

Documentos

ISSN 1516-781X
October, 2024

466

Soybean Disease Identification Guide

*Brazilian Agricultural Research Corporation
Embrapa Soybean
Ministry of Agriculture and Livestock*

*ISSN 1516-781X
October, 2024*

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Embrapa Soja
Londrina, PR, Brazil
2024

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Document originally published under the title "Manual de identificação de doenças de soja", 6. ed., 2023. (Embrapa Soja. Documentos, 256).

1st edition (2024)

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**Cataloging in Publication (CIP)
Embrapa Soja**

Soybean Disease Identification Guide / Rafael Moreira Soares...

[et al.] -- Londrina : Embrapa Soja, 2024.

81 p. - (Documentos / Embrapa Soja, ISSN 1516-781X; n. 466)

1. Plant disease. 2. Fungi. 3. Soybean. I. Soares, Rafael Moreira. II. Godoy, Cláudia Vieira. III. Seixas, Claudine Dinali Santos. IV. Costamilan, Leila Maria. V. Meyer, Maurício Conrado. VI. Henning, Ademir Assis. VII. Almeida, Álvaro Manuel Rodrigues. VIII. Yorinori, José Tadashi. IX. Ferreira, Léo Pires. X. Dias, Waldir Pereira. XI. Série.

CDD 633.3493 (21.ed.)

Valéria de Fátima Cardoso - CRB-9/1188

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Foreword

The first step in carrying out an adequate disease control program in plants is the correct identification. This publication is the result of the effort of the Plant Pathology team at Embrapa Soybean, Embrapa Wheat, and former collaborators who have grouped here the main diseases of soybean crops already observed in Brazil, describing the symptoms, conditions for disease development and measures to prevent, manage, and control them.

Both the presentation of photographs and the format of the publication aim to help identify diseases in the field, being a valuable working tool for farmers, students, and professionals in the agronomic field.

Alexandre Lima Nepomuceno
General Head
Embrapa Soja

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Diseases caused by fungi



Anthracnose (*Colletotrichum* spp.)

Symptoms

It can cause seedling death and black spots on the veins of leaves, stems, and pods. Pods may fall or seeds may deteriorate when a harvest delay occurs. Pods infected at stages R3-R4 turn dark brown to black and become twisted; in filling pods, the lesions begin with anasarca streaks and evolve into black spots. The infected parts usually have several black dots that are the fungus' fruitings (acervuli).

Development conditions

Anthracnose is a disease that affects the initial stage of pod formation and occurs more frequently in the Cerrados, due to high precipitation and high temperatures. In rainy years, it can cause total loss of production, but, more frequently, it causes a reduction in the number of pods, causing the plant to retain leaves and green stems. Use of infected seeds and nutritional deficiencies, especially potassium, contribute to a higher occurrence of the disease. Seeds from crops that experienced harvest delays due to rain may have higher infection rates.

Control

The recommendation is to use seeds that are free of pathogens or treated with fungicides, seed treatment, crop rotation, increase spacing between rows and stands that allow good aeration of the crop and adequate soil management, mainly related to potassium fertilization.



Stem Canker (*Diaporthe aspalathi* and *D. caulivora*)

Symptoms

The initial symptoms, visible 15-20 days after infection, are small black dots that evolve into elongated to elliptical spots and change from black to reddish-brown in color. In the final stage, the spots acquire a light brown color with reddish-brown edges, generally on one side of the stem. Severe infections cause stem breakage and lodging. The lesions are deep, and the color of the necrotic pith varies from reddish-brown, in a still green plant, to light brown to purplish, in a dry stem. One of the indications of a plant in an advanced stage of infection is the presence of yellowed leaves with necrosis between the veins, in the case of *D. aspalathi*.

Development conditions

The pathogen remains viable in crop residues from one season to another. Under prolonged conditions of high humidity, perithecia can form on cankers of green plants. The disease development is slow, since infections occurring early in the soybean's vegetative phase form cankers between flowering and pod filling. Adult plants acquire resistance to the disease. The infection level in seeds are typically low.

Control

The most economical and efficient way to control the disease is through the use of resistant cultivars. The following control measures can also be used: seed treatment, crop rotation with cotton, rice, sunflower, corn, pasture or sorghum and succession with white oats, black oats, millet; sowing with bigger spacing between rows and between plants to avoid etiolation and lodging; balanced fertilization and liming. Seed treatment with systemic and contact fungicides is the safest way to prevent the reintroduction of the fungus.

L.M. Costamilan



R. M. Soares



P.F. Bertagnolli



J. T. Yorinori



Cercospora Leaf Blight and Purple Seed Stain (*Cercospora* spp.)

Symptoms

The fungus attacks all aerial parts of the plant. On the leaves, characteristic symptoms are dark, reddish-brown spots with fuzzy edges, which coalesce and form large dark spots that result in severe blight and premature defoliation. Red dots appear on the pods that evolve into reddish-brown spots. Through the pod, the fungus reaches the seed and causes the purple stain on the seed coat. On the stems, the fungus causes red spots, usually superficial, limited to the cortex. When the infection occurs in the nodes, the fungus can penetrate the stem and cause reddish necrosis in the pith.

Development conditions

The fungus is widespread throughout the country's soybean-producing regions, and it is more severe in the hottest and rainiest regions. It is the fungus most frequently found in seed lots, but it does not affect germination. The fungus can get into the crop through infected seed if it is not treated with fungicide, but it survives in crop residues. The disease is favored by temperatures between 23 °C and 27 °C and high humidity.

Control

Control demands the use of pathogen-free seed, seed treatment and fungicide aerial applications.

R. M. Soares



C.V. Godoy



M.C. Meyer



Asian Soybean Rust (*Phakopsora pachyrhizi*)

Symptoms

They can appear at any stage of the plant development. The first symptoms are characterized by tiny dots (maximum 1 mm in diameter) darker than the healthy tissue of the leaf, greenish to gray-green in color, with a corresponding protuberance (uredia) on the lower page of the leaf. The uredia turn light brown to dark brown and open into a tiny pore, expelling the hyaline spores that accumulate around the pores and are carried by the wind.

Development conditions

The infection process depends on the availability of free water on the leaf surface, requiring at least 6 hours, with a maximum infection occurring between 10 and 12 hours of leaf wetness. Temperatures between 18 °C and 26.5 °C are favorable for infection. The sooner defoliation occurs, the smaller the grain size will be and, consequently, the reduction in productivity. American rust (*P. meibomiae*) is recognized as having little impact on yield; *P. pachyrhizi* is more aggressive and can cause significant losses.

Control

Chemical control with fungicides formulated in a mixture of different chemical groups has proven to be efficient. The fungicide must be applied preventively or at the first symptoms of the disease. Sowing should occur at the beginning of the indicated season, preferably using early cultivars and complying with the soybean-free period (eliminating volunteer soybean plants in the off-season) to reduce the inoculum in the following harvest; avoid sowing soybean after soybean. Resistant cultivars are available for some regions of Brazil, however, they do not eliminate the use of fungicides, since virulent populations can be selected due to the variability of the pathogen.

C.V. Godoy



J.T. Yorinori



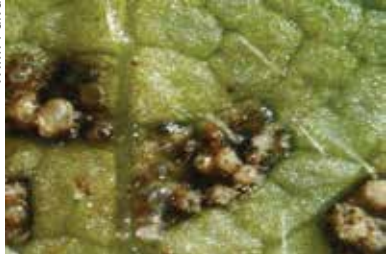
J.T. Yorinori



J.T. Yorinori



W.M. Paiva



Target Spot and Root Rot of *Corynespora* (*Corynespora cassiicola*)

Symptoms

The lesions begin with brown spots, with a yellowish halo, evolving into large circular spots, light brown to dark brown, reaching up to 2 cm in diameter. Generally, the spots have a dark dot in the center, similar to a target. Susceptible cultivars may suffer severe defoliation, with reddish-brown spots on the stem and pods. The fungus also infects roots.

Development conditions

The fungus occurs in practically all soybean-growing regions in Brazil. Apparently, it is native and infects numerous of native and cultivated plants. It can survive in crop residues and infected seeds. High relative humidity is favorable for leaf infection.

Control

The use of resistant cultivars, seed treatment, crop rotation/succession with corn and other grass species and control with fungicides are recommended.

J.T. Yorinori



C. D. S. Seixas



J.T. Yorinori



J.T. Yorinori



Ascochyta Leaf Spot (*Ascochyta sojae*)

Symptoms

Leaf spots begin as small reddish-brown dots, expanding to circular lesions, reaching up to 1.5 cm. With the expansion of the spots, the central part becomes light brown, differentiating itself from the reddish-brown edges. The central part breaks easily, leaving the leaf with holes or tears. In the lighter part of the center, tiny dark brown dots can be seen that constitute the pycnidia of the fungus. The disease usually starts in patches in the field.

Development conditions

Generally occurs in the Cerrados under warm and rainy conditions. The spores (conidia) are expelled from the pycnidia in the form of a mass of spores (cirri) and are dispersed by the action of water.

Control

Due to the low levels of occurrence, control measures are non-recommended.

A.M.R. Almeida



Myrothecium Leaf Spot (*Myrothecium roridum*)

Symptoms

It can be confused with some other foliar diseases, like *Phyllosticta* leaf spot, frog-eye leaf spot, or target spot. The fungus can infect the entire aerial part of the plant, but is more common on the leaves. The lesion begins with a circular, light green spot and evolves into rounded spots, reaching 3-5 mm in diameter. On the upper page of the leaf, the spots have a light brown center and dark brown margin. On the lower page, the color is uniformly dark brown and, under conditions of high humidity, it presents white dots, like small tufts of cotton, which constitute the mycelium of the fungus, where small black masses of spores form in the center of injuries.

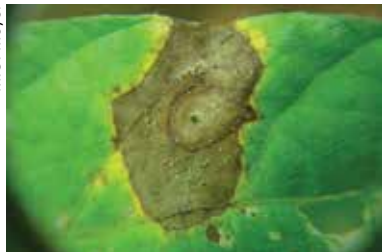
Development conditions

The disease begins in patches. It is more common in the Cerrados. The spreading of spores is through the action of rain and wind.

Control

Due to the low levels of occurrence, control measures are non-recommended.

M.C. Meyer



M.C. Meyer



Frogeye Leaf Spot (*Cercospora sojina*)

Symptoms

The disease can occur at any stage of the plant, but is more common after flowering. It affects the leaf, stem, pod and seed, starting as tiny dots of waterlogging (anasarca), which evolve into spots with light brown centers on the upper side of the leaf, and gray on the lower side, and reddish-brown edges on both sides of the leaves. On the stem and pod, the lesions have a waterlogged appearance in the initial phase, evolving into circular dark-brown spots on the pod and elliptical or elongated spots with a gray center and reddish-brown edges on the stem. In the seed, it causes cracks and brown to gray spots.

Development conditions

The fungus is spread through infected seeds and spores carried by the wind and survives in crop debris. Conditions of high humidity and temperature favor the disease. The pathogen can develop new races. The occurrence in the field is sporadic and can appear in areas cultivated with introduced susceptible cultivars.

Control

The use of resistant cultivars, seed treatment and application of systemic fungicides mixed with contact fungicides are essential for controlling the disease and preventing the introduction of the fungus or a new race.

R.M. Soares



R.M. Soares



R.M. Soares



Brown Spot (*Septoria glycines*)

Symptoms

The first symptoms appear approximately two weeks after emergence, as small reddish-brown spots or spots with angular contours on the single-leaflet leaves. In favorable situations, the disease can affect the first leaves causing defoliation. On the leaves, brown spots appear, smaller than 1 mm in diameter, which evolve and form spots with yellowish halos and an angular center, brown in color on both sides, measuring up to 4 mm in diameter. At the end of the cycle, under conditions of severe infection, it causes defoliation and early maturation.

Development conditions

The fungus survives on crop residues. Infection and disease development are favored by warm, humid conditions. The dispersion of spores occurs through the action of water and wind. The fungus requires a minimum period of wetness of 6 hours and temperatures between 15° C and 30° C to develop symptoms, with an optimum of 25° C.

Control

The fungus survives on crop residues. Infection and disease development are favored by warm, humid conditions. The dispersion of spores occurs through the action of water and wind. The fungus requires a minimum period of wetness of 6 hours and temperatures between 15° C and 30° C to develop symptoms, with an optimum of 25° C.

M. C. Meyer



J.T. Yorinori



R.M. Soares



Rhizoctonia Aerial Blight (*Rhizoctonia solani* AG1)

Symptoms

The fungus can infect soybeans at any stage of development, affecting the entire aerial part of the plant. The infected parts dry quickly, turning light brown to dark brown. Infected leaves and petioles hang along the stem or fall onto neighboring plants, spreading the disease. In dead tissues, the fungus forms thin mycelium webs with abundant production of microsclerotia, beige to dark brown. Infections on the stems and pods result in reddish-brown lesions. The disease occurs in patches.

Development conditions

Temperatures between 25 °C and 30 °C and long humid periods favor the disease. The rainfall frequency and distribution during the crop cycle are determining factors for the occurrence of the disease. The fungus survives in the soil through sclerotia, crop residues, and alternative hosts. Spread occurs mainly through rain splashes and contact between plants. The pathogen has a wide host range.

Control

Integrated measures must involve practices such as the use of soil mulch, through the direct sowing system, balanced nutrition (mainly K, S, Zn, Cu, and Mn), rotation/succession with non-host crops, adequacy of plant population and spacing, seed treatment with fungicides, use of seeds with good sanitary and physiological quality, elimination of weeds and soybean debris and chemical control with fungicides. The greatest efficiency of chemical control is achieved when adopted before the severity reaches the level of 10% of the infected leaf area.

M.C. Meyer



M.C. Meyer



M.C. Meyer



Downy Mildew (*Peronospora manshurica*)

Symptoms

The disease begins in single-leaflet leaves and progresses, reaching the entire aerial part. The initial symptoms are light green spots, with 3 to 5 mm, on the upper leaf surface, evolving into yellowish and later into necrotic tissue. On the back of the yellowish spot, fruiting structures of the pathogen appear with a cottony appearance and a slightly pink to gray color. Infections in the pod can result in seed deterioration or partial infection, with the formation of a powdery crust made up of mycelium and spores, giving a beige to light brown color to the seed coat.

Development conditions

The pathogen introduction into crops is through infected seeds and the spores spread by the wind. The fungus occurs in practically all soybean-producing regions in Brazil. Climatic conditions of mild temperatures (20 °C to 22 °C) and high humidity, especially in the vegetative phase, are favorable to the disease. Transmission by seeds through oospores attached to the seed coat is rare.

Control

There are no recommended control measures due to the low economic importance of the disease.

C.V. Godoy



A.C.B. Oliveira



A.A. Henning



R.M. Soares



Rhizoctonia Damping-off and Root Rot (*Rhizoctonia solani* AG4)

Symptoms

In the seedling phase, the strangulation of the stem at ground level occurs, resulting in wilting and tipping over or temporary survival, with the emission of adventitious roots above the affected region. These plants usually fall over before flowering. At flowering, brown watery rot occurs on the stem close to the soil level. The root system acquires a dark brown color, the cortical tissue becomes soft, and comes off easily, exposing firm, white to light brown wood. These plants die in groups in the field (patches) with the leaves attached facing downwards.

Development conditions

Damping-off occurs between pre-emergence and 30-35 days after emergence, under conditions of high temperature and humidity. Patches of dead plants are generally observed after flowering. The disease is favored by mild temperatures in rainy years. The fungus transmission rate through seeds is low and its importance is questionable, as it occurs naturally in soils.

Control

The occurrence of damping-off caused by *R. solani* can be reduced by treating seeds with fungicide (for protection during emergence, against the fungus in the soil), by rotating crops with grasses, and by eliminating soil compaction to avoid waterlogging.

A.M.R. Almeida



A.M.R. Almeida



A.M.R. Almeida



Sclerotium Blight (*Sclerotium rolfsii*)

Symptoms

It can infect seedlings, causing damping or wilting. Damping-off results from a soft, watery rot that starts shallowly below the ground surface. Usually, it occurs along the rows or in patches of dead plants. Dead seedlings, when pressed with the fingers, feel hollow. In older plants, the infection causes yellowing of the leaves, which wither and fall. The fungus develops along the plant stem, forming a white covering of mycelium, which can produce cream-colored sclerotia that turn dark brown.

Development conditions

The fungus is common in all regions of Brazil, however, the incidence of the disease varies. The presence of decomposing cultural debris may favor the occurrence of the disease. Conditions of high humidity and heat (30 °C to 35 °C) are favorable to the development of the fungus from the germination of sclerotia or mycelium developed in organic matter in the soil. Infections are also commonly seen after a dry period. Dehydrated sclerotia are stimulated to germinate when moisture returns, and the plant exudates are present in the soil. The fungus can be spread through soil adhered to equipment.

Control

The fungus is capable of infecting more than 200 plant species, making it hard to control. The burial of crop residues contributes to the degradation of sclerotia by other microorganisms in the soil.

M.C. Meyer



A.M.R. Almeida



Powdery Mildew (*Erysiphe diffusa*)

Symptoms

Erysiphe diffusa is an obligate parasite that develops throughout the aerial part of the plant. It has a whitish thin coating, made up of mycelium and powdery spores. On the leaves, over time, the white color of the fungus changes to grayish-brown and, in conditions of severe infection, it can cause drought and premature leaf fall.

Development conditions

Infection can occur at any stage of plant development. Conditions of low relative air humidity and mild temperatures (18 °C to 24 °C) are favorable for the development of the fungus.

Control

The most efficient control method is the use of resistant cultivars. Chemical control through the application of fungicides is also efficient.

C.V. Godoy



A.M.R. Almeida



Sclerotinia Stem Rot (*Sclerotinia sclerotiorum*)

Symptoms

Watery spots that evolve into a light brown color and soon develop abundant formation of dense, white mycelium. The fungus is capable of infecting any part of the plant but infections often begin from fallen petals in the axils of leaves and lateral branches. Occasionally, symptoms of wilting and dryness are observable on the leaves. In a few days, some rounded black sclerotia will form from the mycelium, originating the pathogen soil survival structure. Sclerotia vary in size, and can be formed both on the surface and inside the stem and infected pods.

Development conditions

The most vulnerable phase of the plant to infection is from the full flowering stage to the beginning of pod formation. Sclerotia fallen to the ground, under high humidity, and temperatures between 10 °C and 21 °C, germinate and develop apothecia on the soil surface. These produce ascospores that are released into the air and are responsible for infecting plants. Transmission by seed can occur both through dormant (internal) mycelium and through sclerotia mixed with seeds.

Control

Avoid introducing the fungus into the field by using certified pathogen-free seeds. Carry out seed treatment with a mixture of systemic and contact fungicides. The following control measures are applicable where the disease occurs frequently: directly sowing on grass straw, rotation/succession of soybeans with non-host species such as corn, sorghum, millet, oats, or wheat; eliminate the host plants of the fungus; adequate plant nutrition; reduction of the plant population to the minimum recommended. Fungicide applications can be carried out at the beginning of flowering to pod formation.

A.A. Henning



M.C. Meyer



A.A. Henning



A.A. Henning



Charcoal Rot (*Macrophomina phaseolina*)

Symptoms

Root infection can occur from the beginning of soybean seed germination, as the fungus is a natural inhabitant of the soil. Lesions on the neck of the plant are reddish-brown and superficial. Infected rootlets present darkened tissues. The infection is favored by lack of rainfall and symptoms in the aerial part are evident in the soybean reproductive phase when the leaves initially become chlorotic, dry and acquire a light-brown color, remaining attached to the petioles. At this stage, the plants present gray roots, whose epidermis is easily detached, showing black microsclerotia in the tissues immediately below.

Development conditions

Cultivation systems that disrupt and compact the soil make plants more sensitive to drought and favor infection by *M. phaseolina*.

Control

Adequate soil coverage with a grass crop residues, accompanied by an adequate physical and chemical soil management proved to be effective in reducing water stress, reducing the predisposition of plants to attack by *M. phaseolina*. In compacted soils, scarification to facilitate root penetration.

C.V. Godoy



A.A. Henning



A.A. Henning



M.C. Meyer



A.A. Henning



Brown Stem Rot (*Cadophora gregata*)

Symptoms

From the stage of grain filling onwards, brown darkening of the pith of the stem and root can be observed. These symptoms may come with sudden chlorosis and interveinal necrosis of leaves, followed by early fall. The disease does not present external symptoms in the stem and roots.

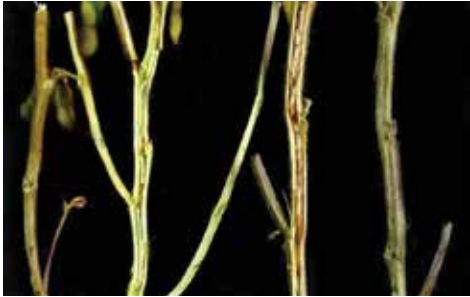
Development conditions

The fungus survives in soybean crop residues in the soil and does not spread by seed. Infection occurs through the root system, approximately 30 days after germination. The increase in the intensity of symptoms, both foliar and internal to the stem, is favored by air temperatures between 15 °C and 27 °C and high soil humidity after flowering.

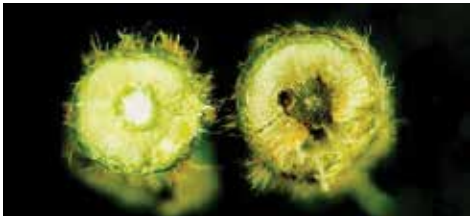
Control

Use of resistant cultivars. Susceptible cultivars can be sown after resistant cultivars, but not for two consecutive seasons in the same area. Crop rotation is only effective after the third year without soybeans in the affected area.

L.M. Costamilan



L.M. Costamilan



L.M. Costamilan



Rosellinia Root Rot (*Rosellinia necatrix*)

Symptoms

Isolated or grouped plants present intense yellow leaves, often more pronounced on one half of the leaflet, and may also present necrosis between the veins. The root has dry rot that decomposes the woody tissue, so that the root breaks easily when uprooting the plant. Under moist soil conditions, the fungus produces a layer of white mycelium and spur-like structures visible at ground level.

Development conditions

The fungus infects several species of perennial plants and is an important agent of wood degradation. It can occur in any growing region, without much influence from the climate.

Control

In general, the disease does not require the adoption of control measures, however, rotation with grasses can alleviate the problem.

J.T. Yorinori



Pod and Stem Blight (*Diaporthe sojae*)

Symptoms

Symptoms of the disease on the plant appear during the final stages of the reproductive phase, being characterized by black spots (pycnidia), which are formed linearly on the stem and petioles, and randomly on the pods.



J.T. Yorinori

Development conditions

The fungus survives as a dormant mycelium or in the form of pycnidia in crop residues or infected seeds. The spores are spread within the crop by rain splashes. Prolonged periods of humidity, associated with high temperatures during maturation, favor the spread of the fungus from the pods to the seeds. Its greatest damage is observed in rainy years, in the initial stages of pod formation and at maturation, when harvest is delayed due to excess humidity.

Control

The use of healthy seeds, seed treatment, crop rotation, and adequate soil management are recommended, particularly regarding potassium fertilization. During seed storage under ambient conditions, *Diaphorthe* spp. loses viability quickly. Seed treatment with systemic fungicides, is effective for eradicating the fungus.

Phytophthora Root and Stem Rot (*Phytophthora sojae*)

Symptoms

Symptoms can be found in soybean plants at any stage of development. Infected seeds can rot or germinate slowly, resulting in the death of seedlings, with the hypocotyls looking soggy and brown. In adult plants, symptoms begin with leaf chlorosis and plant wilting. The leaves dry and remain attached to the stem.

The stem and lateral branches exhibit dark brown rot, which surrounds the stem and progresses from below upwards on the plant, from the soil line, reaching several nodes. Internally, the cortex and vascular tissues become dark.

Development conditions

The ideal climatic conditions for emergence failures and seedlings damping-off are temperatures around 25 °C and high soil humidity during sowing and emergence. Compacted soils and direct seeding also increase the intensity of rot. The pathogen develops resistance structures (oospores), which remain viable in plant debris culture and in the soil for many years. At more advanced stages, symptoms vary with the cultivar's level of resistance/tolerance.

Control

To avoid emergence failures, the use of resistant cultivars, seed treatment and improvement of soil drainage conditions are recommended. There are no control measures indicated for adult plants.

R.M. Soares



L.M. Costamilan



L.M. Costamilan



Sudden Death Syndrome [*Neocosmospora phaseoli* (syn. *Fusarium brasiliense*, *F. tucumaniae*, *F. crassistipitatum*)]

Symptoms

It can occur in plant patches or generally in crops. Root infection begins with a reddish spot, most visible on the main root, generally located one to two centimeters below the soil surface. This spot expands, surrounds the root, and turns from purplish-red to reddish-brown to almost black. The woody tissue of the stem, above ground level, acquires a light brown color. In the aerial part, premature yellowing of the leaves and necrosis between the veins are observed. In severely affected plants, premature defoliation and pod abortion may occur.

Development conditions

The disease usually appears close to flowering. Early cultivars tend to suffer less damage. The disease is most severe in poorly drained soils with compaction problems. The optimum temperature for its development varies from 22 °C to 24 °C.

Control

Use of resistant cultivars. No sowing in compacted or poorly drained soils. Crop rotation with corn or coverage with millet are not efficient in controlling.



Diseases caused by bacteria



Bacterial Blight (*Pseudomonas savastanoi* pv. *glycinea*)

Symptoms

It is common on the leaf, but can attack the stem, petiole, and pod. It begins with watery spots, semi-transparent when viewed against the light, which necrotize and coalesce, forming large areas of dead tissue. There may or may not be a wide yellowish halo around the spots at mild temperatures, and narrow or absent at temperatures above 27 °C. Observation of the black spots with irregular edges on the lower page of the leaf allows diagnosis of the disease in the humid hours of the morning, due to the presence of a shiny film, which is the exudate of the bacteria. Severe

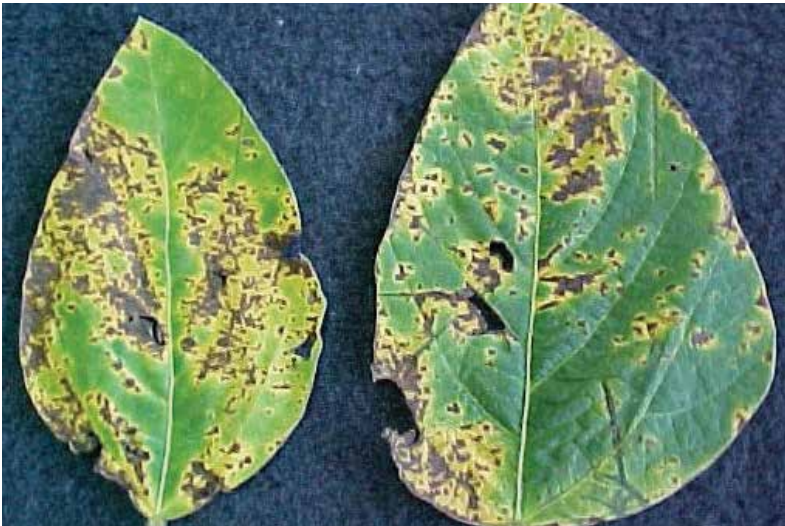
attacks cause the tearing and fall of interveinal spaces in the leaves.

Development conditions

Infected seed and debris from previous soybean cultivation are the initial sources of inoculum. The infected seed shows no symptoms. The disease is favored by high humidity, especially windy rain and mild temperatures (20 °C to 26 °C). On dry days, thin scales of the bacteria's exudate are disseminated on the crop, but for infection to occur there needs to be a film of water on the surface of the leaf. The bacteria enter the leaf through stomata or wounds.

Control

There are no recommended control measures for this disease.



Wildfire (*Pseudomonas syringae* pv. *tabaci*)

Symptoms

They appear on the leaves, where the bacteria produce a toxin that disseminates into the tissues, causing necrotic lesions with a yellowish halo. Lesions vary in size and shape, and may coalesce, forming extensive areas of dead tissue. In severe attacks, early defoliation may occur in susceptible cultivars.

Development conditions

This bacterium can be transmitted by seed and crop residues, which serve as a source of inoculum. It is spread by splashing water. It can take advantage of injuries caused by other pathogens, such as the bacteria that cause bacterial pustule to penetrate plant tissue.

Control

Use of resistant cultivars.



Bacterial Pustule [*Xanthomonas citri* pv. *glycines* (syn. *X. axonopodis* pv. *glycines*)]

Symptoms

Typical on leaves, but also infects stem, petiole, and pod. The spots are rounded, never angular, and brown in color. On the lower page of the leaf, in the center of the lesion, there is a little whitish elevation resembling a volcano. In addition to this elevation, this disease differs from bacterial blight due to the lack of shine on the lower surface. In susceptible cultivars, the large number of pustules on the leaf surface gives the leaf a rough appearance, both to sight and to touch. At more advanced stages of the crop, based on symptoms alone, the pustule can be confused with bacterial blight and rust.

Development conditions

The pathogen is transmitted through the seed, which does not show typical symptoms. Crop remains are also a source of inoculum. Rain and wind, with high humidity and high temperatures (above 28 °C), favor secondary infections. The bacteria can survive in the rhizosphere of the wheat crop, thus maintaining the inoculum for the next soybean crop.

Control

Use of resistant cultivars.



Bacterial Tan Spot (*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*)

Symptoms

It starts with small chlorotic lesions, which enlarge and can take over the entire leaflet. There is no anasarca. Chlorosis begins in an oval or elongated shape, often from the margin of the leaves, and progresses towards the center. The lesions can coalesce, forming necrotic brown areas that, with the action of wind and rain, can tear the leaf. Seeds may look discolored due to bacterial growth, and seedlings from infected seeds may be stunted. The symptom of plant wilt, as occurs in beans rarely in soybeans.

Development conditions

The bacteria transmission can be through seeds. In crops, spread occurs through injuries caused by contact between leaves. It survives in soil and crop residues, infecting seedlings during germination. Temperatures between 25 °C and 30 °C favor the infection.

Control

Use of certified seeds, crop rotation with non-host species and the use of resistant cultivars. Leaf symptoms are reduced after flowering.

R. M. Soares



G. E. S. Carneiro



G. E. S. Carneiro



Diseases caused by viruses



Alfalfa mosaic virus - AMV

Symptoms

Leaves of infected plants become chlorotic and wrinkled. Usually, plants are not affected in their development. However, when plants originate from infected seeds, development is reduced. Seed transmission is observable visually, starting from chlorosis in the primary leaves.

Development conditions

The virus depends on aphids for its transmission and the presence of host plants. In Brazil, aphid presence is well-reduced.

Control

Resistant cultivars are available. However, the virus never became a problem in Brazil.

A.M.R. Almeida



Bean pod mottle virus - BPMV

Symptoms

They are most evident during periods of rapid plant growth and mild temperatures. Typical symptoms are characterized by chlorotic mottling and blisters on young leaves, which tend to decrease in intensity as the leaves get older. In association with the *Soybean mosaic virus*, BPMV causes severe leaf distortion, stunting, and necrosis of the top of the plants.

Development conditions

The virus transmission is by the Coleoptera of the species *Cerotoma trifurcata* and *Epicauta vittata*. BPMV infects few plant species, all of which belong to the Fabaceae family (legumes). Beans, *Lespedeza thunbergii*, *Stizolobium deeringianum*, *Trifolium incarnatum* and *Desmodium paniculatum* are some examples.

Control

There is no description of genotypes resistant to BPMV.

A.M.R. Almeida



Soybean mosaic virus - SMV

Symptoms

Infected plants have shriveled trifoliolate leaves, with some blisters and a mosaic distributed irregularly on the leaf blade. Delayed maturation and green plants among already-matured plants are frequent. Susceptible genotypes produce seeds with spots (coffee spot). These spots are brown or black, depending on the color of the hilum. There are, however, susceptible genotypes that do not produce stained seeds. Seeds without blemishes can transmit the virus and result in infected seedlings. However, not all stained seeds produce infected seedlings.

Development conditions

The Soybean Mosaic Virus was introduced into Brazil through infected seed and is distributed in all regions where soybeans are grown. It is transmitted by aphids from the host plants. Climatic conditions that favor the aphid population contribute to a higher incidence of the virus in the field.

Control

As with other plant viruses, the most efficient way to control this disease is through resistant cultivars.



Cowpea mild mottle virus - CPMMV

Symptoms

At flowering and the beginning of pod formation, the symptoms become evident with the appearance of bud burn and stem necrosis when the plants end up dying. Stems cut lengthwise show a darkening of the pith. Plants that do not die show severe dwarfism and deformed leaves. Infected plants may produce deformed pods and small grains.

Development conditions

The virus transmission is by whiteflies (*Bemisia tabaci*). Any condition that favors the development of the whitefly population also favors the appearance of the disease, as long as there is an infected host plant available. *Desmodium tortuosum* and *Arachys pintoii* are host plants for this virus in Brazil.

Control

Use resistant cultivars. Whitefly control is not effective. In addition to the difficulties in controlling this insect, non-persistent transmission favors the spread of the virus in soybean fields.

A.M.R. Almeida



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A.M.R. Almeida



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Tobacco streak virus - TSV

Symptoms

Plants infected by the virus have a curved, necrotic, and easily breakable apical shoot. Normally, they present darkening of the pith of the main stem, which is the main symptom for diagnosing this disease. After the death of the apical bud, the plants produce excessive axillary sprouting, with tapered leaves of reduced size. Growth is paralyzed, giving it the appearance of a dwarf plant. The formed seed may present a stain associated with the rupture of the seed coat, which becomes less shiny.

Development conditions

The virus is transmitted by thrips and infects several plant species such as sunflower and peanuts. In the field, the main source of inoculum is the clove plant (*Ambrosia polystachya*).

Control

There are no resistant cultivars. As the thrips population is reduced by the action of rain, late sowing is recommended, a time when the incidence of the virus remains below 15% of infected plants, with negligible losses. The use of insecticides, by spraying or granules, applied together with the seed does not provide control, since the viruliferous thrips continue to migrate for a long period, from outside to inside the crops, and can infect the plants before dying due to the effect of the insecticides.



Diseases caused by nematodes



Soybean Cyst Nematode (*Heterodera glycines*)

Symptoms

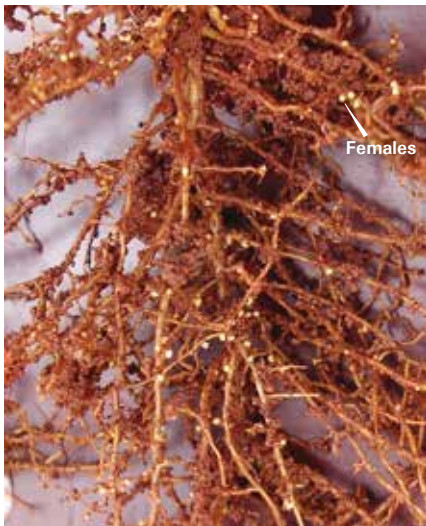
The nematode penetrates the roots of the plant and hinders the absorption of water and nutrients, causing a reduction in the size and number of pods, chlorosis, and low productivity. Symptoms appear in patches and, in many cases, the plants die. The root system is reduced, presenting tiny females with a slightly elongated lemon shape, white to yellowish in color. When the female dies, her body transforms into a resistant structure, dark brown, full of eggs, called a cyst, which detaches from the root and remains in the soil. Diagnosis requires analysis of soil and/or root samples in a nematology laboratory.

Development conditions

The cyst can remain in the soil for more than eight years, even in the absence of the host. In moist soil, with temperatures of 20 °C to 30 °C, the juveniles hatch and, if they find the root of a host plant, they penetrate and the cycle is completed in about four weeks. The traffic of machines, equipment and vehicles, carrying particles of contaminated soil, are agents of dispersion of the nematode. It can also be spread by runoff, animals and seed-containing soil particles.

Control

Infestation prevention must be done by cleaning machines, implements, tools and shoes and using processed seed, without soil particles. Control strategies include crop rotation with non-host species, soil management (adequate level of organic matter, balanced fertilization, absence of compaction, among others) and the use of resistant cultivars. In Brazil, there are resistant cultivars adapted to different growing regions.



Root-Knot Nematodes (*Meloidogyne incognita* and *M. javanica*)

Symptoms

In infested areas, it occurs in patches, where the leaves of affected plants normally present chlorotic spots or necrosis between the veins. Sometimes, there may be no reduction in the size of the plants but at the time of flowering, there is intense pod abortion and premature ripening. On the attacked roots, galls are observed in varying numbers and sizes, depending on the susceptibility of the soybean cultivar and the population density of the nematode. Diagnosis requires analysis of soil or root samples in a nematology laboratory.

Development conditions

The root-knot nematodes parasitize a large number of plant species and survive in some weeds, making control difficult. Their life cycle is temperature-dependent, with optimal conditions at 25 °C, where the nematode completes its developmental cycle within approximately 21 to 28 days.

Control

The most effective management strategies involve crop rotation and the deployment of resistant cultivars. However, crop rotation must be meticulously planned as many

cultivated species can serve as hosts, facilitating nematode proliferation. Accurate identification of the *Meloidogyne* species and, if feasible, the corresponding race is critical for the success of these strategies. It is essential to adopt cover crops in the rotation to restore soil organic matter and enhance microbial activity, both of which contribute to nematode suppression. Additionally, the practice of no-till sowing aids in minimizing the spread of nematodes.

A. A. Henning



W.P. Dias



Root Lesion Nematode (*Pratylenchus brachyurus*)

Symptoms

In addition to the general symptoms described for other nematodes, soybean roots show necrotic areas. This is due to the attack on cortical parenchyma cells, where the parasite injects toxins during the feeding process. Its movement at the root also disorganizes and destroys cells. Parasitized roots can be invaded later by fungi and bacteria. There is no gall formation, and the root system is reduced and darkened. Diagnosis requires soil analysis or root samples in a nematology laboratory.

Development conditions

In addition to soybeans, the nematode can parasitize corn, sugar cane, cotton, and peanuts, among others. The maximum damage occurs in soils with high sand content, especially in soybeans planted after degraded pasture.

Control

As *P. brachyurus* is a polyphagous nematode, parasitizing most crops with economic value, there is still no resistant soybean cultivar. Control has been carried out by sowing infested areas, in the off-season, with resistant *Crotalaria* species or some millet genotype that multiplies the parasite less. However, as nematode populations rapidly grow again after a new soybean crop, these measures have to be repeated every year.



Reniform Nematode (*Rotylenchulus reniformis*)

Symptoms

Infested soybean crops are characterized by significant unevenness, with extensive areas of underdeveloped plants that are very similar to problems of mineral deficiency or soil compaction. Typically, there are no rollbacks. There is no gall formation, and the root system is small. At some points on the roots, it is possible to observe a soil layer adhered to the nematode egg masses externally produced. Mature females have a kidney-like conformation.

Development conditions

Cotton is the crop most affected by this nematode. However, depending on the cultivar and the nematode population in the soil, damage can also occur in soybeans. Unlike other species that occur in soybeans, the reniform nematode does not seem to have its occurrence limited by soil texture, occurring in both sandy and clayey soils.

Control

Rotate/succeed with non-host crops and use resistant cultivars. Corn, rice, peanuts and brachiaria are resistant and can be used in rotation with soybeans or cotton. Of the plants used as cover crops in no-till sowing, brachiaria, forage turnip, forage sorghum, black oat, millet, and crow's foot grass are resistant. Because the reniform nematode is very persistent in the soil, depending on population density, there may be a need for a minimum of two years of cultivation with a non-host species.



Green Stem Nematode (*Aphelenchoides besseyi*)

Symptoms

The plants exhibit leaves with a darker green color, reduced hairiness, tapering, and bubbling on the leaf blade. Reddish-brown to brown angular necrotic lesions may appear. The stems show fluting, besides node thickening and twisting of the internodes at the top of the plants. There is flower abortion, and in some cases, rosetting of the floral racemes. The pod number might reduce drastically, and the remaining pods usually show deformations and brown necrotic lesions. The beans formed in these pods typically remain green and eventually rot. Affected plants do not complete their cycle, remaining green with retained leaves.

Development conditions

The areas of highest incidence and severity are in the hot and rainy regions of the states of Mato Grosso, Pará, Rondônia, Amapá, Acre, Maranhão, and Tocantins. The nematode can survive saprophytically in the soil, feeding on fungi that decompose organic matter or, in extreme conditions, enter anhydrobiosis and survive for months in crop residues. Spread occurs through contact between diseased and healthy leaves in the presence of water. During harvesting, the nematode dispersion is through diseased plant residues expelled by harvesters and wind action. Notable weed hosts include *Commelina benghalensis*, *Leonotis nepetifolia*, *Amaranthus viridis*, and *Synedrellopsis grisebachii*.

Control

The recommendation is to sow soybeans on completely desiccated plant straw (desiccation 15 to 20 days in advance). Weed control should be initiated right at the beginning of soybean development, in the post-emergence stage. Cultivating corn as a second crop whenever possible is advisable, and avoiding the succession of soybeans with other host plants such as cotton, beans, cowpea, sesame, tobacco, chickpeas, sunflower, and wheat.

M. C. Meyer



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Soybean development stages

Period	Stage	Description
Vegetative	VE	Cotyledons above the soil surface
	VC	Fully open cotyledons
	V1	Fully developed unifoliate leaves ¹
	V2	Fully developed first trifoliate leaf
	V3	Fully developed second trifoliate leaf
	Vn	Fully developed umpteenth trifoliate leaf
Reproductive	R1	Beginning of flowering – An open flower at any node on the stem ²
	R2	Full flowering - An open flower in one of the last 2 nodes ³ of the stem with a fully developed leaf
	R3	Beginning of pod formation - Pod 5 mm long at one of the last 4 nodes of the stem with a fully developed leaf
	R4	Fully developed pod - Pod 2 cm long at one of the last 4 nodes of the stem with a fully developed leaf
	R5	Beginning of grain filling - Grain 3 mm long in pod at one of the 4 last nodes of the stem, with a fully developed leaf
	R5 Stage subdivision	R5.1 - grains perceptible to the touch (equivalent to 10% of the grain); R5.2 – 11% to 25% of the the grain filled; R5.3 – 26% to 50% of the the grain filled; R5.4 – 51% to 75% of the the grain filled; R5.5 – 76% to 100% of the the grain filled.
	R6	Full, or complete grain - pod containing green grains filling the pod cavities of one of the 4 last nodes of the stem, with a fully developed leaf
	R7	Beginning of maturation - A normal pod on the stem with mature color
R8	Full maturity - 95% of pods with ripe color	

Font: Fehr and Caviness (1977) scale, associated with the details of the R5 stadium proposed by Ritchie et al. (1977).

¹A leaf is considered fully developed when the edges of the trefoils of the next leaf (above) no longer touch. ²Stem means the main stem of the plant. ³Last nodes refer to the last top nodes.

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Embrapa

Soybean

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