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Field Diagnosis of Groundnut Diseases

Information Bulletin no. 36
(Revised)

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

Diseases are major constraints to groundnut production throughout the world. This handbook is designed to assist agricultural research and extension workers, who may have little formal training in plant pathology, to make tentative diagnosis of diseases of groundnut caused by 29 fungi, 2 bacteria, 11 viruses, a mycoplasma-like organism, 4 nematodes, and a parasitic flowering plant. The most characteristic field symptoms of each disease are illustrated and described. It is emphasized that for confirmation of field diagnosis the assistance of skilled plant pathologists will be required in most cases.

Résumé

Diagnostic au champ des maladies de l'arachide. Les maladies des cultures représentent les contraintes principals à la production de l'arachide partout dans le monde. Ce manuel est destine aux personnes travaillant en matière de la recherché et la vulgarization agricoles et ayant un accès limité à la formation formelle en la phytopathologie. Le document doit leur permettre d'effectuer des diagnostics provisoires des maladies de l'arachide causes par 29 champignons, 2 bactéries, 11 virus, un organisme de type mycoplasmique, 4 nématodes, ainsi que par une plante parasite à fleurs. Les symptoms les plus caractéristiques se présentant au niveau du champ sont illustrés et décrits pour chaque maladie. Cependant, il faut signaler que la confirmation du diagnostic au champ exigerait l'assistance des phytopathologistes compétents dans la plupart des cas.

Resumen

Diagnosis del campo de las enfermedades del maní. Las enfermedades constituyen mayors obstácios a la producción del maní por todas partes del mundo. Este manual propone ayudar a aquellas personas dedicadas a la investigación agrícola quienes tengan poca formación en la patología de plantas, para que puedan hacer una diagnosis tentative de las enfermedades del maní causadas por 29 hongos, 2 bacteria, 11 viruses, un organism de tipo de micoplasmo, 4 nematodes, y una planta parasitica floreciente. Se describen y se ilustran los síntomas caracteristicos de cada enfermedad. Se hace hincapie en el hecho de que para la verificación de la diagnosis tentative, en la mayoría de los casos, se require la ayuda patólogos expertos.

Field Diagnosis of Groundnut Diseases

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Contents

Introduction

Cultivated groundnut (peanut), *Arachis hypogaea* L., an annual legume native to South America, is primarily cultivated in areas of the world bounded by latitudes 40°N and 40°S. Approximately 80% of the world groundnut crop is produced in developing countries where the yields are usually very low. Diseases are major constraints to groundnut production throughout the world. A large number of diseases caused by fungi, bacteria, viruses, mycoplasma, nematodes, and parasitic flowering plants have been reported, and with some exceptions, they are widely distributed. All parts of the groundnut plant are susceptible to diseases.

This handbook is designed to assist agricultural scientists and extension workers in the preliminary field diagnosis of common diseases of groundnut caused by fungi, bacteria, viruses, mycoplasma, nematodes, and parasitic flowering plant. The most characteristic field symptoms of each disease are illustrated and described. It is important to understand the diagnosis of diseases based on their pattern of occurrence and macroscopic symptoms can in most cases be only tentative, and that for a critical differentiation of diseases with nearly similar field symptoms, microscopic examination of the diseased tissues and fruiting structures of the pathogen is required. A hand lens (15x to 25x) is necessary for field diagnosis of some diseases. Identification of most virus diseases requires laboratory tests such as enzyme-linked immunosorbent assay (ELISA), use of diagnostic test plants, and electron microscopy.

As disease symptoms can be influenced by genotype and environment, the users of this handbook are advised to have the diseased specimens/tissues further examined under the microscope and laboratory tests conducted by crop protection scientists to confirm the field diagnoses. Several publications that should prove to be useful in such confirmatory work are listed on pages 80-82.

Tools/techniques available for plant disease diagnostics

The first and most important step for better management of a plant disease is to correctly identify it. Without proper identification of the disease and the disease-causing agent, disease control measures can be a waste of resources and can lead to further plant losses. Although some diseases can be diagnosed quickly by visual examination, majority of the plant diseases require laboratory testing for accurate diagnosis. These laboratory procedures are often time consuming, labor-intensive and require skilled technicians to execute the job. With recent advances in molecular biology, new techniques and products are becoming available that will complement or replace time-consuming laboratory procedures. However most of the procedures require laboratory equipment and training, while a few can be performed on site by a person with no specialized training. **Tissue print ELISA** and **lateral flow devices** have been designed and can be performed on-site for few viruses and bacteria.

Biotic causal agent	Available tools/tests
Viruses	ELISA Electron Microscopy PCR/RT-PCR Lateral flow devices
Bacteria	BIOLOG test FISH PCR/Real-time PCR Lateral flow devices
Fungi	Microscopy PCR/Real-time PCR

Sampling tips for proper plant disease diagnostics

Disease diagnosis is a critical initial step for successful disease management. Accurate diagnosis is a pre-requisite for implementing the best disease-control measures and it starts with proper sample collection. Samples should be collected as soon as disease symptoms develop and they should be submitted to the nearest Plant Disease Clinic.

Points to remember while drawing a disease sample.

1. Collect whole plants when possible
2. Always dig, never pull plants
3. Collect more than one plant
4. Collect plants that show a range of symptoms
5. Keep collected plants as fresh as possible
6. Keep foliage from becoming contaminated with soil
7. Collect other important background information including history of the field.

Diseases Caused by Fungi

Foliar Diseases

Early Leaf Spot

Cercospora arachidicola Hori

Distribution. Worldwide.

Symptoms. Lesions are sub-circular, dark brown on the upper leaflet surface where most sporulation occurs, and a lighter shade of brown on the lower leaflet surface [Fig. **1,** three leaflets showing upper surface, one leaflet (top right) turned to show lower surface]. A chlorotic halo commonly surrounds the lesion on the upper surface. Spores of *C. arachidicola* are produced mainly on the necrotic tissue of lesions on the upper leaflet surface. Lesions are also produced on petioles, stems, stipules, and pegs; these are oval to elongate and have more distinct margins than leaflet lesions (Fig. **2**). When the disease attack is severe, affected leaflets become chlorotic, then necrotic, and lesions often coalesce, resulting in premature senescence and shedding of leaflets (Fig. **3**).

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Late Leaf Spot

Phaeoisariopsis personata (Berk. & M.A. Curtis) Van Arx

Cercosporidium personatum (Berk. & M.A. Curtis) Deighton

Distribution. Worldwide.

Symptoms. When the lower leaflet surface is viewed, late leaf spots (Fig. **4**, right) are nearly circular and darker than early leaf spots (Fig. **4**, left). On the lower leaflet surface where most of the sporulation occurs the lesions are black and slightly rough in appearance (Fig. **5**, right, 6x). Circular rings of fruiting structures on the lesions of the lower leaflet surface can be seen with the aid of a hand lens. Late leaf spot lesions can be distinguished from those of early leaf spot that are lighter in color and may be surrounded by a chlorotic halo (Fig. **5**, left, 6x). When disease attack is severe, affected leaflets become chlorotic, then necrotic, and lesions often coalesce, resulting in premature senescence and shedding of the leaflets (Fig. **6**). Oval to elongate lesions similar to those of early leaf spot (Fig. **2**) are also formed on petioles, stems, stipules, and pegs. Late leaf spot attack is usually coincident with that of rust.

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Rust

Puccinia arachidis Spegazzini

Distribution. World wide.

Symptoms. Orange-colored pustules (Fig. **7**, 7x) appear on the lower surfaces of leaflets and rupture to release masses of reddish-brown spores. In susceptible (Fig. **8**) cultivars the original pustules may be surrounded by colonies of secondary pustules. Pustules may appear late on the upper surface of the leaflets opposite those on the lower surface. Lesions can be formed on all aerial plant parts except flowers. Those on the stems are elongate (Fig. **9**). In contrast to the rapid defoliation associated with leaf spots, leaves infected with rust become necrotic and dry up, but tend to remain attached to the plant (Fig. **10**). Rust disease usually occurs at the same time as late leaf spot.

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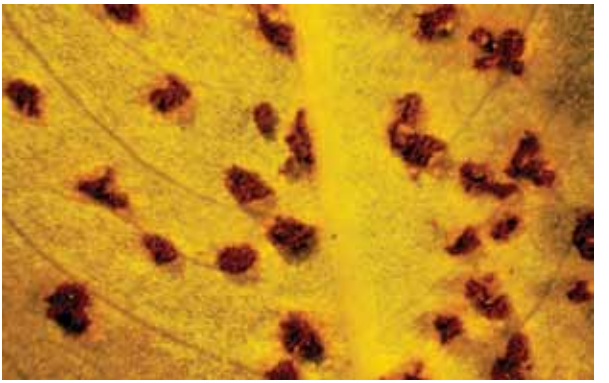

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Web Blotch

Phoma arachidicola Marasas, Pauer & Boerema

Didymella arachidicola (Choch.) Taber, Pettit & Philley

Distribution. Angola, Argentina, Australia, Brazil, Canada, China, Commonwealth of Independent Sates, Japan, Lesotho, Malawi, Nigeria, South Africa, Swaziland, USA, Zambia, and Zimbabwe.

Symptoms. Lesions first appear on the upper surfaces of the lower leaves as scattered tan-colored specks or streaks that form a webbed pattern (Fig. **11a**, and **b**). The discolored areas expand, forming large, nearly circular, purplish-brown to dark brown blotches with inconspicuous margins (Fig. **11c**). Blotches often coalesce and cover the entire leaflet. Mature lesions are nearly black and have roughened surfaces (Fig. **11d**). On the lower leaflet surface, disease symptoms become visible only after the blotches on the upper surface are well developed. Petioles, stipules, and stems are also invaded by the fungus. Severe disease attack leads to premature defoliation. Under moist conditions fruiting bodies are formed on infected fallen leaves and may be detected by use of a hand lens.

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Scab

Sphaceloma arachidis Bitancourt & Jenkins

Distribution. Argentina, Brazil, Japan, and Swaziland (?).

Symptoms. Numerous round to irregular lesions appear on both surfaces of leaflets and are either uniformly distributed over the entire leaflet or are clustered near the midrib. The lesions on upper leaflet surfaces are light tan with sunken centers and raised margins. Lesions are frequently covered with continuous velvet like layers of grayish live-green fruiting bodies. On the surface of lower leaflets the lesions are darker and their margins are not raised. On petioles and branches lesions are numerous, larger, and more irregular in appearance than lesions on leaflets. The lesions on petioles and branches may develop into cankerous scabs, giving the plants a burnt appearance (Fig. **12**). Lesions cover nearly all of the plant, including pegs. In advanced stages of disease development plants are stunted and stems become sinuous (Fig. **13**).

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Alternaria Leaf Spot and Veinal Necrosis

Alternaria alternate (Fries) Keissler

Distribution. India, Vietnam, and Thailand.

Symptoms. Small, chlorotic, water-soaked lesions appear randomly over both surfaces of the leaflets. They enlarge, become irregular in shape, and are brown with darker brown margins (Fig. **14**); the central portions later become pale, dry rapidly, and disintegrate.

Veins and veinlets adjacent to the lesions become necrotic. Affected leaflets are chlorotic and in severe attacks they prematurely senesce. When many lesions are present they coalesce, giving the leaf a ragged and blighted appearance. Profuse sporulation occurs on older lesions on the upper surfaces of the leaflets.

This pathogen also causes leaf blight.

Phyllosticta Leaf Spot

Phyllosticta arachidis-hypogaea Vasant Rao

Distribution. Burkina Faso, India, Malawi, Mozambique, Niger, Nigeria, Swaziland, Thailand, and Zimbabwe.

Symptoms. This fungus is a secondary pathogen. Infection starts in damaged and necrotic tissue and subsequently spreads into the living green areas of the leaflets. Lesions are circular to irregular and are light tan in color surrounded by a reddish-brown border (Fig. **15**). Shot-holes may appear later. Lesions may coalesce into irregular necrotic patches. When examined using a hand lens, numerous scattered dark brown fruiting bodies can be observed on the lesions on both leaflet surfaces.

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Powdery Mildew

Oidium arachidis *Chorin*

Distribution. India and Israel.

Symptoms. Large spots cover the upper surfaces of leaflets. These spots are covered with superficial sporulating fungal growth which gives them a powdery white appearance (Fig. **16**). The centers of the spots later become brown and necrotic.

Cercospora Leaf Blight

Cercospora canescens **Ellis & Martin**

Distribution. Thailand.

Symptoms. Small necrotic lesions appear on leaflets, these lesions enlarge and become irregular or angular shaped light brown spots. When long periods of leaf wetness occur, the spots coalesce leading to blighting and defoliation (Fig. **17**). When closely examined, white masses of spores are visible on necrotic areas of both leaf surfaces.

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Myrothecium Leaf Blight

Myrothecium roridum Tode ex Fries

Distribution. India and Thailand.

Symptoms. Lesions are round to irregular with grey brown colored centers and brown margins surrounded by chlorotic halos. They occur on both surfaces of leaflets. When lesions coalesce leaves appear blighted. Abundant olive green to black fruiting bodies, often arranged in concentric rings, are formed on the necrotic areas of both leaflet surfaces (Fig. **18**).

Zonate Leaf Spot

Cristulariella moricola (Hino) Redhead

Distribution: India, Thailand, and USA.

Symptoms: Necrotic spots ranging from 2 to 12 mm in diameter appear on leaflets (Fig. **19**). Small lesions have a light brown center surrounded by a brown ring of necrotic tissue, but larger lesions show a zonate pattern on both leaflet surfaces. Spores may be produced on necrotic tissues of both leaflet surfaces.

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Sclerotium Leaf Spot

Sclerotium rolfsii Saccardo

Distribution. India, Malawi, and Thailand.

Symptoms. Appear on mature plants as grey necrotic ring spots which may develop shot holes (Fig. **20**). During long periods of leaf wetness the spots coalesce leading to a severe blight. Minute sclerotia (about 0.5 to 0.8 mm in diameter) initially white, but later brownish in color can be seen on both leaflet surfaces.

This pathogen also causes stem, root, and pod diseases which are more damaging than the leaf spots.

Choanephora Wet Blight

Choanephora cucurbitarum (Berk. & Ravenel) Thaxt.

Distribution. Thailand and Philippines.

Symptoms. Water-soaked lesions first appear on the tips of young unfolding leaves. Subsequently the lesions become necrotic and are covered with a dark brown spore mass (Fig. **21**). If leaves stay wet for long periods, the fungus can attack young shoots and can kill the growing tips. These symptoms can be mistaken for damage caused by coreid bugs. Dead tissue damaged by *C. cucurbitarum* can be distinguished from bug-damaged tissue by the presence of spores produced by the wet blight pathogen.

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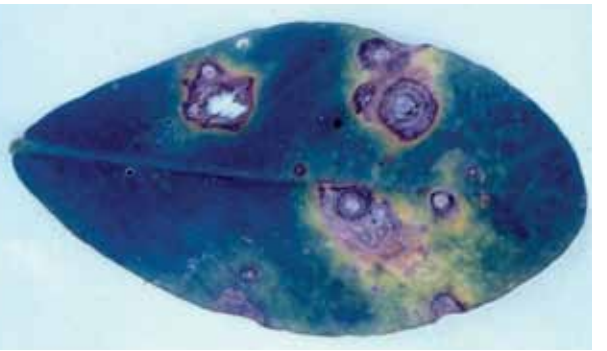

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Pepper Spot and Leaf Scorch

Leptosphaerulina crassiasca (sechet) Jackson & Bell

Distribution. Angola, Argentina, Burkina Faso, India, Madagascar, Mauritius, Malawi, Mozambique, Niger, Nigeria, Senegal, Swaziland, Thailand, Taiwan, USA, Vietnam, Zambia, and Zimbabwe.

Symptoms. The pepper spot phase of the disease is recognized by the appearance of minute necrotic spots on lower leaves (Fig. **22**, above). The spots are numerous, dark brown to black, irregular to circular and occasionally depressed. Discrete lesions appear on both sides of the leaflet; but are more often found on upper surfaces. When abundant, lesions coalesce giving the leaflet surface a netted appearance.

Leaf scorch, the most common symptom, frequently develops on the tips, and occasionally on the margins, of leaflets. The wedge-shaped lesions have a bright yellow zone along the periphery of their advancing margins (Fig. **22**, below). The necrotic tissue becomes dark brown and tends to fragment along the leaflet margins, so that the leaves look tattered.

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Anthracnose

Colletotrichum arachidis Sawada

Colletotrichum dematium (Pers.) Grove

Colletotrichum mangenoti Chevaugeon

Distribution. India, Niger, Nigeria, Sudan, Senegal, Taiwan, Tanzania, Thailand, Uganda, and USA.

Symptoms. Wedge-shaped lesions which resemble those caused by *Leptosphaerulina crassiasca* appear on the leaflet tips (Fig. **23**). Lesions may also develop on the leaflet margins leading to marginal blight. The periphery of the advancing margins of the lesion is surrounded by a bright yellow zone. The necrotic tissue becomes dark brown and tends to fragment along the leaflet margins. The disease may also extend to stipules and stems. Fruiting bodies, visible through a hand lens, are abundant on diseased tissues.

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Alternaria Leaf Blight

Alternaria alternate (Fr.) Keissler

Alternaria tenuissima (Kunze *ex* Pers.) Wiltshire

Alternaria arachidis Kulkarni

Distribution. India, Nigeria, and Thailand.

Symptoms. Light to dark brown irregular spots appear towards the tips or margins of the leaves. These rapidly enlarge and coalesce to form wedge-shaped lesions. A distinct chlorotic zone commonly develops along the edge of necrotic tissue (Fig. **24**). In the later stages of disease development, blighted areas become dark brown and brittle and tend to fragment. Dark spore masses appear on necrotic tissues. Defoliation occurs when the disease is severe.

The scorch symptoms resemble those caused by *Leptosphaerulina crassiasca* and *colletotrichum* spp, and it is often difficult to distinguish between these diseases in the field. *Alternaria alternata* also causes leaf spots and veinal necrosis as described earlier.

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Pestalotiopsis Leaf Blight

Pestalotiopsis arachidis Satya

Distribution. India, Nigeria, and Thailand.

Symptoms. Dark brown circular lesions surrounded by faint yellow haloes appear on infected leaves. Lesions enlarge and coalesce leading to severe necrosis of leaflets, especially on the margins (Fig. **25**). Very small black spherical fruiting bodies visible through a hand lens can be found in the centers of the lesions or in blighted areas of leaflets.

Symptoms of this disease resemble those of alternaria leaf blight, except that the yellow border surrounding the blighted areas is less conspicuous.

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Seed and Seedling Diseases

Preemergence Seed and Seedling Rots

Aspergillus niger van Tieghem

Aspergillus flavus Link ex Fries

Macrophomina phaseolina (Tassi) Goidanich

Sclerotium rolfsii Saccardo

Rhizoctonia solani Kühn

Lasiodiplodia theobromae (Pat.) Griffon & Maubl.

Rhizopus spp*, Penicillium* spp, *Pythium* spp*, and Fusarium* spp

Distribution. Worldwide.

Symptoms. Infected seed and seedlings are reduced to a dark brown or black spongy mass of rotted tissue covered with sporulating mycelium which varies in color depending upon the species involved. Figure **26** shows a seedling attacked by *Pythium* spp. Decay is most rapid when infected seeds are sown because the seed borne fungi become active as soon as the seeds absorb water.

Bacteria are also involved in seed rotting but are normally secondary invaders of seed attacked by fungi.

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Aspergillus Crown Rot/Collar Rot

Aspergillus niger van Tieghem

Distribution. Worldwide.

Symptoms. In a moist soil environment seeds may be attacked and killed leading to a preemergence rotting. If seeds that did not emerge are carefully removed from the soil they may be covered with masses of black conidia which give them a sooty appearance. Post-emergence infection often culminates in death and rapid decay of seedlings.

The first symptom in emerged seedlings is usually rapid desiccation of the entire plant. Affected tissue is covered by the sporulating fungus at the soil surface. As the infection progresses, the entire collar region becomes dark brown and shredded. Seedling infection commonly occurs in the cotyledonary-hypocotyl region shortly after emergence. The infected areas become water-soaked and light brown, and are soon covered with black fungal spores (Fig. **27**).

Mature plants are also attacked. Lesions develop on the stem just below the soil surface and then spread upward along the branches. Because of the woodiness of mature plants, symptoms are generally not observed until either the branches wilt permanently, or wilting of the entire plant is apparent. The dead and dried branches are easily detached from the disintegrated collar region. The fungus sporulates on the surface of mature pods resulting in patches of black sooty spores (Fig. **28**).

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Yellow Mold

Aspergillus flavus Link *ex* Fries

Distribution. Worldwide.

Symptoms. Seeds and nonemerged seedlings attacked by the fungus are rapidly reduced to a shriveled, dried brown or black mass covered by yellow or greenish-yellow spores. Decay is most rapid when infected seeds are sown and the fungus becomes active as the seeds hydrate. In some cases the emerging radical and hypocotyls become infected and rapidly decay. After seedling emergence there might not be any new infection, but previously infected cotyledons have necrotic lesions with reddish-brown margins covered by yellow or greenish-yellow spores (Fig. **29**). This phase of the disease is very similar to the crown rot caused by *Aspergillus niger,* and in some diseased plants both fungi may be present. When the strain of *A. flavus* causing the seedling disease produces aflatoxin, the plants may be severely stunted with chlorotic or pale green leaves with vein-clearing of leaflets, that are smaller than usual and have pointed tips (Fig. **30**). Root development is reduced by infection. This symptom is known as 'aflaroot'.

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Diplodia Collar Rot

Lasiodiplodia theobromae (Pat.) Griffon & Mubl.

Distribution. Australia, India, Israel, South Africa, Thailand, USA, and Venezuela.

Symptoms. Seedlings or maturing plants are infected at or near the soil surface and the fungus quickly invades the stem. Wilting of lateral branches or the entire plant is the first field symptom. Infected plants usually die within a few days. The base of the infected plants and the tap root become slate grey to black and easily shred (Fig. **31**). Black pycnidia develop as pimple-like dots on the necrotic tissues.

Rhizoctonia Damping-off

Rhizoctonia solani Kühn

Distribution. Worldwide.

Symptoms. Pre-or postemergence invasion by seed or soilborne inoculums results in seedling death. In emerged seedlings, lesions are most frequently observed on the hypocotyl as sunken, elongate, dark brown areas just below the soil surface (Fig. **32**). The lesions enlarge, become black, and girdle the hypocotyl leading to typical 'damping-off' symptoms. Similar lesions develop on tap roots, and extend to the entire root system leading to dry root rot, which subsequently kills the plant. The decayed areas are often covered by a light brown mycelia mat. Dark brown, pinhead-sized sclerotia may develop on the dead tissues.

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Stem, Root, and Pod Diseases

Stem Rot

Sclerotium rolfsii Saccardo

Distribution. Worldwide.

Symptoms. The pathogen attacks all parts of the plant, but stem infection is the most common and destructive. Yellowing and wilting of branches near the base of the plant is the first symptom. Sheaths of white mycelium develop at or near the soil line around the affected areas of the stem which become shredded (Fig. **33**). Abundant sclerotia, white initially and later turning brown, develop on the infected areas. The entire plant can be killed, but in some cases only two or three branches are affected. Infection of pegs, pods, and roots occurs either independently or together with stem infection. Lesions on the developing pegs may retard pod development. Orange or brown colored lesions may be found on the pods. Severely infected pods are completely covered with a white mycelia mat, and eventually decay. In some cases the seeds from the diseased pods show a characteristic bluish-grey discoloration of the testa known as 'blue damage' (Fig. **34**).

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Sclerotinia Blight

Sclerotinia minor Jagger

Sclerotinia sclerotiorum (Lib.) de Bary

Distribution. Argentina, Australia, China, Taiwan, USA, and Zimbabwe.

Symptoms. First evidence of infection is the sudden wilting of lateral branches, which are usually invaded at the soil surface. Small, light green, water-soaked lesions appear on the stems. These later become sunken elongated, and turn a light tan color. Older lesions are dark brown with a distinct border between infected and healthy tissues. The fungus can spread from the lateral branches to infect the main stem. The foliage on infected branches becomes chlorotic, turns dark brown, and withers, resulting in a blighted appearance. White, fluffy mycelium develops on dead tissues in wet weather (Fig. **35**). Pegs are usually invaded at the soil line. Shredding of the branch and peg tissues is characteristic of the disease, and it results in severe pod loss. Black, irregularly shaped sclerotia are produced abundantly on infected leaflets, branches, and pegs. Sclerotia are also produced on pods (Fig. **36**). And on seeds inside the pods (Fig. **37**).

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Cylindrocladium Black Rot

Cylindrocladium crotalariae (Loos) Bell & Sobers

Distribution. Australia, India, Japan, and USA.

Symptoms. Diseased plants appear in the field in localized patches (Fig. **38**) which enlarge in subsequent years. Early symptoms are chlorosis and wilting of foliage on the main stem. Lateral branches may not be affected, and occasionally plants may not wilt but appear chlorotic and stunted. Reddish-orange fruiting bodies are formed in dense clusters on infected branches at the soil line (Fig. **39**). All subterranean plant parts can be affected. Lesions on pegs and pods may remain discrete (Fig. **40**), or in severe cases the disease may destroy pods and roots.

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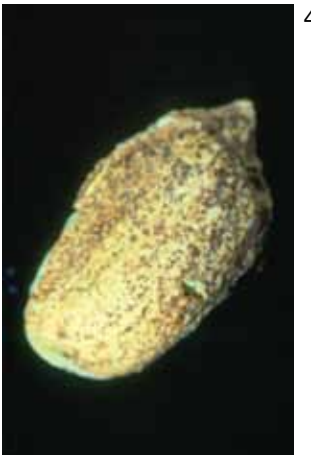

Botrytis Blight

Botrytis cinerea Pers. ex Fries

Distribution. Australia, Commonwealth of Independent States, Japan, Malawi, Romania, South Africa, Swaziland, Tanzania, USA, Venezuela, Vietnam, and Zimbabwe.

Symptoms. Foliage in contact with the soil surface is invaded and may decay rapidly. Infected stems and leaves are sparsely covered with grey sporulating fungal growth (Fig. **41**). The disease spreads to pegs and pods and the entire plant may be killed. Black sclerotia develop on the diseased stems and pods (Fig. **42**).

Verticillium Wilt

Verticillium albo-atrum Reinke & Berthier

Verticillium dahlia Kleb.

Distribution. Argentina, Australia, Israel, and USA.

Symptoms. Early symptoms usually appear at the flowering stage. They include; marginal chlorosis of leaves (Fig. **43**), loss of leaf turgidity, and leaf curling. Later symptoms are general yellowing and leaflet necrosis, followed by wilting and defoliation. During the early stages of disease development, plants wilt during the middle of sunny days but usually recover turgidity during the night. Wilting eventually becomes permanent. Wilt symptoms are generally more severe on younger plants than on older ones. The roots of infected plants have a brown discoloration of the vascular tissues. Occasionally plants die, and the roots of dead plants are severely rotted.

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Fusarium Wilt

Fusarium oxysporum **Schlechtend. Emend snyder & Hans.**

Distribution. Worldwide.

Symptoms. The disease normally occurs in plants subjected to prolonged drought stress. Infected plants may wilt suddenly or gradually. When plants wilt suddenly all their leaves turn grayish-green, and in dry weather the entire plant becomes bleached and dry. When slow wilting occurs the foliage becomes chlorotic, and leaflets are shed before the plant dies. There are no external symptoms on either the stem or roots, but if the roots are cut longitudinally, vascular discoloration is evident. This discoloration is a common feature of other vascular wilts caused by *Verticillium* spp and *Pseudomonas solanacearum.* Hence, field diagnosis of fusarium wilt must be confirmed by laboratory tests. Pegs and pods may be invaded by the fungus which causes a pink discoloration of the inner pod surface (Fig. **44**).

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Charcoal Rot

Macrophomina phaseolina (Tassi) Goidanich

Distribution. Worldwide

Symptoms. Water-soaked necrotic lesions develop on the hypocotyls of young plants near the soil surface. The lesions enlarge, become dull brown, girdle the hypocotyls, and kill the plant.

Older plants are infected near the soil surface. The infection spreads upward within the stems and branches, and downward into the root system killing the plant. Sometimes, the disease is restricted to the roots. Root lesions are initially water-soaked but later become light brown. The lateral roots become rotted and blackened, and the tap root shreds. When pods are invaded their interior surfaces turn grey because of the abundant production of microsclerotia (Fig. **45**).

When the weather is warm and wet at harvest time *M. phaseolina* and some other fungi, e.g, *Lasiodiplodia theobromae, Aspergillus niger, and Aspergillus flavus,* invade the seed and produce mats of mycelium between the inner surfaces of the cotyledons (Fig. **46**). When this occurs with no external symptoms of disease on the kernels it is known as 'concealed damage'.

Black Hull/Black Pod Rot

Thielaviopsis basicola (Berk. & Broome) Ferraris (syn. *Chalara elegans* Nag Raj & Kendrick)

Distribution. Israel, Argentina, Italy, South Africa, and USA,

Symptoms: Numerous black lesions develop on the pod surface (Fig. **47**). The lesions enlarge and coalesce producing large masses of spores which give the pod surface a blackened appearance. Severe peg infection

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Pod Rot

Pythium myriotylum **Dreschler**

Rhizoctonia solani **Kuhn**

Fusarium solani **(Mart.) Saccardo f. sp phaseoli (Burkholder) Snyder & Hans.**

Fusarium oxysporum **Schlechtend. Emend Snyder & Hans.**

Macrophomina phaseolina **(Tassi) Goidanich**

Distribution. Worldwide.

Symptoms. Pod rots are characterized by the presence of brownish-black lesions on the shell (Fig. **48**). The lesions enlarge and coalesce, and the entire pod surface becomes discolored, and in advanced stages the shell tissues disintegrated and the kernels decay. The texture and color of the rotted tissues vary depending on the organisms involved and other edaphic factors. Pods rotted by species of Fusarium have pink-or purple-stained shells.

Sclerotium rolfsii, Sclerotinia spp, *Verticillium* spp, and *Botrytis cinerea* cause pod rotting in addition to the other damage described earlier. *Rhizoctonia solani* in addition to causing pod, root, and stem rots can also invade lower leaves in contact with soil causing a leaf blight (Fig. **49**).

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Diseases Caused by Bacteria

Bacterial Wilt

Ralstonia (Pseudomonas) solanacearum
(E.F. Smith)

Distribution. Angola, China, East Indies, Ethiopia, Australia, Fiji, Indonesia, Sri Lanka, Libya, Madagascar, Malaysia, Mauritius, Nigeria, Papua New Guinea, Philippines, Somalia, South Africa, Swaziland, Taiwan, Thailand, Uganda, USA, Vietnam, Zambia, and Zimbabwe.

Symptoms. Infection of young plants can result in sudden wilting and death, but the leaves remain green (Fig. **50**). Infection of mature plants results in loss of turgidity, and leaves become light green chlorotic, and curl at the tips. Eventually leaflets become brown but remain attached to the plant. In some instances only a single branch may wilt and die. The vascular system of the tap root becomes plugged and discolored and this extends into the main stem and lateral branches. Masses of bacteria ooze from the cut ends of infected roots and stems when these are placed in water (Fig. **51**).

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51

Bacterial Leaf Spot

Unidentified bacterium

Distribution. India and Vietnam.

Symptoms. Small, light brown, circular to irregular lesions appear on the lower leaves of young plants (Fig. **52**). During the early stages of disease development lesions are prominent on the upper surfaces of leaflets. The lesions enlarge, become irregular in shape, and the tissues around them become chlorotic. When fully developed, the center of the lesion is colored a light brown and the margin is dark brown. In wet weather, the lesions coalesce and the leaves become chlorotic and are shed.

52

Diseases Caused by Viruses and a Mycoplasma-like Organism

Peanut Mottle

Peanut Mottle Virus (PMV)

Distribution. All groundnut-producing countries in Africa, the Americas, Asia, and Oceania.

Symptoms. Appear on young leaves as irregular dark green islands. Mosaic symptoms are not apparent on older leaves, which show mild mottle symptoms visible in transmitted light. Plants are not severely stunted. Some genotypes show characteristic interveinal depression and upward rolling of leaflet margins (Fig. **53**). Infected plants produce only a few small pods.

Peanut Stripe

Peanut Stripe Virus (PStV)

Distribution. Most groundnut-producing countries in South and Southeast Asia, and USA.

Symptoms. In earlier reports from some countries PStV was misidentified as PMV but, unlike PMV, PStV causes a wide range of leaf symptoms. Symptoms vary, depending on the virus isolate and groundnut cultivar. Necrotic and stripe isolates (Fig. **54**) cause severe yield reductions, whereas mild mottle and blotch isolates (Fig. **55**) have little or no effect on yield. An “oak leaf” symptom (Fig. **56**) is occasionally seen.

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Peanut Clump

Peanut Clump Virus (PCV)

Distribution. India and West Africa. Probably several other countries in Asia.

Symptoms. This soilborne disease occurs in patches in the field which recur in the same position when groundnuts are sown again in the same field (Fig. **57**). Young leaves show mosaic, mottling, and chlorotic ring symptoms (Fig. **58**). Older leaflets are darker green with faint mottling. Early-infected plants are conspicuous in the field because they are severely stunted and dark green.

57

58

Peanut Bud Necrosis

Peanut Bud Necrosis Virus (PBNV)

Distribution. South and southeast Asia.

Symptoms. The disease is caused by a thrips-vectored tospovirus, which is serologically distinct from TSWV though both produce similar symptoms in groundnut.

Initial symptoms appear on young leaflets as chlorotic spots or mottling that may develop into chlorotic and necrotic rings and streaks (Fig. **59**) until the whole groundnut plant is affected (Fig. **60**). Terminal bud necrosis often occurs when temperatures are relatively high. Early infection results in stunting and sometimes proliferation of axillary shoots (Fig. **61**). Leaflets produced on axillary shoots show a wide range of symptoms including reduced size, distortion of the lamina, mosaic, and general chlorosis. Any seeds produced by early-infected plants are small, shrivelled, and mottled (Fig. **62**).

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Tomato Spotted Wilt

Tomato spotted wilt virus (TSWV)

Distribution. Africa, the Americas, Australia and Europe

Symptoms. The disease is caused by thrips-vectored tospovirus called TSWV and causes a wide array of symptoms on groundnut.

Symptoms include concentric ring spots, various patterns of chlorosis on leaflets, stunting of all above-ground plant parts. Symptoms range in severity from minor spotting on one or a few leaflets to severe stunting and death of entire plants (Fig. **63**).

Stem Necrosis

Tobacco Streak Virus (TSV)

Distribution. India, Australia, Brazil

Symptoms. Symptoms in groundnut first appear on young leaves as necrotic lesions and veinal necrosis (Fig. **64**). The necrosis later spreads to the petiole and stem. Necrotic lesions on the stem later spread upwards killing the bud (Fig. **65**). Majority of the plants infected within a month after sowing die due to necrosis, which also spreads downwards in case of early infection. In some cultivars, pods harvested from the infected plants show necrotic lesions.

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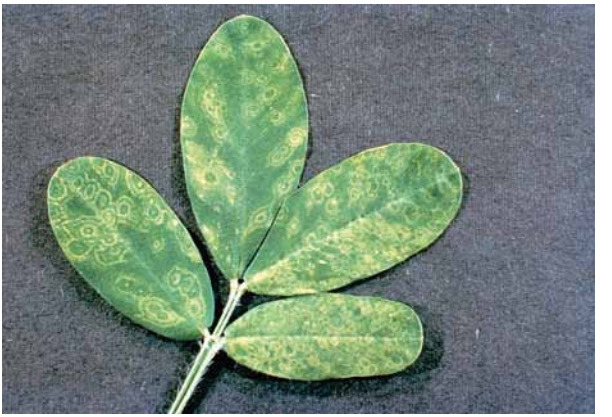

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Groundnut Rosette

A complex of two viruses (Groundnut rosette assistor virus [GRAV], Groundnut rosette virus [GRV]) and a satellite RNA (Sat RNA)

Distribution. Sub-Saharan Africa, Madagascar.

Symptoms: The most destructive groundnut virus disease in Africa. Three types of rosette have been recorded.

Chlorotic rosette, which is prevalent throughout Africa, is characterized by stunted plants with chlorotic, twisted, and distorted leaflets (Fig. **66**). Yield from early-infected plants is severely reduced.

Mosaic rosette is recorded only in eastern, central, and southern Africa. Younger leaflets show conspicuous mosaic symptoms.

Green rosette currently occurs only in western Africa. Symptoms resemble those of peanut clump. Young leaves show mild mottling. Older leaves are dark green, reduced in size, and show downward rolling of leaflet margins. Plants are severely stunted (Fig. **67**).

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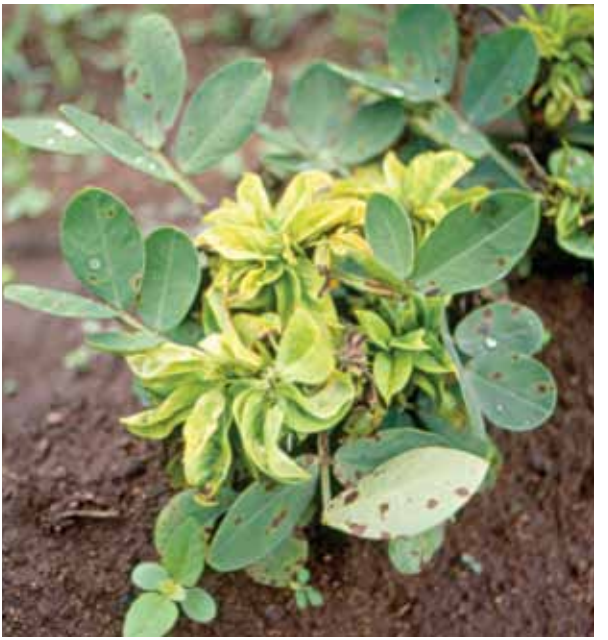

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Peanut Stunt

Peanut Stunt Virus (PSV)

Distribution. North America and southern China.

Symptoms. The virus exists as several distinct isolates; the one prevalent in North America causes severe dwarfing of either the entire plant or one or more of its branches (Fig. **68**). In China a different isolate of the virus does not cause severe stunting, but the leaflets on infected plants are malformed with various chlorotic symptoms.

Groundnut Streak Necrosis

Sunflower Yellow Blotch Virus (SYBV)

Distribution. Southern Africa.

Symptoms. Early symptoms are discrete, bright yellow patches on leaflets. Ring spots and line patterns are common. Leaflets produced after infection occurs have yellow streaks along the veins, and ultimately the streaks become necrotic. The youngest leaflets are distorted, puckered, and small, with irregular streaks or marginal necrosis (Fig. **69**).

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Cowpea Mild Mottle

Cowpea Mild Mottle Virus (CMMV)

Distribution. Asia and Africa.

Symptoms. Infected plants are conspicuous by the outward rolling of their leaflet edges (Fig. **70**) and severe stunting. Younger leaflets often show vein banding and older leaflets may become necrotic. The incidence of CMMV in groundnuts can be as high as 30% if they are sown adjacent to infected soybean (*Glycine max*) and/or cowpea (*Vigna unguiculata*), two highly susceptible crops.

Peanut Yellow Spot

Peanut Yellow Spot Virus (PYSV)

Distribution. Thailand and India.

Symptoms. Chlorotic spots first appear along the midribs of young leaflets where the thrips vector feeds. The spots increase in size (Fig. **71**) and may coalesce and become irregular in shape as the leaves approach maturity (Fig. **72**). At this stage the color of the spots is distinctively yellow. Since the infection is localized, symptoms appear only on infected leaflets.

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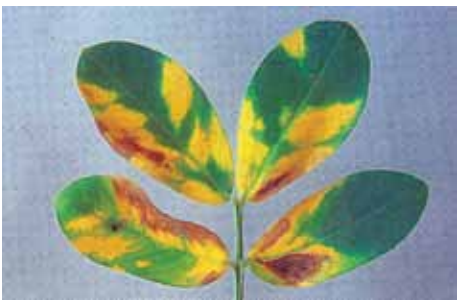

Witches' Broom

Mycoplasma-like organism

Distribution. Burkina Faso, China, India, Indonesia, Japan, Niger, Taiwan, Thailand, and USA.

Symptoms. The excessive proliferation of leaflets gives infected plants a broom-like appearance. Leaves are small and chlorotic and the plant is stunted (Fig. **73**). If pegs are formed, they curl upwards against gravity (Fig. **74**).

73

74

Diseases Caused by Nematodes

Root-knot

Meloidogyne arenaria (Neal) Chitwood

Meloidogyne hapla Chitwood

Meloidogyne javanica

Meloidogyne incognita

Distribution. ***Meloidogyne arenaria***: Egypt, India, Israel, Malawi, Senegal, Taiwan, USA, and Zimbabwe. ***Meloidogyne hapla***: Australia, China, India, Israel, Japan, South Africa, South Korea, USA, and Zambia. ***Meloidogyne javanica***: USA, ***Meloidogyne incognita:*** USA.

Symptoms. Galls often form on roots, pegs, and pods of infected plants. Nematode damage is frequently not suspected until roots and pods are examined for the presence of galls, which may reach a diameter of several times the normal adjacent root. Root system development is commonly reduced. Pods also become infected and develop knots, or small warts (Fig. **75**). Pegs and pods occasionally begin to deteriorate at maturity. Severely infected plants are stunted and have chlorotic leaves. Symptoms of root-knot nematode infection are similar for all species; however, the galls produced by *M. hapla* are smaller than those produced by *M. arenaria*. Roots infected with *M. hapla* attend to form branches near the pint of nematode invasion. This frequently produces a dense, bushy root system.

75

Root-lesion

Pratylenchus brachyurus (Godfrey) Filipjev & Sch. Stekh.

Distribution. Australia, Benin, Egypt, Gambia, India, Nigeria, Senegal, Thailand, USA, and Zimbabwe.

Symptoms. Root-lesion nematodes attack roots, pegs, and pods and feed within the parenchymatous tissues. Roots of infected plants are restricted in length and total volume, and tend to be discolored. The pod lesions begin as tiny, tan-to-brown colored, pin-point areas on the shell surface, and, as the nematodes feed and reproduce, the affected area becomes larger and darker (Fig. **76**). Older lesions are characterized by a blotchy appearance and indistinct margins. Severely attacked plants are stunted and chlorotic with reduced root systems. Other microorganisms may colonize the necrotic areas and penetrate the pod causing seed damage.

Kalahasti malady

Tylenchorhynchus brevilineatus Williams

Distribution. India.

Symptoms. Infected plants appear in patches in the field, and are stunted with greener than normal foliage. Small brownish-yellow lesions appear on the pegs, and on young developing pods. The margins of the lesions are slightly elevated because of the proliferation of host cells around the lesions. Peg length is reduced and in advanced stages of the disease the entire pod surface becomes blackened (Fig. **77**). Discoloration can also be observed on roots, but this is less conspicuous than pod discoloration. Kernels from diseased pods are apparently healthy, although commonly smaller than normal.

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77

Peanut Chlorosis

Aphasmatylenchus straturatus Germani

Distribution. Burkina Faso.

Symptoms. Infected plants are severely stunted and chlorotic, and appear in large circular patches in the field. These patches enlarge year after year if groundnuts are repeatedly grown in the same field. Chlorosis usually appears 35 to 45 days after sowing. Leaflets are yellow or pale green but the primary and secondary veins remain green (Fig. **78**). Leaf size is nearly normal. Roots are severely distorted and poorly nodulated.

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Disease Caused by a Parasitic Flowering Plant

Witch Weed

Alectra vogelii Benth.

Distribution. Angola, Burkina Faso, Malawi, Nigeria, Zambia, and Zimbabwe.

Symptoms. *Alectra vogelii* is a root parasite of groundnut and several other leguminous crop plants. Mature plants of *A. vogelii* are 18 to 46 cm high, with small lemon-yellow flowers, and stems that branch out at the base of the plant (Fig. **79**). The connection between *A. vogelii* and the groundnut roots can be seen by carefully excavating the soil in the root zone (Fig. **80**). Parasitized plants are weakened and reduced in size and yield.

79

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Notes

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The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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