), which are visible to the naked eye.

Foliar symptoms that develop after prolonged periods of high humidity include necrosis of laminar veins, leaf rolling, petiole cankering, and premature defoliation.

Pods infected early bear no seed (pod blanking) or few shrivelled seeds. Mycelia may fill pod cavities, and seeds become moldy.

Disease cycle. *C. truncatum* and *C. glycines* can over-season as mycelium in infested crop residue or in infected seeds. Plants are susceptible to infection at all stages of development, particularly from bloom to pod fill.

Control:

- sow seeds free of the pathogen;
- treat infected seeds with a recommended fungicide;
- plow under crop residue;
- spray with appropriate fungicides when conditions favoring infection occur between bloom and pod fill;
- rotate soybeans with other crops.

**Target leaf spot.** Causal agent: *Corynespora cassiicola* (Berk and M.A. Curtis). At least two races of the fungus are known and these may belong to different species. The fungus infecting the hypocotyl, roots and stems differs pathologically and morphologically from the fungus infecting leaves, pods, and seeds. *C. cassiicola* grows and sporulates well in potato dextrose agar, Czapek, and V-8 juice agar at pH 6.5 under continuous light. Optimum temperature for growth is 18-21 $^{o}$C.

Importance. Target leaf spot was first reported in the United States in 1945 and has now been reported in Zaire, Cameroon, and Nigeria. Yield losses of 18-32 % have been recorded for very susceptible soybean lines, grown during years when rainfall is above normal in the growing season. Target leaf spot is considered potentially serious, especially in late-maturing cultivars.

Symptoms. The disease affects leaves, stems, pods, seeds, hypocotyls, and roots. Leaf lesions are round to irregular and reddish brown. They are frequently surrounded by a dull green or yellowish green halo. Larger spots are often distinctly zonate, hence the common name "target spot". Severely infected leaves drop prematurely.

Disease cycle. *C. cassicola* overseasons in diseased soybean stems, roots, and seeds and can survive in fallow soil for more than two years. The fungus can colonize a wide range of plant residues in the soil.

Leaf infection takes place only when the relative humidity is 80 % or more, or when free moisture is present on the leaves. Dry weather inhibits infection on both leaves and roots. Disease is less severe on late-planted soybeans. The causal fungus is cosmopolitan and abundant in the tropics where it causes distinct leaf spots on a wide range of host plants, including cassava, cowpea and cotton.

Control:

- use resistant or tolerant varieties where available;
- use fungicides (resistance to benomyl has been reported).

**Web blight.** Web blight is also known as aerial blight. Causal agent: *Rhizoctonia solani* Kuhn. *R. solani* is highly variable in cultural characteristics, pathogenicity, and response to environmental changes. Isolates that cause root and stem decay of soybeans may not cause aerial and foliage blight. Isolates are classified by anastomosis groups (AG) 1-4. Most soybean pathogens fall in AG-4 and grow well at 25-30 $^{o}C$ in potato dextrose agar.

Importance. The pathogen was first reported in the Philippines in 1918 and now occurs in subtropical and tropical areas; in China, India, Mexico, U.S., Nigeria, Zaire, Zambia, and Cameroon. Yield losses of up to 35 % have been attributed to the disease. *R. solani* also attacks many crops including common bean, cowpea and rice.

Symptoms. Symptoms appear on leaves, stems, and pods, beginning on the lower or middle parts of the plant and moving upwards. Infected leaves are water-soaked at first, then take a greenish brown to reddish brown appearance, and later become tan, brown or black. Diseased tissues in older lesions that are no longer expanding generally fall out during dry weather, creating a ragged, shothole effect. Severely affected plants may be totally defoliated. Seed infection is associated with pod infection.

Disease cycle. The disease occurs in geographical areas characterized by prolonged periods of high humidity and warm weather. Symptoms may appear at any stage of plant development. Sclerotia, which survive in the soil for extended periods, serve as primary inoculum.

Control:

- seed treatment limits early season disease development;
- apply a foliar fungicide at first sight of the disease;
- use resistant cultivars when and where available.

**Sclerotium blight.** Sclerotium blight is also known as southern blight, southern stem rot, and white mold. Causal agent: *Sclerotium rolfsii* Sacc. *S. rolfsii* produces cord-like, septate hyphae. Spherical sclerotia are 1-2 mm in diameter and develop 6-12 days after formation of the mycelial mat.

Importance. Sclerotium blight is generally considered a minor disease of soybean, but it could occur at epidemic levels. Significant yield losses can occur in soybean monoculture or in short rotations of soybeans with other crops susceptible to the disease.

First noticed on tomato in Florida in 1893, sclerotium blight has subsequently been reported on 500 species in 100 plant families. It is usually found but not restricted to the tropics and warmer regions worldwide.

Symptoms. Soybean is susceptible to sclerotium blight any time from seedling emergence through pod fill. Infections usually occur at or just below the soil surface. Light brown lesions quickly darken and enlarge until the hypocotyl or stem is girdled. Yellowing or wilting of plants are usually the first symptoms. Leaves of infected plants turn brown, dry, and often cling to the dead stem. The most characteristic sign of the pathogen is a white mat of fungal mycelia forming on stem bases, leaf debris, and the soil surface around infected plants. Numerous tan to brown and spherical sclerotia form on infested plant material and on the soil surface.

Disease cycle. Sclerotium blight develops in hot, wet weather. Maximum disease development occurs at a temperature of 25-35 °C, which is the optimum temperature for mycelial growth and sclerotial formation. Damage is favored by high moisture levels, both in the soil and under the crop canopy.

Sclerotia on or near the soil surface survive longer than those buried in the soil. Germination of sclerotia in soil is stimulated by volatile organic exudates from crop residue. Seed transmission of *S. rolfsii* has been reported.

Control:

- alternate soybeans with nonhost crops, such as maize;
- clean fallow for up to two years to reduce inoculum;
- bury crop residue to a depth of 15-25 cm to reduce inoculum and delay disease;
- plant resistant or tolerant cultivars.

**Sclerotinia stem rot.** Sclerotinia stem rot of soybeans is also known as whetzelinia stem rot or Sclerotinia blight. Causal agent: *Sclerotinia sclerotiorum* (Lib.) deBary (Syn. *Whetzelinia sclerotiorum* (Lib.) Korf and Dumont). The fungus produces hard, black, irregularly shaped sclerotia (2-20 mm in diameter). They are easily distinguished from the smaller, round, tan to reddish brown sclerotia of *Sclerotium rolfsii*.

Importance. Sclerotinia stem rot is generally considered a minor disease of soybean in tropical Africa, except for local outbreaks in parts of southern Africa where plants are killed before maturity. Estimated annual yield losses of up to 50 % occur in parts of central and southern Brazil from the disease.

The disease was first reported on soybeans in Hungary in 1924 and in the United States in 1946. In Brazil, the first outbreak of the disease occurred in 1976. It occurs in other soybean growing areas of the world. It was recently observed for the first time in West Africa in the mid-altitudes of Nigeria.

Symptoms. The first symptoms of sclerotinia stem rot are wilting and eventual death of upper leaves. Symptoms generally develop in growth stages $R_2$ (full bloom) and $R_3$ (beginning pod). Infected leaves remain attached to the stems. Infection originates at stem nodes and usually develops 10-50 cm above the soil level. Plants are killed by the fungus girdling the stem.

At crop maturity, diseased stem tissues have a shredded appearance if disturbed and are white, with a reddish discoloration frequently interspersed within diseased stem tissues. Multiple stem infections also occur. Side branches and pods may also be infected. Cottony mycelial growth on all diseased plant parts is a characteristic sign of the pathogen. Large, black, round to irregularly shaped sclerotia of varying sizes form on stems, which are partially covered with dense white mycelium. Sclerotia are often formed in the stem pith and are conspicuous only when the stem is opened.

Disease cycle. Sclerotia of *S. sclerotiorum* survive in the soil for long periods. They are highly resistant to fungicides and to dry heat up to 70 °C. Sclerotia within 5 cm of the soil surface germinate in the field by producing apothecia or mycelia. Prolonged periods of low soil temperature and high soil moisture are most favorable for apothecial development. Asci containing ascopores are formed in a layer on the apothecial surface.

Ascospores are forcibly ejected from the asci and are windborne to nearby stems, branches, and pods, where infection occurs if the relative humidity is high. Plants of all ages can be infected. Infection of leaves, petioles, and internodes can occur through contact with adjacent diseased plants or through wounds.

Control:

- avoid planting soybeans directly after other legumes especially common bean *(Phaseolus* spp.) and sunflower.
- avoid row spacing of less than 75 cm in fields with a history of Sclerotinia stem rot.
- avoid cultivars that are susceptible to lodging and management practices that promote lodging or result in a dense canopy.
- plant resistant or tolerant cultivars.
- reduce irrigation before flowering.

**Fusarium rot and blight.** *Fusarium oxysporum* Schlechtend (*F. oxysporum* f. sp. *tracheiphilum* (E.F. Sm.) W.C. Snyder and H.N. Hansen and f. sp. *vasinfectum)* (Atk.) W.C. Snyder and H.N. Hansen and other Fusarium species *(F. semitectum* Berk. and Ravenel var. *majus* Wollenweb; *F. orthoceras* [synonymous with *F. oxysporum* sometimes cited as *F. oxysporum* var. orthoceras (Appel and Wollenweb.) Bilai] cause blight, wilt, pod and collar rot and root rot diseases in soybean. Because of host specificity, isolates of *F. oxysporum* are differentiated on the basis of their pathogenicity on crop plants and classified into form species (f. sp). Mycelium on potato dextrose agar looks white or tinged with purple.

Importance. *Fusarium*-induced diseases occur in most soybean-growing areas of the world. Economic losses of up to 50 % from reduced pod formation have been reported, 59 % from wilt or blight, and 64 % from root rot.

Symptoms. Symptoms appear about midseason. Characteristic symptoms are browning or blackening of the vascular system in roots and stems.

Root rot usually develops on seedlings and young plants in cool weather. When severe infection occurs, seedling emergence is slow and poor, and affected seedlings are stunted and weak. Infection is generally confined to the roots and lower stems. Pod infection may result in seed transmission of the pathogen.

Disease cycle. *F. oxysporum* inhabits the soil by colonizing various plant residues, and overseasons as chlamydospores or mycelium. Primary inoculum comes from the soil and penetrates soybean plants through wounds. Soybean cyst and sting nematodes predispose seedlings and young plants to infection. *F. oxysporum* interacts with *R. solani* to cause root rot of soybean.

Control:

- grow cultivars resistant to fusarium rot, soybean cyst nematode, and root-knot nematode;
- plant high quality seeds in warm, well drained soils;
- delay cultivation until soil moisture is low;
- in fields with a history of the disease, ridge soil around plant bases to promote adventitious roots from stem base.

**Charcoal rot.** Causal agent: *Macrophomina phaseolina* (Tassi) Goid. The fungus infects over 500 hosts, including crops and weeds. It grows well on potato dextrose agar and produces abundant microsclerotia. Optimum temperature for growth ranges from 28-35 $^{o}$C.

Importance. The pathogen attacks the plant throughout the season. The fungus is widely distributed in soils and occurs worldwide. In the tropics, where charcoal rot causes blight of emerging seedlings, plant losses of up to 77 % have been recorded.

Symptoms. Infected seedlings show a reddish brown discoloration at the emerging portion of the hypocotyl. The discolored area turns dark brown to black and infected seedlings die. In older plants, the charcoal rot phase appears after midseason. Infected leaves turn yellow and wilt, but stay attached to the plant. Frequently, microsclerotia are produced in the pithy area of the stem.

Disease cycle. Microsclerotia can survive in the soil or host residue for long periods. Growth in soil relies on nutrients stored in microsclerotia and continues even when soil nutrient levels are insufficient for fungal competitors. Soil population of microsclerotia increases when soybean is grown continuously in the same field. *M. phaseolina* causes disease by plugging xylem vessels with microsclerotia and through toxin production.

Control:

- rotate soybean with poor hosts, such as cereals, for 1 or 2 years in severely infected fields;
- avoid excessive seeding rates (crowding leads to weak seedlings that are more vulnerable);
- fertilize plants to encourage vigorous plant growth;
- irrigate to increase soil moisture, or flood field for 3-4 weeks before planting.

**Soybean cyst nematode.** Causal organism: *Heterodera glycines.* Cysts of the nematode are lemon-shaped. Young females are white and turn yellow with age. Upon death, the body wall hardens and becomes a brown cyst. The female produces a gelatinous matrix at the vulva, and the entire body is filled with eggs. The male is vermiform and long. The nematode has an egg stage, four juvenile stages, and an adult stage.

Root exudates stimulate hatching in the female. Juveniles penetrate roots and start feeding. As feeding continues, nematodes enlarge and become sedentary. Males mature faster than females and are required for reproduction. Eggs within the cyst can survive for up to 11 years. Nematodes can be disseminated by wind, water, soil, and machinery.

Symptoms. Foliar symptoms of seedlings vary from slight stunting to severe chlorosis and death. Mature plants may be stunted, chlorotic, or both. Symptoms alone are not an adequate diagnosis because $N_2$ and K deficiencies can cause similar symptoms on plants. Because of the misleading symptoms, diagnosis of the disease must be based on signs such as the white to yellow females, which erupt from the roots. The root system shows symptoms ranging from slight discoloration to severe necrosis.

Control:

- rotate crops, because only a few crops are susceptible;
- grow resistant cultivars instead of a nonhost plant. However, continuous or frequent use of resistant cultivars may result in "resistance-breaking" races;

- apply nematicides, but this is also expensive;
- practice long-term control measures including rotation, resistance, and good crop management in an integrated pest management (IPM) strategy.

**Root-knot nematodes.** Causal organisms: *Meloidogyne arenaria, M. hapla, M. incognita, and M. javanica. M. javanica* is probably the most damaging species and occurs in most soybean growing areas of the world.

Importance. Root-knot diseases of soybeans are reported from many soybean growing areas of the world. The incidence is greater in subtropical than in temperate regions and is considered endemic in warm soils. Yield losses vary from insignificant to total. Infection decreases nodule formation and increases host susceptibility to other vascular pathogens.

Symptoms. The primary symptom for identifying the disease is the presence of galls on infected roots. Galls are produced by increased size and number of cells in infected and adjacent tissue in response to root-knot nematode feeding. Vascular elements of infected tissues are disrupted. Water and nutrients flowing through the plant can be inhibited.

Disease cycle. The disease cycle in soybean begins with the invasion of roots, mostly near the root tip, by the vermiform second stage juveniles. Juveniles normally settle at feeding sites close to the point of entry. Galling is evident within 23 days. Females become swollen and pear-shaped. Nematodes in plants reach a maximum number at crop maturity. The number rapidly decreases when food reserves are depleted, and predatory and parasitic activities of other micro-organisms in the soil increase.

Damaging levels of infection occur following several years of uninterrupted soybean cultivation. Both preventive and corrective management is needed to avoid this problem.

Control:

- clean planting and cultivating equipment from contaminated soils before moving to uninfested fields;
- control weeds;
- rotate soybean with grass crops less susceptible to the nematode to effect reduction in residual juvenile populations;
- use cultivars that are tolerant to nematodes;
- apply nematicides judiciously; however, nematicides are rarely profitable for controlling nematodes.

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Hartman, G.L.; Datnoff, L.E.; Levy, C.; Sinclair, J.B.; Cole, D.L.; Javahen, F. 1987. Red leaf blotch of soybean. Plant Disease 71: 113-118.

Oyekan, P.O.; Naik D.M. 1987. Fungal and bacterial diseases of soybean in the tropics. Pages 47-52. In: Singh, S.R.; Rachie, K.O.; Dashiell, K.E. (eds.). Soybeans for the tropics. John Wiley, New York, USA. 230 p.

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# 9 Suggestions for trainers

If you use this Research Guide in training:

**Generally:**

- Distribute handouts (including this Research Guide) to trainees one or several days before your training activity, or distribute them at the end of your presentation.
- Do not distribute handouts at the beginning of a presentation, otherwise trainees will read instead of listen to you.
- Ask trainees not to take notes, but to pay full attention to the training activity. Assure them that your handouts (or this Research Guide) contain all relevant information.
- Keep your training activities practical. Reduce theory to the minimum that is necessary to follow the practical exercises.
- Use the questions on page 4 (or a selection of questions) for examinations (quizzes, periodical tests, etc.). Allow consultation of handouts and books during examinations.
- Promote interaction of trainees. Allow questions, but do not deviate from the subject.
- Control your time.

**Specifically:**

- Discuss with trainees their experiences with soybean production and soybean diseases (10 minutes).

- Present the content of this Research Guide, using the study materials listed on page 3. You may photocopy the illustrations of the Research Guide on transparencies for projection with an overhead projector.

  Have real samples of diseased plants available for each trainee.

  You may take a whole morning and organize your presentation in a combination of theoretical explanation and practical exercises. Pure lecturing and showing color slides is too monotonous.

- Do not describe all the diseases listed in this Research Guide. Describe only the diseases that are important in your area.

- In the afternoon, or during a field excursion, in group work, identify diseases in the field and demonstrate control methods.

  Organize your practicals/demonstrations well. Make sure that each trainee has an opportunity to practice. Have resource persons available for each group and practical.

  Prevent trainees from scattering around the field.

International Institute of Tropical Agriculture (IITA)
Institut international d'agriculture tropicale (IITA)
Instituto Internacional de Agricultura Tropical (IITA)

*The International Institute of Tropical Agriculture (IITA) is an international agricultural research center in the Consultative Group on International Agricultural Research (CGIAR), which is an association of about 50 countries, international and regional organizations, and private foundations. IITA seeks to increase agricultural production in a sustainable way, in order to improve the nutritional status and well-being of people in tropical sub-Saharan Africa. To achieve this goal, IITA conducts research and training, provides information, collects and exchanges germplasm, and encourages transfer of technology, in partnership with African national agricultural research and development programs.*

*L'Institut international d'agriculture tropicale (IITA) est un centre international de recherche agricole, membre du Groupe consultatif pour la recherche agricole internationale (GCRAI), une association regroupant quelque 50 pays, organisations internationales et régionales et fondations privées. L'IITA a pour objectif d'accroître durablement la production agricole, afin d'améliorer l'alimentation et le bien-être des populations de l'Afrique tropicale subsaharienne. Pour atteindre cet objectif, l'IITA mène des activités de recherche et de formation, divulgue des informations, réunit et échange du matériel génétique et encourage le transfert de technologies en collaboration avec les programmes nationaux africains de recherche et développement.*

*O Instituto Internacional de Agricultura Tropical (IITA) é um centro internacional de investigação agrícola pertencendo ao Grupo Consultivo para Investigação Agrícola Internacional (GCIAI), uma associação de cerca de 50 paises, organizações internacionais e regionais e fundações privadas. O IITA procura aumentar duravelmente a produção agrícola para melhorar a alimentação e o bem-estar das populações da Africa tropical ao sul do Sahara. Para alcançar esse objetivo, o IITA conduz actividades de investigação e treinamento, fornece informações, reúne e troca material genético e favorece a transferência de tecnologias en colaboração com os programas nacionais africanos de investigação e desenvolvimiento.*