Field Guide to African Soybean Diseases, Pests & Nutrient Deficiencies

Version 2.0

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Front Cover: Soybean plots in Mozambique. Photo credit: Steve Boahen

Back Cover: SIL Pan-African Soybean Variety Trial (PAT) operators undergoing a training on soybean disease identification and severity rating, led by Dr. Harun Muthuri Murithi, co-author of the guide.

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Introduction

The purpose of this soybean field guide is to provide soybean growers, agronomists, researchers, seed companies, and others with a means to diagnose soybean abnormalities as they are observed in the field.

In Version 2.0, we have expanded the guide to include symptoms of nutrient deficiencies, common pests of soybean, and a management section. This guide also expands on previous sections to include more soybean diseases that have been identified in Africa.

This guide is not all inclusive as there are many areas in Africa with diverse growing environments that when further surveyed may result in the identification of more diseases and pests.

This guide is organized to enable important soybean diseases to be identified on soybean leaves, stems, pods, seeds, and roots. Diseases are presented with images and symptom descriptions based on their most common occurrence on the plant. All images are courtesy of the authors unless otherwise stated.

Healthy Soybeans

The goal of producing soybean is to attain a high-quality grain for marketing, whether for soybean oil or soybean meal, or for direct consumption as soy milk, textured soy protein, soy flour, or in whole bean form.

The quality and quantity of grain production can be limited by diseases and pests, and abiotic stresses such as nutrients and water.

Producing a healthy crop requires inputs including recognizing problems affecting the health of the crop. A healthy crop starts with good seed quality that is free of pathogens and has a high germination percentage.

Seed bed preparation is important to obtaining optimum plant density. Further care of the crop includes monitoring and proper disease, pest, and weed control.

Healthy appearing soybeans in research plots in Zambia.

Photo credit: Justin Nkhoma

Healthy Soybeans

Soybean flowers are self-pollinated and range from white to dark purple.

Pods are mostly 3-seeded and glabrous (without surface features) to dense pubescence.

Healthy appearing soybean leaves.

Healthy soybean seeds can be different colors ranging from yellow, green, brown, mottled, and black. This photo shows yellow, green, and brown mottled seeds mixed from three different soybean genotypes.

Soybean Diseases

Pathogens and pests that attack soybean infect all plant parts including the root, shoots and stems, leaves, pods and seeds.

Most commonly, symptoms are observed first on leaves, then perhaps stems and pods. Roots are rarely observed for pathogens and pests even though many diseases can occur primarily or at least initially on roots.

Diseases are caused by a wide range of organisms including bacteria, fungi, nematodes, phytoplasmas, and viruses. Pests vary widely too, from insects to mammals.

Management or control of a disease or pest problem relies on the proper diagnosis.

Leaf Diseases

Leaf diseases can be caused by a large number of pathogens, some of which cause diseases on roots, stems, pods, and seeds. Some only occur, or primarily occur, on leaves.

Many of the common leaf disease symptoms are well defined, especially leaf spots and lesions caused by bacteria and fungi.

Symptoms caused by viruses include leaf mosaic, brittleness of leaves and stems, and stem and leaf discoloration ranging from yellow, red, brown, and necrotic. The entire plant may be stunted while still green, and seeds may become misshapen and discolored.

Identifying virus and virus-like diseases using symptoms alone is unreliable. Other leaf diseases that are often said to be virus-like are caused by certain groups of bacteria, including those referred to as phytoplasmas, which are mostly transmitted by leaf hoppers. Symptoms of phytoplasma infection include yellowing, dwarfing, proliferation of axillary shoots, green stems, and sterility.

BACTERIAL BLIGHT

- Bacterial blight is one of the most common bacterial diseases of soybean and is found worldwide.
- Young leaves are most susceptible and this disease is most noticeable in the upper canopy.
- Lesions become dark and surrounded by a yellow halo, one of the most diagnostic characteristics of bacterial blight.
- In severe infections, lesions will coalesce and cause the leaf to look ragged.
- The causal pathogen can be seedborne and can infect leaves, stems, petioles, and pods.

Yellow halos surrounding necrotic lesions is a distinguishing factor for bacterial diseases.

Photo credit: T. Mueller

In severe infections, lesions will coalesce and cause the leaf to look ragged as infected tissue often dies and drops from the leaf.

BACTERIAL PUSTULE

- Symptoms most commonly occur on leaves as minute, pale-green spots that enlarge to irregularly shaped lesions.
- When the lesions join, leaves become ragged and may drop from the stem. Most lesions have prominent pustules on the underside of the leaf.
- The disease also occurs on pods, appearing as slightly raised spots with some discoloration on seeds.
- The disease may cause premature defoliation and often under severe conditions premature death.

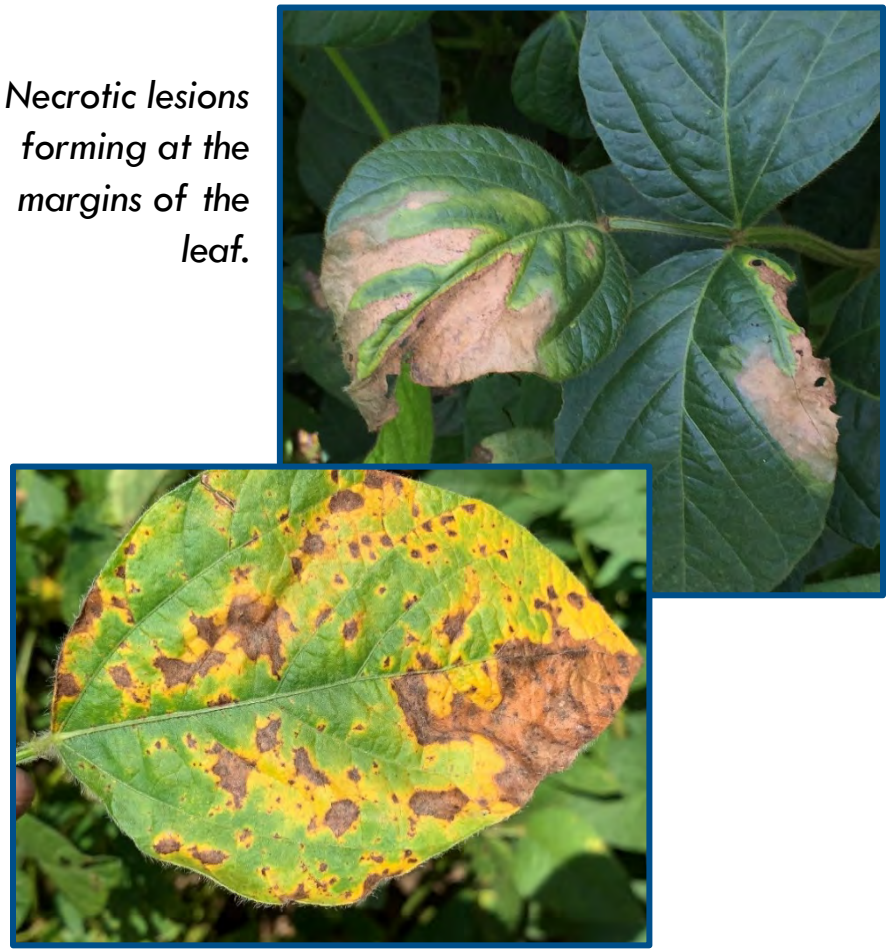
Minute lesions through the leaf tissue in Senegal.
Photo credit: Djibril Sarr

A diagnostic factor for bacterial pustule is the pustules that form on the underside of the leaf tissue.
Photo credit: A. Robertson

BACTERIAL TAN SPOT

- Bacterial tan spot is less prominent than bacterial blight or bacterial pustule but is known to occur in several African countries.
- Necrotic lesions will form, often starting from the margin of the leaf. Lesions will have a yellow border.
- The same pathogen also causes vascular wilting of the plant at any age and infects seeding.
- The causal pathogen can be seedborne.

Necrotic lesions forming at the margins of the leaf.



BROWN SPOT

- Symptoms most commonly occur on leaves as irregularly shaped lesions, often with a yellow border surrounding a necrotic area.
- When the lesions join together, the spots enlarge, often covering much of the leaf's surface.
- This disease also occur on petioles, pods, and stems.
- This disease may cause premature defoliation starting from the lower leaves and moving upward.

Brown spot lesions, initially small in size, showing yellowing surrounding the small brown spots.

CERCOSPORA LEAF BLIGHT

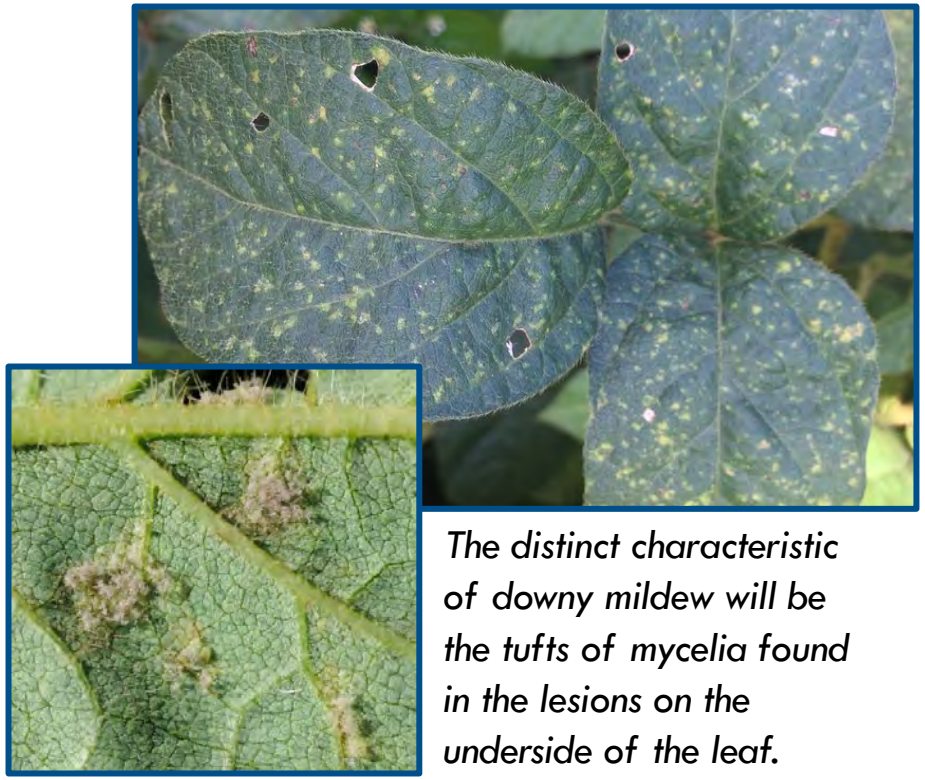
- Leaf symptoms are most pronounced during pod fill when upper surfaces of upper leaves exposed to the sun become discolored.
- The discoloration may be reddish-purple or bronze covering most of the leaf or can be contained to discrete irregularly-shaped blotches.
- Severe symptoms may cause necrotic patches on the leaves which coalesce until the entire leaf dies.
- Blight may occur without the purple-bronze symptoms and may also occur on petioles, stems, pods, and seeds (see purple seed stain, pages 57-58).

Bronzing or purpling on the surface of the leaf is a distinct characteristic of Cercospora leaf blight.

This purpling will show up on stems, petioles, and seeds as well.

DOWNY MILDEW

- Initial infection appears as pale-green or light-yellow spots on the upper surface of young leaves.
- Older lesions will turn grayish-brown to brown and have a yellowish-green margin.
- The most diagnostic characteristic of this disease is the greyish or pale-purple tufts of spores on the underside of the leaf.
- The disease can infect pods and seeds may be coated with a white crust of mycelia and spores.



The distinct characteristic of downy mildew will be the tufts of mycelia found in the lesions on the underside of the leaf.

The same fungus can infect seeds, showing up as a white/yellowish crust on the top of the seed. This is composed of mycelia and spores.

FROGEYE LEAF SPOT

- Leaf lesions are circular to angular up to 5 mm in diameter, with ash gray to light brown centers.
- Older lesions are light to dark brown with white centers that may contain minute, dark fungal structures called stromata. These centers sometimes drop from the lesion or are eaten by insects, leaving a hole in the center of the lesion.
- Lesions may coalesce to form larger, irregularly shaped spots, that if numerous enough cause the leaves to wither quickly and fall prematurely.
- Lesions can also occur on petioles, stems, pods, and seeds.

The distinct characteristic of frogeye leaf spot is the dark brown border around the lesions. In older lesions the necrotic areas will drop out giving the appearance of a frog's eye.

MUSTARD LEAF SPOT

- This disease appears as yellow spots throughout the leaf.
- Symptoms appear as yellow spots throughout the leaf, sometimes few in number and other times coalescing and filling up most of the leaf surface.
- Since the causal agent of mustard leaf spot is not known, it is referred to as a disorder and listed under leaf disease in this guide, but it could be a nutritional disorder.
- Mustard leaf spot has been reported in several countries in Africa and in Brazil and the USA.

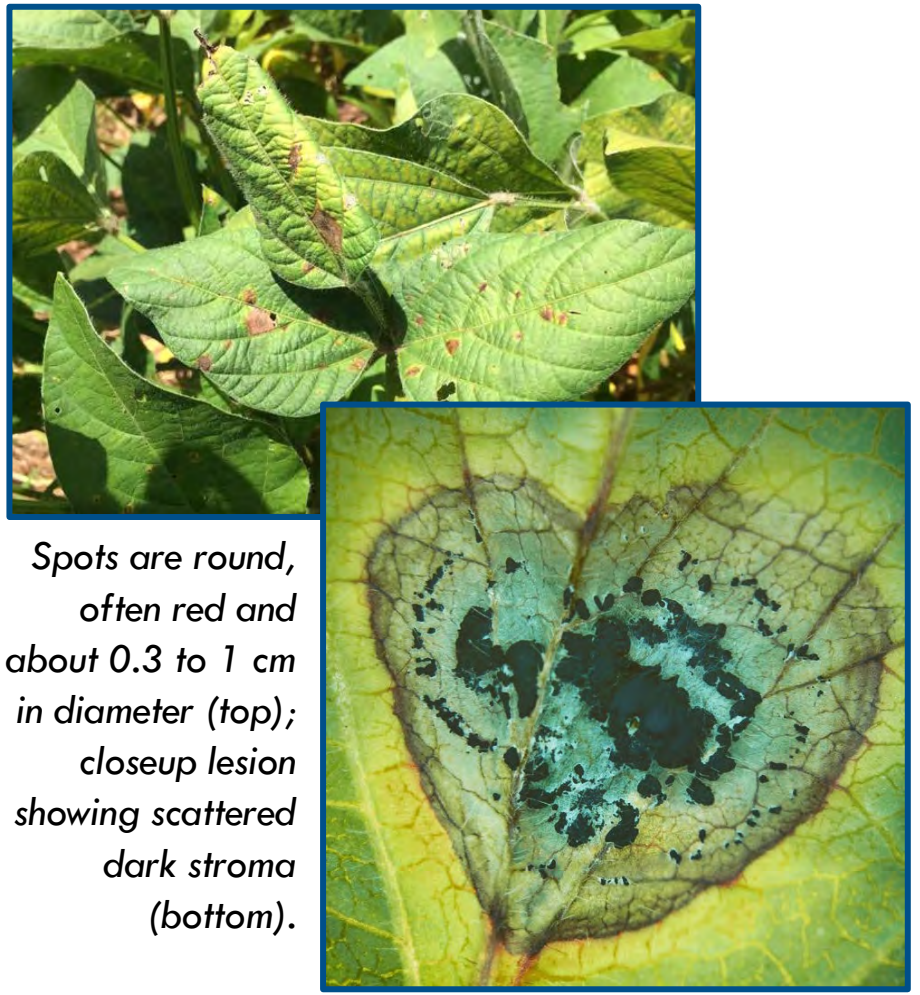
Yellowing spots on leaves from mustard leaf spot.

Mustard leaf spot symptoms in Malawi.

Photo credit: Robert Chana

MYROTHECIUM LEAF SPOT

- This disease was discovered on soybeans in Ghana in 2016. Its distribution is not known.
- Lesions somewhat resemble those of red leaf blotch, and lesions typically are roundish with buff or reddish centers and darker margins.
- Older lesions may have large greenish-black spore producing structures.
- There is nothing known to date about the life cycle on soybean or its impact on soybean production.



Spots are round, often red and about 0.3 to 1 cm in diameter (top); closeup lesion showing scattered dark stroma (bottom).

RED LEAF BLOTCH

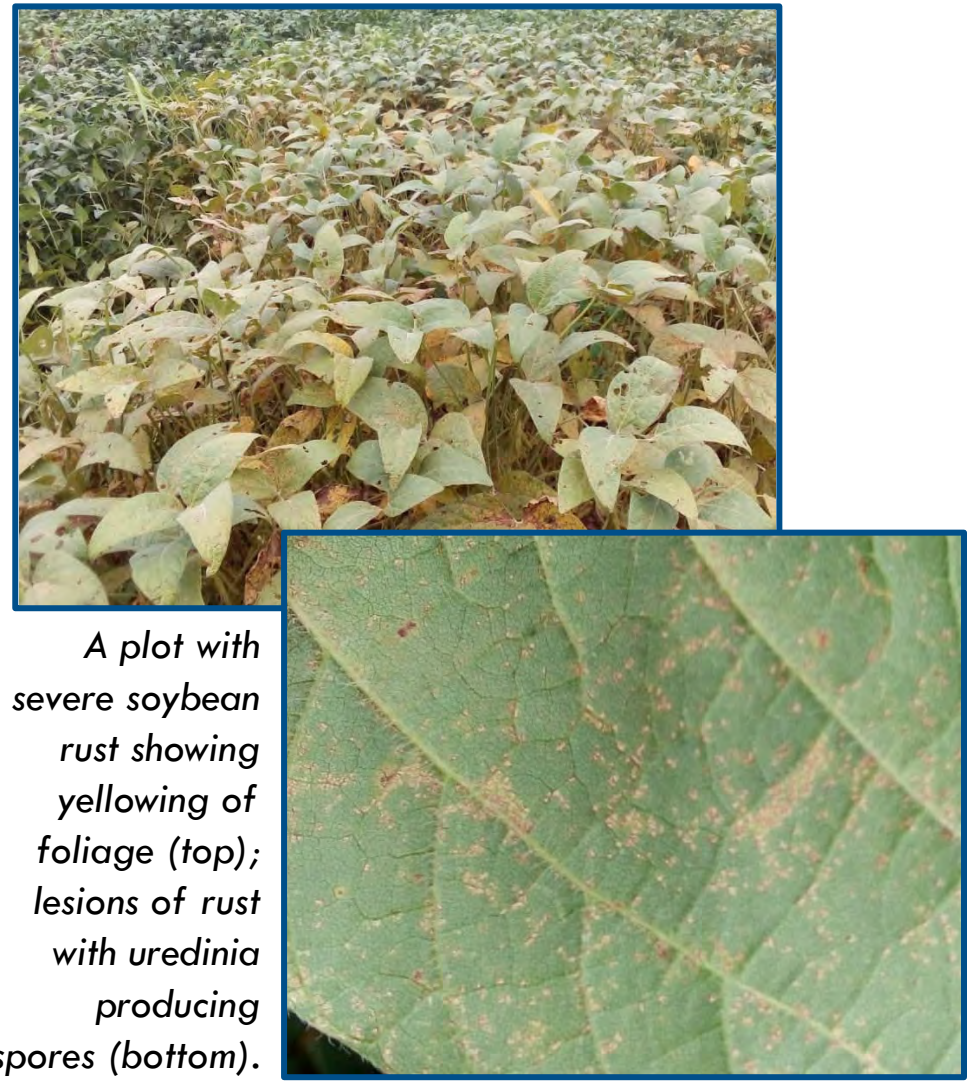
- Lesions occur on leaves, petioles, pods, and stems.
- Lesions are dark red on the upper surfaces of leaves and reddish brown on the lower surfaces.
- Lesions grow to form necrotic blotches up to 2 cm in diameter.
- Within older lesions, diagnostic fungal structures may be found. These include sclerotia (a resting structure) and pycnidia (a spore-producing structure).
- Severe infection causes premature defoliation and early maturation.

Lesions appear as reddish-brown blotches with dark borders and can be found on leaves, petioles, pods, and stems.

Diagnostic characteristic in older lesions is the presence of overwintering bodies (sclerotia).

RUST

- The first symptoms may appear as small yellow, tan to dark-brown, or reddish-brown lesions.
- Later, one to many erupting volcano-like fungal structures called uredinia are just barely visible with the naked eye.
- On occasion, lesions occur on petioles, but not typically on stems or pods.
- Severe infection causes premature defoliation and maturation.
- Early symptoms of soybean rust can be confused with bacterial pustule.



A plot with severe soybean rust showing yellowing of foliage (top); lesions of rust with uredinia producing spores (bottom).

Photo credit: Emmanuel Ziramba

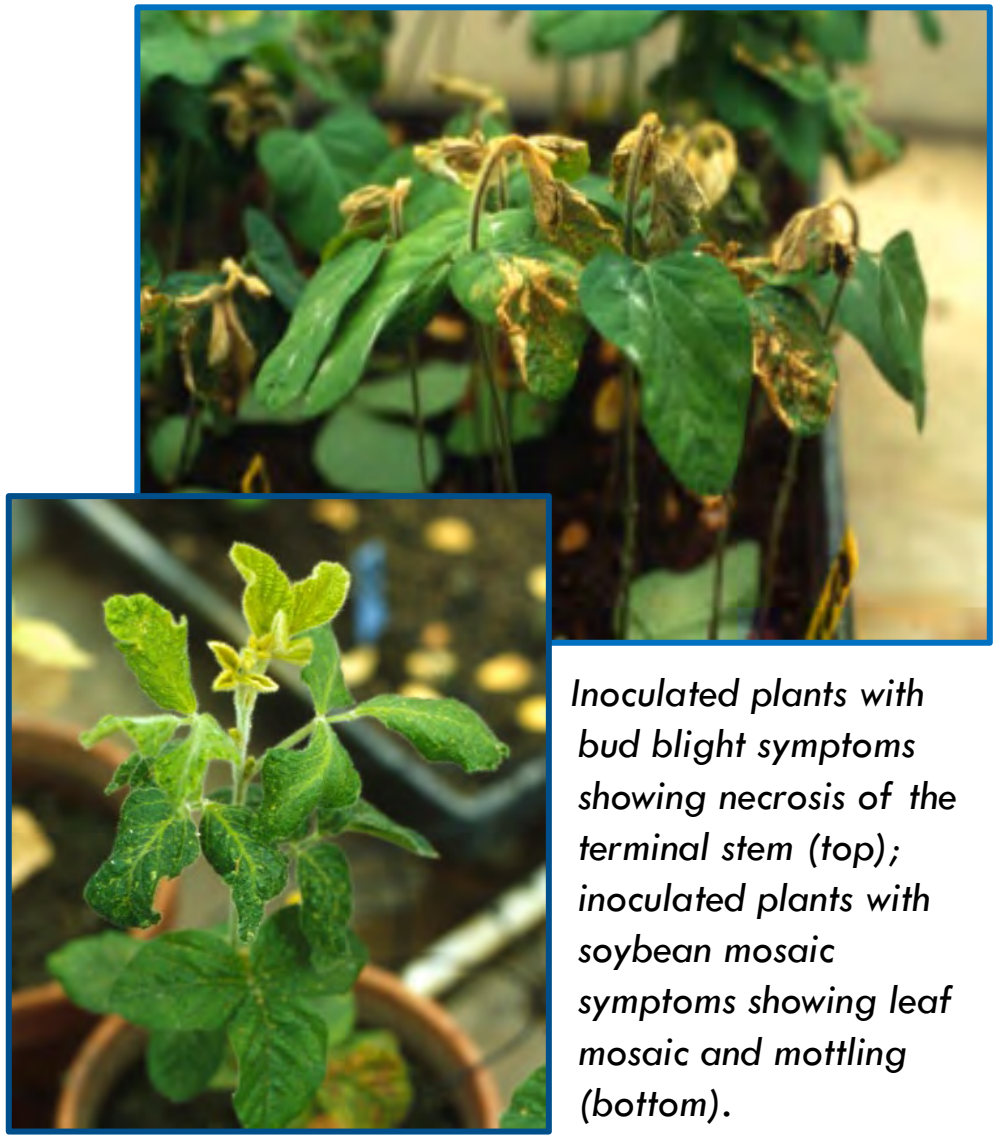
WITCHES' BROOM

- Bud proliferation is often the most obvious symptom observed. Multiple shoots develop. Plants may develop apical necrosis. Infected plants produce none or few and poor-quality seed.
- The cause of this abnormality is associated with phytoplasmas which are vectored by leafhoppers. Symptoms of viruses and those caused by phytoplasmas may overlap.

Note proliferation of multiple shoots.

VIRUSES

- Leaves appear mottled and puckered with sterile or poor pod set and may die prematurely.
- Symptoms of viruses and those caused by phytoplasmas often overlap and infect the whole plant. Both are often vectored by insects, including aphids, beetles, and leafhoppers.
- Virus symptoms caused by many of the viruses are similar including those that cause bean pod mottle and soybean mosaic.
- Identifying virus and virus-like diseases using symptoms alone is unreliable.



Inoculated plants with bud blight symptoms showing necrosis of the terminal stem (top); inoculated plants with soybean mosaic symptoms showing leaf mosaic and mottling (bottom).

Stem Diseases

Diseases in this section are those that have the most characteristic symptoms for identification occurring on stems. However, the majority of pathogens producing symptoms on stems also produce symptoms on other tissues.

For example, a fungal disease known as charcoal rot may be noticeable on stems, but it initiates infection in the roots and for this guide is covered under root diseases.

ANTHRACNOSE

- Irregularly shaped black areas appear on stems and petioles.
- In the advanced stages of anthracnose (usually late reproductive stages), infected tissues are covered with black fruiting bodies (acervuli) that can be seen with the unaided eye.
- The fungus causing this disease also attacks pods and seeds.
- When the disease is severe, premature defoliation occurs and plants senesce earlier than usual.

Irregularly shaped black blotches are distinct characteristics of anthracnose. These blotches can appear on the stems and petioles.

Photo credit: D. Mueller

GREEN STEM

- The term green stem is used to encompass all maladies related to delayed stem senescence.
- The cause of green stem is not known, but various abiotic stresses and biotic infections have been implicated.
- The term green stem disorder has been used to define plants with non-senescent stems mostly with petioles detached, but with normal, mature pods and seeds at harvest maturity.

Green stem disorder is identified by petioles and leaves dropped off and pods matured, but stems remain green into harvest.

POD AND STEM BLIGHT

- Symptoms are not usually apparent on green growing tissue, even though the fungus may have colonized the area.
- Once the tissue dies, it is rapidly covered with speck-sized fruiting bodies of the fungus called pycnidia, usually arranged linearly.
- The pycnidia fungus can also be found on petioles and pods.

A distinct characteristic of pod and stem blight is the rows of black fruiting bodies (pycnidia) that appear on the stems and petioles.

Pycnidia can also appear on the pods.

Photo credit: Yechalew Sileshi

SCLEROTIUM BLIGHT

- Infection occurs at or just below the soil surface and appears as light to dark brown lesions that girdle the stem.
- A sudden yellowing or wilting of the plant often occurs. Leaves turn brown and dry, often clinging to the dead stem.
- A leaf spot phase is characterized by circular, tan to brown lesions with dark brown margins.
- Under moist conditions, a white, fanlike mat of fungal growth and many small white, tan or brown spherical overwintering structures (sclerotia) form on and around the stem base.

White fungal growth appears to be girdling the stem; unverified diagnosis of Sclerotium blight.

Photo credit: Abush Tesfaye

SCLEROTINIA STEM ROT

- Infection occurs by spores produced in a fingernail sized cup shaped fungal structure (apothecium) that land and germinate on matured flower petals.
- The fungus often grows into stems and may cause the plant to wilt and may also infect the pods and seeds.
- Under moist conditions, white fungal growth forms on and around the stem and/or pods.

Stem bleaching, white mat of fungal growth, and large black sclerotia are distinct characteristics of Sclerotinia stem rot.

Photo credit: Joaquin Navas

Fruiting structures (apothecia) in debris will form and disperse spores onto soybean flowers.

Pod and Seed Diseases

Soybean seed health is affected by many factors, including abiotic and biotic stresses. Plants stressed by too much or too little water or by nutrient imbalances often produce seeds that are abnormal. Biotic factors including bacteria, fungi, and viruses often affect seed health.

Disease symptoms on seeds may include mottling, shriveling, discoloration of part or all of the seed coat, and decreased seed weight. Seed mottling is often caused by viral infection of the plant, and viral symptoms especially on leaves may also be evident. Fungal infection of the seed can be diagnosed somewhat by color; however, seed infection can also be symptomless.

ANTHRACNOSE

- Necrotic lesions are first observed on pods. Seeds may be shriveled and discolored or be symptomless. Stink bugs (pages 93-94) can also cause pod and seed shriveling and discoloration.
- This fungal pathogen also infects other plant organs and is often associated with leaf and stem anthracnose causing vein and stem necrosis (see anthracnose on stems).
- Pre-emergence and post-emergence damping off may occur when infected seeds are planted. Dark-brown, sunken cankers often develop on stems and cotyledons, killing the plant.

Necrotic lesions on pods (left); shriveled and discolored seeds (right).

PHOMOPSIS SEED DECAY

- Seeds may show few symptoms or may be whitish and shrunken, severely shriveled, elongated, and cracked.
- Affected seeds may not germinate or may be slow to germinate resulting in pre- and post-emergence damping off.
- Soybean pods can be infected at any time after being formed and may be discolored or aborted.
- This disease can be important when seed is used for seed stock (perpetuating the disease), and when used for human consumption (discolored or non-marketable seed).

Shriveled soybean seeds covered in white mycelia are distinct characteristics of pod and stem blight.

Photo credit: John MacRobert

PURPLE SEED STAIN

- Seed discoloration varies from pink to dark purple, and discolored areas range from specks to the entire seed coat.
- The infection of seeds by this fungus can be important when seeds are used for seed stock (perpetuating the disease), and when used for human consumption where it may affect the quality of edible soy products.

Purplish stains on seed coats are distinct characteristics of purple seed stain.

SEED MOTTLING

- Seeds from virus-infected plants may have tan, brown or black mottling.
- A number of viruses cause this symptom, making specific diagnosis by symptoms alone impossible.
- Most virus-infected plants occur as a result of virus vectors, most commonly insects.
- Seed bleeding from hilum may be characteristic of an infected plant, although not all seeds may harbor the virus.

Seeds from virus-infected plants with black mottling.

Root Diseases

There are many root diseases that occur widely in soybean, including charcoal rot, Pythium root rot, Rhizoctonia root rot, and diseases caused by nematodes. Distribution of root disease in Africa based on surveys is lacking.

Many of these root diseases cannot be diagnosed by symptoms alone, although a few produce symptoms or life structures of the pathogen that are diagnostic.

Root pathogens can often kill the roots of infected plants but can also infect the plant and cause vascular browning.

CHARCOAL ROT

- Soil-borne pathogens may cause premature death of the plant, often with leaves left dried on the plant.
- Symptoms include wilting and/or yellowing due to vascular plugging.
- Roots and stems of diseased plants have a charcoal or grayish colored appearance due to the aggregated appearance of tiny fungal structures called microsclerotia.
- The pathogen also infects seeds, producing microsclerotia, often in seed coats.

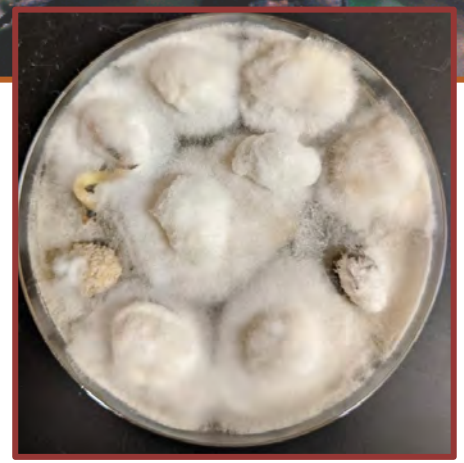
Soybean root dislocation due to the fungus causing charcoal rot.

Microsclerotia are a distinct characteristic of charcoal rot and can be present on stems, roots, pods, and seeds.

FUSARIUM ROOT ROT

- Fusarium species are prevalent worldwide and many of them can infect soybean roots causing the roots to rot.
- Rot is often restricted to the roots and lower stems.
- Younger plants, especially seedlings, are most susceptible to Fusarium root rot. Infected seedlings will be slow to emerge and weakened or stunted.

Root lesions on field grown plants include blackish rotted roots that are often indistinguishable from other organisms causing root rot. If the roots have a blue tinge of macroconidia as shown in the image then it is known to be caused by the Fusarium species (see sudden death syndrome, next pages).



The pathogen that causes Fusarium root rot can also infect and rot the seed.

SUDDEN DEATH SYNDROME

- The most prominent symptoms occur on foliage and include interveinal chlorosis, necrosis, and premature death of the plant.
- Severely affected leaves detach from the petioles, which often remain attached to the stem.
- Although infection may occur earlier, visual symptoms become most noticeable on leaves when the plant reaches the full-pod stage.
- The root mass of affected plants is reduced, and roots appear discolored, often preceding foliar symptoms. Severely infected plants can be easily pulled from the ground.

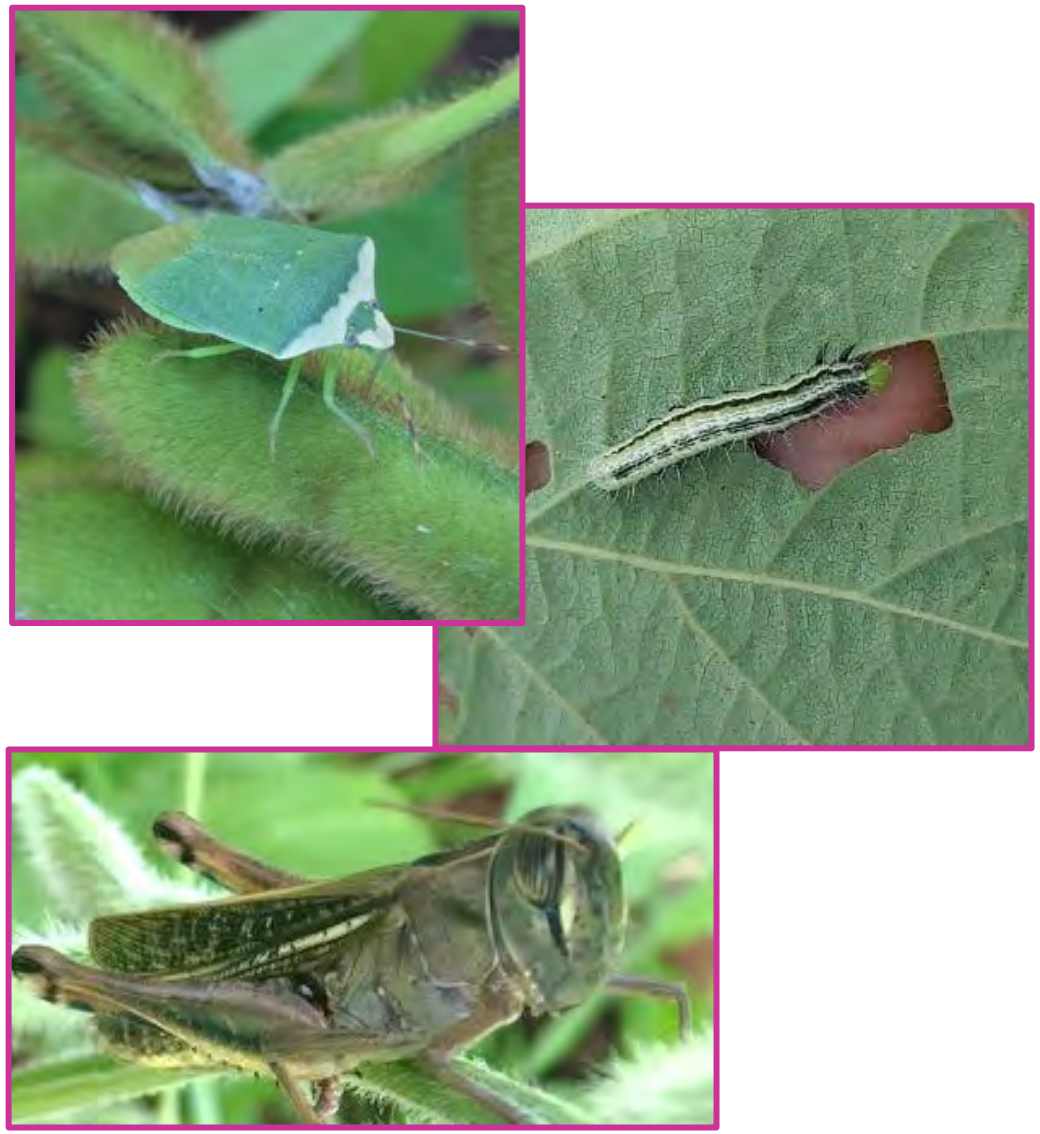
The pathogen will stay in the root tissue but will create toxins that are carried into the above ground tissue and will cause interveinal chlorosis and necrosis.

Leaflet with severe chlorosis and necrosis often leads to premature defoliation.

PESTS

Insect pests can cause significant yield losses in soybean. Insect pests of soybean can be categorized into foliage feeders (defoliators), stem feeders, fruit (flower, pod and seed) feeders, and root, nodule and planted seed feeders. Some pests can be found in more than one category.

Soybean pests attack at any growth stage from the seedling through to harvest and can be especially severe from flowering to plant maturity. Soybean pests cause damage through direct feeding thereby exposing plants to attack by other pathogens and indirectly by transmission of viruses and other pathogens.



BEAN LEAF FOLDER

- The bean leaf folder, also known as bean leaf webworm or bean leaf roller, was observed in Ghanaian soybean production.
- It is an important local pest of soybean and cowpea especially during periods of drought.
- The adult moth is pale brown with dark lines and patches across the wings.
- The caterpillars are pale green with a pale brown head, often with a thin dark green line through the top abdomen.
- The caterpillars roll and join soybean leaves by silk threads where they spend all their life.

Caterpillars of bean leaf folder.

BLISTER BEETLES

- Adult blister beetles exhibit a defensive behavior called reflex bleeding. Noxious bloody fluid containing toxic substances called ‘cantharidin’ is released to deter potential enemies.
- Direct contact with substance may produce blisters on human skin.
- Adults feed mostly on soybean flowers, young pods, or tender stems with minimal injury to the plant, but can cause considerable damage when large numbers infest a crop causing yield loss. Larvae do not feed on plant material and are generally beneficial when feeding on grasshopper eggs.

Gray adult blister beetles with long antennae and alternating light and dark gray bands. *Photo credit: Emmanuel Ziramba*

BROAD-HEADED BUGS

- Broad-headed sucking bugs were captured in Ghanaian soybean fields. They feed on soybean pods causing direct damage to the soybean crop.
- Adults are cylindrical, light brown with a broad head. They are sometimes referred to as leaf-footed bugs.
- Nymph feed and cause similar damage like adults.
- Best management practice is to use multiple control tactics including cultural practices that support natural enemies.

Adult bug on a soybean leaf, upper and lower.

Photo credit: pnas.org

BRUCHIDS

- Bruchids, or weevils, are common storage pests that can cause up to 100% damage.
- Female bruchids will lay eggs on mature soybean seeds in the field. In storage, the eggs will hatch, and larvae will infiltrate the embryo of the seed and feed until adulthood.
- The most distinct characteristic of bruchids is the circular hole the adults make while eating their way out of the soybean seed.

Adult Chinese bruchid found in seed from Malawi.
Photo credit: Doris Lagos-Kutz

Adult Chinese bruchids, eggs, and distinct soybean seed damage caused by bruchids.
Photo credit: Doris Lagos-Kutz

CATERPILLAR

- Caterpillars are chewing pests and can cause serious defoliation to soybean.
- Caterpillar eggs are light green and are deposited on leaves, pods, and stems.
- Caterpillars are easily identified by their vigorous wriggling and twisting when disturbed.
- Adult velvetbean moths (butterflies) are fairly big with a large diagonal black line across their wings.

Velvetbean caterpillars.

Caterpillar feeding damage.
Photo credit: Godfree Chigeza

GRASSHOPPERS

- Both adults and nymphs feed on soybean leaves.
- Grasshopper damage causes round to ragged holes on the leaves which extend in from the leaf margins and between the veins.
- They may also feed on and damage soybean pods, often chewing through the pod tissue into the seed.
- Plants are most susceptible to damage when they are small, from the time of emergence to V2.

Adult grasshopper on a soybean plant.

GROUNDNUT LEAF MINER

- This pest, also known as webworm, is a recent important pest of soybeans in Africa.
- The pest was first observed on soybean in South Africa in 2001 and in Uganda in 2011.
- The larvae web the leaflets together, feed on them and remain within the fold, hence the name “webworm”.
- The larvae mine the leaf midrib, the leaves become brown, roll down and eventually drop off.

Larvae of groundnut leaf miner.

Soybean leaves roll down due to larvae feeding.

MEALYBUG

- Mealybugs damage plants by sucking sap from roots, tender leaves, petioles and fruit.
- They tend to live in clusters on plant parts.
- Both nymphs and adults suck the sap, causing withering and yellowing of leaves, while pods may drop prematurely.
- Heavy mealybug attacks appear as white, waxy masses of mealybugs on stems, pods and along the veins on the underside of leaves.

White, waxy masses of mealybugs on soybean stems.

PINK POD BORER

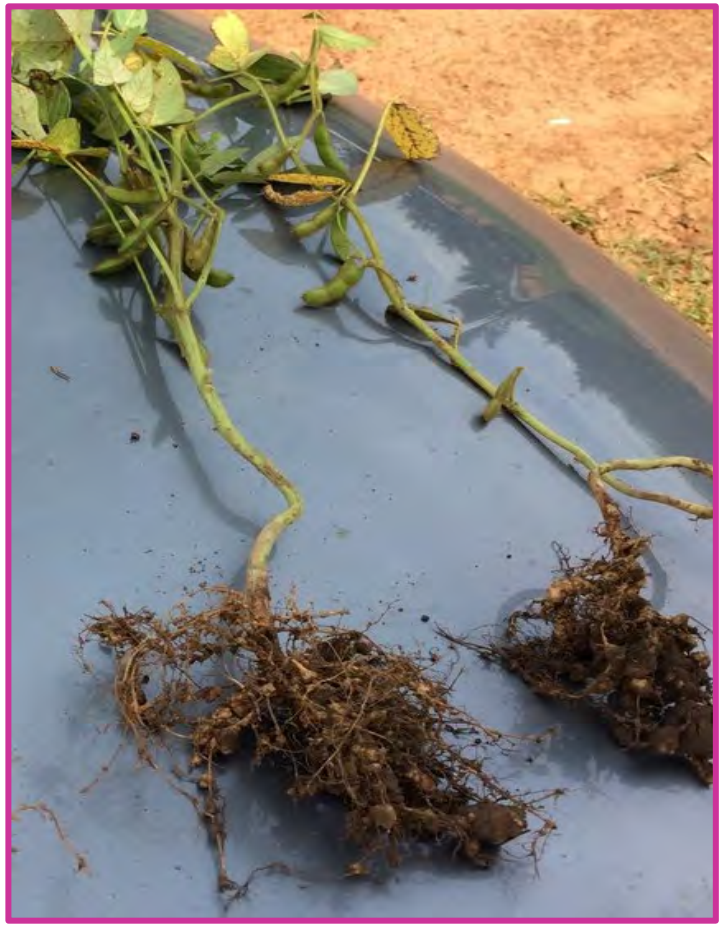
- Pink pod borer was observed in Ghanaian soybean, becoming a locally important pest of soybean.
- The adult moth of the pink pod borer (C. *ptychora)* is small, dull brown or black.
- Adult female moths lay eggs on nearly matured peduncle or pods. The eggs hatch and the emerging (first instar) larvae bore into the seed where it remains to feed.
- The first emerging larvae are whitish, but later instars develops from pink to bright red in color.

Pink pod borer larvae.

Damaged seeds from pink pod borer larvae.

ROOT-KNOT NEMATODE

- The primary symptom for identifying this disease is the presence of galls on infected roots.
- The galls vary in number and size depending on the intensity of the infection, and the entire root system may appear greatly swollen.
- Because of the infection, plants may be stunted with yellowed wilted leaves that become more common under drought or heat stress.



Galling from root-knot nematode evident on soybean roots.

SOYBEAN LOOPER

- The larvae has a distinct looping pattern and feeds on the underside of the leaves causing window-like feeding patterns.
- Soybean loopers feed from the inside out on the lower plant canopy.
- Feeding causes a ragged appearance on the plants.
- Severe infestation causes defoliation of the whole plant.

Distinct looping pattern of the soybean looper larvae.

Window-like feeding patterns caused by soybean loopers.

STEM BORER

- Stem borer is a small, long-horned beetle whose larvae attacks soybeans. It is also commonly referred to as Dectes stem borer.
- Adult beetles are gray to bluish gray. They have long antennae and alternating light and dark gray bands.
- The larvae are legless and creamy white to yellow, with brown, incomplete head capsules.
- Females lay eggs into the stems at the petioles. When the eggs hatch the larvae bore into the stem and begin to feed inside the stem.

- Larvae feeding weakens the stem causing the plant to lodge. Lodging can cause difficulties in harvesting and result in significant yield losses.

Adult stem borer beetle.
Photo credit: S. Stewart

STINK BUG

- There are several species of stink bugs, but the most common in Africa is the green stink bug. Adults have a characteristic “shield” shape.
- Apart from soybean, the pest is known to cause damage to more than 50 host plants.
- Stink bugs feed on pods and seeds by injecting toxins that affect seed germination and quality and may lead to pod distortion. The pods become shriveled and eventually detach from the plant.
- The seeds are discolored and have low oil content.

Green stink bug.

Brown stink bug.

Photo credit: Ronica Mukaro

Green stink bug nymphs.

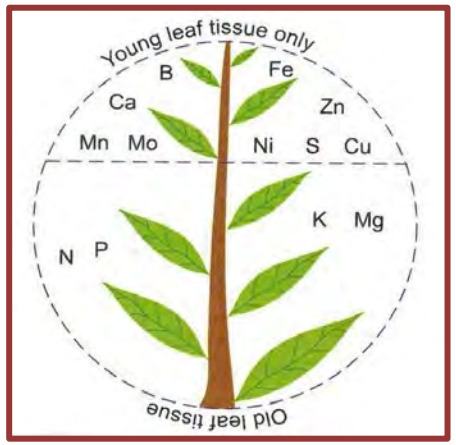
Nutrient Deficiencies

This section presents common nutrient deficiencies and their symptoms. The symptoms of nutrient deficiencies, diseases, and herbicide injury in soybean often look alike. Determining whether leaf discoloration or stunted growth is caused by a nutrient imbalance or a disease, or by another factor, is critical for identifying the appropriate management practices. Nutrient deficiencies can also occur in conjunction with diseases.

Nutrient toxicities refer to an excess of nutrients. Toxicities are often managed by changing soil pH. Toxicities are rarely a problem in soybean systems in Sub-Saharan Africa.

Nutrient deficiencies refer to insufficient amounts of a nutrient for healthy plant growth. Nutrient deficiencies may be managed by adding fertilizers and/or changing soil pH.

The most commonly deficient nutrients in soybean production are Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Sulfur (S), and Calcium (Ca). Soil testing will help you identify potential nutrient deficiencies. The symptoms of nutrient toxicity and deficiency appear in different parts of the plant depending on the mobility of the nutrient.



Nutrient deficiency symptoms may appear in young leaf tissue or old leaf tissue.

Image credit: Soil Fertility Manual (2016), IPNI

Nitrogen deficiency symptoms (leaf discoloration) are first evident in old leaf tissue.

NITROGEN (N)

- Soybeans require large amounts of N for optimal growth and development. Soybeans produce N through biological nitrogen fixation (BNF) but may still experience N deficiencies.
- N deficiency symptoms appear in older leaves. Leaves will turn light green or yellow, but leaf veins will remain green.
- Roots will have few nodules and/or inactive nodules. Active nodules are red inside when cut open while inactive nodules are white.
- Soybean inoculation is an easy way to promote good nodulation and BNF.

Nitrogen deficiency symptoms (leaf discoloration) are first evident in old leaf tissue.

Nitrogen deficient plants have few or no nodules.

Active nodules will be large (top); and red on the inside (bottom).

PHOSPHORUS (P)

- P is critical in protein and sugar synthesis (photosynthesis) and is often a limiting nutrient in soybean systems.
- P availability is strongly affected by soil pH. The ideal pH range for P availability is 6.0-7.0.
- P deficiency symptoms appear first in older leaves. P-deficient soybean plants may be stunted and have poor root development.
- Application of P fertilizers, such as Diammonium phosphate (DAP) and Triple superphosphate (TSP) can correct P deficiencies.

Soybean plants with sufficient P (left) vs. insufficient P (right). Plants with sufficient P have larger leaves and grow more quickly than those with P deficiencies.

Photo credit: Zanao, Jr., IPNI (2016)

POTASSIUM (K)

- K is essential for enzyme activity for protein and sugar synthesis (photosynthesis). K deficiencies make soybean plants more susceptible to drought, pest, and disease stress.
- Soybean plants that are deficient in K exhibit light green to yellow discoloration at the leaf margins. Symptoms first begin to appear on older leaves.
- K deficiency leads to stunted plant growth.
- K deficiencies can be corrected by using fertilizers such as Potassium chloride (KCl) and Potassium sulfate (K_2SO_4).

Soybean plants with K deficiencies exhibit yellowing at the leaf margins and stunted growth.

A close-up of soybean leaves exhibiting yellowing leaf margins due to K deficiency.

MAGNESIUM (Mg)

- Mg is critical for chlorophyll production, which gives leaves their green color. It is also essential for protein synthesis and nutrient transport.
- Mg is often a limiting nutrient in acidic soils.
- Mg deficiency symptoms first appear in older leaves. Leaves turn pale green with yellowing (chlorosis) between the leaf veins. Leaves may also begin to curl, known as leaf cupping. Plants will be stunted and have underdeveloped roots.
- Lime can be applied to acidic soils to increase Mg availability. Fertilizers containing Mg can also be applied.

Soybean plants with Mg deficiencies exhibit yellowing between leaf veins.

Photo credit: Francisco, IPNI (2016)

Leaf cupping can occur in soybean plants with severe Mg deficiencies.

SULFUR (S)

- S is critical for protein synthesis. It also plays an important role in BNF as it is necessary for nodule formation.
- S deficiency is more common in soils with low organic matter and/or sandy soils. Leaf tissue analysis in addition to soil testing is often necessary to diagnose S deficiency.
- S deficiency symptoms first appear on younger leaves. Leaves may turn light green or yellow and plant growth will be delayed.
- S deficiency can be avoided by top-dressing soybean fields with a sulfate-containing fertilizer.

Soybean plants with S deficiencies exhibit yellowing in the top leaves.
Photo credit: Casarin, IPNI (2016)

The top leaves will initially turn light green when soybean plants are deficient in S.
Photo credit: Sela, G. (2019)

CALCIUM (Ca)

- Ca is necessary for cell growth in roots, stems, and leaves. It is also an essential element of BNF.
- Ca becomes less available to plants in acidic and dry soils.
- Symptoms of Ca deficiency appear first on younger soybean leaves. Leaf curl and scorched shoots are common symptoms. Leaves may also show burning at the tips.
- Ca availability can be increased by applying of liming materials such as Calcium carbonate ($CaCO_3$) or gypsum.

Leaf curl and a burnt appearance of leaf tips in the top (younger) leaves of soybean plants can indicate a Ca deficiency.

Photo credit: Sela, G. (2019)

Leaf scorch is a common symptom of Ca deficiency.

Photo credit: Roberts (2016)

Management Practices

Yield and grain quality losses from diseases, pests, and nutrient problems can be reduced by implementing principles of integrated management. These include preventative, preemptive, and remedial strategies.

To optimize management options, the identity of the abiotic or biotic agent is necessary since this could be a nutritional problem, a misapplication of a pesticide, or caused by pathogens or pests. If the problem is caused by pathogens or pests, there may be a need to identify their specific type (biotypes, pathotypes, strains, or races)

that are causing the issue, which could be due to overcoming host resistance genes or overcoming the efficacy of pesticides.

The use of software programs that use location, identification, real time reporting of occurrences and risk for outbreaks of diseases and pests can provide a quick and appropriate management response. This technology will improve in time and become more commonplace.

In summary, management strategies for disease, pest, and nutrient problems encompass a decision matrix that involves one or more of the practice types discussed in the following pages (see nutrient section for specific recommendations on nutrients).

BIOLOGICAL CONTROL

- Biological control is the use of beneficial microbes to alleviate nutrient stress and protect plants from harmful pathogens and pests.
- **Plant growth promoting rhizobacteria** (PGPR) such as nodule-forming *Bradyrhizobium japonicum* can enhance nutrition, aiding the plant in defending itself against other microbes.
- Other PGPR like ***Azospirillium*, *Bacillus*, and *Pseudomonas* spp.** are known to benefit plant growth as well as directly interact with pathogens and pests.

- **Arbuscular mycorrhizal fungi** can form a symbiotic relationship with soybean roots and supply nutrients (especially phosphorus) and water and protect against pathogens and pests.

Soybean grown with mycorrhizal fungi (left) and without (right).

- **Entomophagous or hyperparasites** are fungi that can be used for control by directly attacking or interacting with a pathogen or pest.

White muscadine disease, Beauveria bassiana with killed armyworms (left), healthy armyworm (right).

Photo credit: K. Weller, USDA-ARS, Bugwood.org

CULTURAL CONTROL

- Cultural control methods are proactive ways to make your field a less appealing home for pathogens and pests. These practices can help alleviate the impacts of diseases and pests, especially when there are no other control options.
- **Clean seed** by screening out pathogens and pests before storing and planting; this reduces inoculum and introduction of pathogens and pests into new areas.
- **Crop rotation** with a non-host works well with diseases and pests that are specific to soybean.

- **Cover crops** may be used and can act as biofumigants, inducers of host resistance, and stimulate beneficial microbes that aid in root health or act directly on soilborne pathogens.

Clean soybean.

Poor quality due to discoloration and non-uniform seed size.

CULTURAL CONTROL (cont.)

- **Eradication** involves removal (elimination) of pathogens/pests in an area before it becomes well established or widespread. Examples include removal of alternate hosts, debris, and weeds that serve as hosts or reservoirs, aimed at breaking pathogen or pest cycles.
- **Sanitize or disinfect** equipment, clothing, and field supplies as these can be carriers for pathogens and pests.
- **Tillage** can reduce damage by pathogens and pests by burying and accelerating the breakdown of inoculum sources.

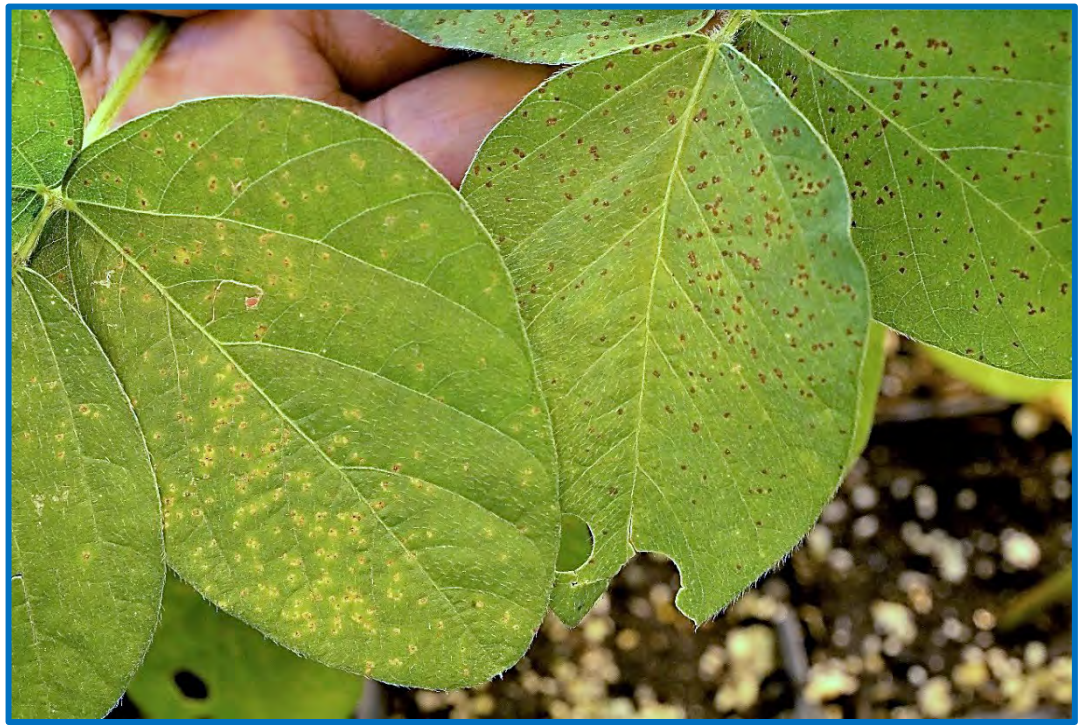
- **Weed management:** Weeds can serve as hosts of bacterial, fungal, nematode, and viral pathogens.

Tillage.

Weeds that can serve as hosts.

GENETIC CONTROL

- The use of soybean varieties with genetic resistance to economically important diseases or pests can be an effective, low-input management method.
- A few of the most important soybean diseases can be managed with resistance. This includes diseases caused by frogeye leaf spot, Phytophthora root and stem rot, root-knot nematode, southern stem canker, soybean cyst nematode, and soybean rust.



Varieties with a resistance gene to soybean rust produce a hyper-sensitive response (right) that appears as a reddish-brown lesion, while the susceptible variety produces a tan lesion with ample spores for reinfection (left).

CHEMICAL CONTROL

- Fungicides, insecticides, and nematicides can be used to treat seed, soil, or foliage.
- Recommendations to use pesticides varies by disease and pest, the environment, and the growth stage of the crop. In most cases, pesticides are not recommended unless the problem is persistent and/or known to be of economic importance.
- Some late season fungicide applications can be beneficial for harvesting higher quality seeds for seed production and sales.

- Fungicides vary by composition from elemental copper or sulphur to synthetics. Most fungicides are synthetic and include the benzimidazoles, triazoles, strobilurins, pyridinamines, and dicarboximides.

Agro-dealers typically offer a wide range of synthetic pesticides. Carefully read the label prior to purchasing pesticides to ensure that they are an appropriate tool to manage pest problems.

Additional resources

Hartman, G. L., Rupe, J. C., Sikora, E. F., Domier, L. L., Davis, J. A., and Steffey, K. L. 2015. Compendium of Soybean Diseases and Pests. American Phytopathological Society, St. Paul.

Hartman, G. L., West, E., and Herman, T. 2011. Crops that feed the world 2. Soybean-worldwide production, use, and constraints caused by pathogens and pests. Food Security 3:5-17.

Crop Protection Network
https://cropprotectionnetwork.org/resources/encyclopedia

Cabi.org

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