Handbook of Pigeonpea Diseases

Information Bulletin No. 42
(Revised 2012)

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International Crops Research Institute
for the Semi-Arid Tropics

Citation: Reddy MV, Raju TN, Sharma SB, Nene YL, McDonald D, Pande S and **Sharma M.** 2012. Handbook of Pigeonpea Diseases (Revised). Information Bulletin No. 42. Patancheru, AP 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 64 pp. ISBN 92-9066-277-8. Order code IBE 042.

Abstract

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is one of the most important grain legume components of subsistence farming systems in the semi-arid tropics. Many fungi, viruses, nematodes, bacteria, and mycoplasma-like organisms attack pigeonpea, but only a few of these are important constraints to pigeonpea production. This bulletin provides information on the causal agents, distribution, economic importance, symptoms, epidemiology, and management of major diseases of pigeonpea. The text is supplemented with color photographs of disease symptoms and a diagnostic key is included to facilitate identification. Information provided on control measures includes the use of resistant varieties, cultural practices and chemicals. Supporting literature on the major diseases is listed.

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Cover: (Top) Sterility Mosaic Disease infected leaves, (Bottom from L to R) Phytophthora blight lesions of stem, Fusarium wilt xylem browning, Alternaria blight infected flower and flower bud.

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2012

Acknowledgment

We thank G Gopika, ICRISAT, for help in preparation and the revision of the bulletin.

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Introduction

Pigeonpea (*Cajanus cajan* (L) Millsp.) is an important grain legume crop of rainfed agriculture in the semi-arid tropics. The Indian sub-continent, eastern Africa, and central America, in that order, are the world's three main pigeonpea-producing regions. Pigeonpea is cultivated in more than 25 tropical and sub-tropical countries, either as a sole crop or intermixed with cereals such as sorghum [*Sorghum bicolor* (L.) Moench], pearl millet [*Pennisetum glaucum* (L.) R. Br.], or maize [*Zea mays* L.], or with legumes, eg, groundnut [*Arachis hypogaea* L.]. Being a legume, pigeonpea enriches the soil through symbiotic nitrogen fixation. A short-day plant with a deep root system, pigeonpea tolerates drought, but is highly sensitive to waterlogging. The crop has many uses; fresh pigeonpea is eaten as a vegetable, the grain is cooked and eaten as *dhal* (dry split cotyledons), the wood is used as fuel, and the leaves and husks provide livestock feed. The crop is cultivated on marginal lands by resource-poor farmers, who normally grow traditional medium- and long-duration (5-11 months) landraces. Short-duration pigeonpea (3-4 months) suitable for multiple cropping have recently been developed. Traditionally, the use of such inputs as fertilizers, weeding, irrigation, and pesticides are minimal, so present yield levels are low (750 kg ha^{-1}). Greater attention is now being given to managing the crop because it is in high demand at remunerative prices. There is also a trend away from traditional intercropping to sole cropping. Diseases are major biological constraints to production, and more than 60 pathogens including fungi, bacteria, viruses, mycoplasma, and nematodes can infect pigeonpea. Fortunately, only a few of them cause economic losses. Of these, sterility mosaic and witches' broom are region-specific, whereas others such as Fusarium wilt and Phytophthora blight are widespread across regions. This handbook has been prepared to assist in field diagnosis of pigeonpea diseases. The diseases are grouped according to the kind of damage they cause. In addition to symptomatology, information on distribution, economic importance, epidemiology, and control measures is included to make the handbook more useful to growers, scientists and extension practitioners.

Diagnosis

In the majority of cases, plant disease diagnosis is routinely based upon signs and symptoms present at the time of diagnosis. A prior knowledge of the system and host history of the area are important tools in the success of these diagnosis. In many cases, diagnosis is made in the field when the disease is common to the area and familiar to the diagnostician. For example, wilt of pigeonpea (*Fusarium udum*) is a common disease worldwide occurring most of the years to varying degrees. Accurate diagnosis of wilt is routinely made in the field by extension agents/ scientists and university specialists as well producers, based on upon symptoms alone. However, pigeonpea plant mortality due to wilt is associated with other soil borne pathogens (*Phytophthora dreshleri* f. sp. *cajani*), so plant samples with wilt need to be submitted to a laboratory to confirm the association of two pathogens. There are certain risks to field diagnosis; symptoms can vary as a function of many variables including, age of the plant, plant genotype, plant species, environmental conditions and the like. One pathogen species may cause different symptoms on different host species of different genotypes of the same species, while different pathogen species may cause the same symptoms on the same or different host species and genotypes. The probability of misdiagnosis based upon symptoms alone is highest for host species and diseases new to the area. It is extremely important to get laboratory confirmation of diagnosis for any potential or high consequence disease.

Tools/techniques available for plant disease diagnostics

The first and most important step for good management of a plant disease is to correctly identify it. Without proper identification of the disease and the disease causing agent, it is difficult to devise effective disease control measures. Although some diseases can be diagnosed quickly by looking at their characteristic symptoms, the majority of plant diseases require laboratory testing for accurate diagnosis. These laboratory procedures are often time-consuming, labor intensive and require skilled technicians to follow the proper protocol and techniques. Traditional diagnostics in plant clinics and plant pathology laboratories have limited access to modern technologies, and they rely on morphological and cultural characteristics of the pathogen. Morphological and cultural characteristics are not always reliable diagnostic determinants due to similarity among different pathogen species. This can delay the implementation of appropriate mitigation measures. With the recent advances in molecular biology, new techniques and products are becoming available that will complement or replace time-consuming laboratory procedures. The following are molecular biology techniques available for precise and quick diagnosis:

Biotic causal Agent	Available tools/tests
Fungi	Microscopy
	PCR/ Real-time PCR
Viruses	ELISA, Electron Microscopy
	PCR/Real-time PCR
	Lateral flow devices
Bacteria	BIOLOG kits, FISH,
	PCR/Real-time PCR
	Lateral flow devices

Sampling tips for proper plant disease diagnostics

Disease diagnosis is a critical step for successful disease management. Accurate diagnosis is prerequisite for implementing the best disease-control measures and it starts with the 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 out, never pull out 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 that Kill the Plant

This section deals with several diseases caused by fungi, one caused by a bacterium, and one abiotic stress - waterlogging - that commonly result in death of plants.

Collar Rot

Sclerotium rolfsii Saccardo

Distribution. India, Pakistan, Puerto Rico, Sri Lanka, Trinidad and Tobago, USA and Venezuela.

Economic importance. A minor disease that can cause severe losses when undecomposed organic matter is left on the surface of seedbeds. Pigeonpea following cereal crops such as sorghum is likely to be infected if stubble has not been cleared from the field.

Epidemiology. Temperatures of about 30°C and high soil moisture at sowing predispose seedlings to infection. In India, the disease is more of a problem in early-sown (June) than in later-sown crops.

Symptoms. A seedling disease that usually appears within a month of sowing, when patches of dead seedlings at the primary leaf stage are seen scattered over the field (Fig. 1). The seedlings may turn slightly

Figure 1. Field showing patches of dead seedlings affected by collar rot.

chlorotic before they die. The confirmatory symptom is rotting in the collar region that is covered with white mycelial growth; this differentiates collar rot from other seedling diseases caused by species of *Fusarium, Rhizoctonia,* or *Pythium.* Seedlings affected by collar rot can be uprooted easily, but the lower part of their root usually remains in the soil. Sometimes white or brown sclerotial bodies of the fungus can be found attached to the collar region of a dead seedling or in the soil around it.

Phytophthora Blight

Phytophthora drechsleri Tucker f. sp. *cajani*

Distribution. Dominican Republic, India, Kenya, Panama and Puerto Rico.

Economic importance. A devastating disease that kills young (1-7-week-old) plants, leaving large gaps in plant stands. Yield losses are usually higher in short duration pigeonpea than in medium- and long-duration types.

Epidemiology. The disease is soilborne. The fungus survives as chlamydospores, oospores and dormant mycelium in soil and on infected plant debris. Cloudy weather and drizzling rain with temperatures around 25°C favor infection that requires continuous leaf wetness for eight hours to occur. Plants gradually develop tolerance to the disease as they grow older and are not infected after they are 60 days old. The disease is more common on Alfisols than on Vertisols, and appears first in low-lying areas of fields where water temporarily stagnates. The thick canopy of short-duration types occasioned by close spacing (30 x 10 cm), and their higher genetic susceptibility, seems to encourage blight build-up. Warm and humid weather following infection results in rapid disease development and plant death. Wind and rain help to disseminate zoospores and due to the plant damage they cause, facilitate infection. *Cajanus scarabaeoides* var. *scarabaeoides,* a wild relative of pigeonpea, is also a host of the blight pathogen.

Symptoms. Phytophthora blight resembles damping off disease that causes seedlings to die suddenly (Fig. 2). Infected plants have water-soaked lesions on their leaves (Fig. 3) and brown to black, slightly sunken lesions on their stems and petioles (Fig. 4). Infected leaves lose turgidity, and become desiccated. Lesions girdle the affected main stems or branches which break at this point, causing the foliage above the lesion to dry up (Fig. 5). When conditions favor the pathogen, it is

Figure 2. Phytophthora blight resembles damping off disease.

Figure 3. Water soaked lesions on leaves.

Figure 4. Brown to black lesions on stems and petioles.

Figure 5. Broken stem at the point of infection.

common for many plants to die (Fig. 6). Pigeonpea plants that are infected by blight, but not killed, often produce large galls on their stems especially at the edges of the lesions (Fig. 7). The pathogen infects the foliage and stems but not the root system.

Figure 6. Plants killed by phytophthora blight.

Figure 7. Infected plant showing galls on their stems.

Fusarium Wilt

Fusarium udum Butler

Distribution. Bangladesh, Ghana, Grenada, India, Indonesia, Kenya, Malawi, Mauritius, Myanmar (Burma), Nepal, Nevis, Tanzania, Thailand, Trinidad and Tobago, Uganda, and Venezuela.

Economic importance. The annual losses due to wilt have been estimated at US$71 million in India and US$5 million in eastern Africa.

Epidemiology. The disease is seed and soilborne. The fungus can survive on infected plant debris in the soil for up to 10 years. Wilt symptoms usually appear when plants are flowering and podding, but sometimes occur earlier when plants are 1-2 months old. Disease incidence is more severe on Vertisols than on Alfisols. Early sowing, good weed management, and good crop growth encourage wilt development. Long- and medium- duration types suffer more from wilt than short duration types. Ratooning predisposes the plant to wilt. Pigeonpeas intercropped with sorghum are less attacked by wilt than sole-cropped plants.

Symptoms. Patches of dead plants in the field when the crop is flowering or podding are the first indications of wilt (Fig. 8). The most characteristic symptom is a purple

Figure 8. Patches of plants killed by fusarium wilt.

band extending upwards from the base of the main stem (Fig. 9). This band is more easily seen in pigeonpea with green stems than in those with colored stems. Partial wilting of the plant is a definite indication of fusarium wilt, and distinguishes this disease from termite damage, drought, and Phytophthora blight, which kill the whole plant. Partial wilting is associated with lateral root infection, while total wilt is due to tap root infection. The other characteristic symptom of wilt is browning of the stem tissue in the region of the purple band (Fig. 10) and browning or blackening of the xylem, visible when the

Figure 9. Purple band on stem.

Figure 10. Browning of stem tissue.

main stem or primary branches are split open (Fig. 11). The intensity of browning or blackening decreases from the base to the tip of the plant. Sometimes, branches (especially lower ones) dry, even if there is no band on the main stem. These branches have die-back symptoms with a purple band extending from tip downwards, and intensive internal xylem blackening (Fig. 12). When young plants (1-2 months old) die from wilt, they may not show the purple band symptom, but have obvious internal browning and blackening. Plants infected by *F. udum* also exhibit a series of leaf symptoms before they die, including loss of leaf turgidity, inter-veinal clearing, and chlorosis to bright yellow color of leaves.

Figure 11. Browning or blackening of xylem.

Figure 12. Die-back symptom with purple band.

Dry Root Rot

Macrophomina Stem Canker

Rhizoctonia bataticola (Taub.) Butler

Macrophomina phaseolina (Tassi) Goidanich

Distribution. India, Jamaica, Myanmar (Burma), Nepal, Sri Lanka, and Trinidad and Tobago.

Epidemiology. A serious problem in late-sown or summer crops and in perennial or ratooned pigeonpeas. The disease also affects short-duration pigeonpeas sown in the rainy season. Hot (30°C and above) and dry weather encourage disease development, which is more prevalent on Vertisols than on Alfisols. Rain after a prolonged dry spell predisposes plants to the disease. Crops are more susceptible in the reproductive stage than in the vegetative stage.

Symptoms. Infected plants suddenly and prematurely dry up (Fig. 13). When such plants are uprooted, their roots are rotten and shredded roots are seen (Fig. 14).

Figure 13. Dried plants.

Figure 14. Rotten and shredded roots.

The finer roots mainly are affected and have dark, blackened streaks underneath their bark with evident dark sclerotial bodies (Fig. 14). Such roots are brittle and break when touched. Under hot, humid conditions root rotting extends to the base of the stem (Fig. 15). Early symptoms on stems and branches are spindle-shaped lesions (Fig. 16) with light gray centers and brown margins and scattered pycnidial bodies (Fig. 17, x200). The lesions finally coalesce and cause the branches or whole plants to dry up and die.

Figure 15. Root rotting extends to the base of stem.

Figure 16. Spindle shaped lesions on stem and branches.

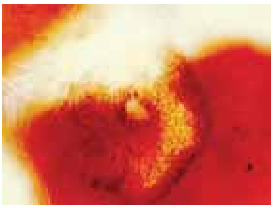

Figure 17. Pycnidial bodies.

Phoma Stem Canker

Phoma cajani (Rangel) Khune & Kapoor

Distribution. Brazil and India.

Symptoms. Normally seen at advanced stages of plant growth. Initial symptoms on stems appear as lesions with gray centers and dark brown margins. The lesions contain pycnidia. As the disease progresses, lesions coalesce and girdle the stem, then develop into large swollen cankers (Fig. 18) leading to the premature death of the plant.

Figure 18. Large cankers on stem.

Anthracnose

Colletotrichum cajani Rangel

Colletotrichum graminicola (Ces.) Wilson

Distribution. Brazil, India, Puerto Rico and USA (Hawaii).

Symptoms. A minor stem disease that appears as irregular brown to grayish stem lesions containing dark scattered acervuli (Fig. 19). Severe infection leads to drying and death of infected branches. Minute spots with dark margins and gray centers scattered with acervuli are also common on the leaves and pods of infected plants.

Figure 19. Lesions on stem with dark acervuli.

Waterlogging

Epidemiology. Pigeonpea is highly susceptible to waterlogging that can result in the sudden death of plants. Waterlogging is most severe when a few days of rain and cloudy weather are followed by sunny days. Pigeonpea suffers less damage from waterlogging in weedy or intercropped fields than in well-weeded sole cropped fields.

Symptoms. Dead plants (Fig. 20) do not show any external stem symptoms, but can be easily uprooted. Waterlogged roots are rotten, foul-smelling, and their bark is easy to peel off. It is possible to confuse death due to waterlogging with that due to wilt or Phytophthora blight. However, the most characteristic symptom of waterlogging is the presence of brown patches with

Figure 20. Dead plants caused by waterlogging.

wavy margins in the collar region, and which can also be seen when the bark is peeled off (Fig. 21). Reddish brown discontinuous streaks can be seen in the wood; these differ from wilt streaks, which are black and continuous. Death from waterlogging and stem lesions caused by Phytophthora blight can sometimes occur simultaneously, and in such cases it may be difficult to decide the exact cause of death. In adult plants waterlogging causes sudden death, while Phytophthora blight takes time to kill a plant. Adult pigeonpea plants are more susceptible to waterlogging than are seedlings.

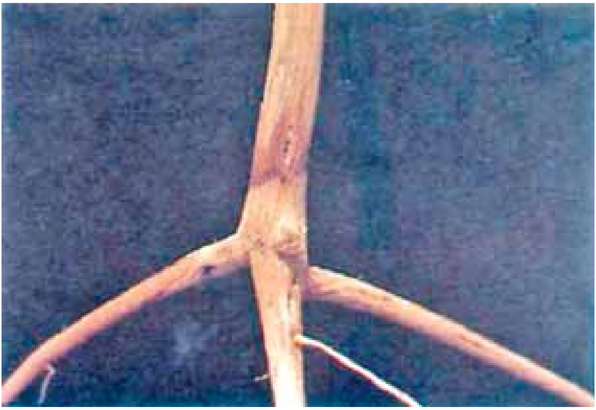

Figure 21. Peeled bark showing wavy margins in the collar region.

Leaf Spots, Blights and Defoliating Diseases

This section brings together diseases that affect the foliage. Some of the diseases may cause severe damage, but they rarely lead to death of plants.

Bacterial Leaf Spot and Stem Canker

Xanthomonas campestris pv. *cajani*

(Kulkarni, Patel & Abhyankar) Dye

Distribution. Australia, India, Myanmar (Burma), Panama, Puerto Rico, and Sudan.

Epidemiology. Warm (25-30°C) and humid weather favors disease development. Disease incidence is generally higher in low-lying waterlogged areas of the field than in well-drained areas. African germplasm is more susceptible to the disease than Indian germplasm. Pigeonpea with purple stems are less susceptible to stem canker than those with green stems. While leaf infection can occur at all stages of plant growth, stem infection usually occurs in younger plants.

Symptoms. In India the disease usually appears in the rainy season during July and August. It can be seen on the lower leaves of plants that are about 1 month old as small necrotic spots surrounded by bright yellow halos. Later, rough, raised, cankerous lesions appear on the stem (Fig. 22). Leaf spots (Fig. 23) do not usually cause defoliation. Cankers can cause stems to break, but the broken part usually remains attached to the plant (Fig. 22). Stems often break at the point where the primary leaves are attached. Often, the affected plants do not break, and the stem cankers increase in size until they are 15-25 cm long (Fig. 24). In cases of severe infection the affected branches dry.

Figure 22. Broken stem with cankerous lesions.

Figure 23. Necrotic leaf spots.

Figure 24. Enlarged stem cankers.

Powdery Mildew

Oidiopsis taurica (Lev.) Salmon

(Teleomorph: ***Leveillula taurica*** [Lev.] Arnaud)

Distribution. Ethiopia, India, Kenya, Malawi, Sri Lanka, Tanzania, Uganda, and Zambia.

Epidemiology. This is a polycyclic disease, ie, there is an initial infection and secondary spread. Infection is directly proportional to the quantity of inoculum available as conidia. Indian varieties with thin, succulent leaves that are easily colonized by the fungus are more susceptible than those from Kenya, which have thicker leaves. The disease develops at temperatures ranging from 20 to 35°C, but 25°C is the optimum. A cool, humid climate is congenial to fungal infection and colonization, but a warm humid climate is good for sporulation and spore dispersal. Sporulation is more frequent on young leaves than on older ones. Plants attacked by sterility mosaic or phyllody support abundant sporulation. Since sterility mosaic and phyllody-infected plants remain green in the field for long periods, they provide a continuous source of inoculum. The fungus survives on perennial pigeonpeas and volunteer plants growing in the shade, and on the ratoon growth of harvested stubbles.

It also survives as dormant mycelium on infected plant parts, eg, axillary buds. In India early sowing and irrigation encourage disease establishment.

Symptoms. Infected plants have white powdery fungal growths on all their aerial parts, especially the leaves, flowers, and pods. Severe infections result in heavy defoliation (Fig. 25). The disease causes stunting of young plants, followed by the visible symptoms of white powdery growth that appear gradually before the flowering stage. The initial symptoms develop as small chlorotic spots on the upper surface of individual leaves (Fig. 26) and subsequently the corresponding lower surfaces develop white powdery patches (Fig. 27). When the fungus sporulates, this white powdery growth covers the entire lower leaf surface (Fig. 28).

Figure 25. Defoliation in severely affected plants.

Figure 26. Small chlorotic spots on upper surface of leaf.

Figure 27. Powdery patches on lower surface of leaf.

Figure 28. Entire lower surface of leaf covered with powdery growth.

Cercospora Leaf Spot

Cercospora cajani Hennings (most prevalent)

Cercospora indica Singh

Cercospora instabilis Rangel

Cercospora thirumalacharii Sharma & Mishra

(Teleomorph: ***Mycovellosiella cajani*** **[**Henn.**]** Rangel ex Trotter)

Distribution. Bangladesh, Brazil, Colombia, Dominican Republic, Guatemala, India, Jamaica, Kenya, Malawi, Mauritius, Nepal, Nigeria, Puerto Rico, Sri Lanka, Tanzania, Trinidad and Tobago, Uganda, Venezuela, Zambia and Zimbabwe.

Economic importance. The disease is a problem in humid regions. Yield losses up to 85% have been reported from eastern Africa, and losses are severe when defoliation occurs before flowering and podding.

Epidemiology. Cool temperatures (25°C) and humid weather favor the disease, which normally appears when plants are flowering and podding. Cyclonic rains in southern and north-eastern peninsular India result in sudden outbreaks of the disease in certain years. The disease is more common in the long-duration and perennial pigeonpeas grown in eastern Africa.

Symptoms. First appear as small circular to irregular necrotic spots or lesions usually on older leaves (Fig. 29). These lesions coalesce causing leaf blight and defoliation. During epidemics, lesions appear on young branches and cause their tips to dry and die. The Indian isolates of the pathogen produce a fluffy mycelial growth on their lesions, while the African isolates produce concentric zonations on their lesions (Fig. 30)

Figure 29. Small necrotic spots on older leaves.

Figure 30. Concentric zonation on leaf.

Alternaria Blight

Alternaria sp

Alternaria tenuissima (Kunze ex Persoon) Wiltshire

Alternaria alternata (Fries) Keissler

Distribution. India, Kenya and Puerto Rico.

Epidemiology. Emerging disease under climate change scenario. Not a serious problem in rainy-season crops sown at the normal time, but does cause problems in crops sown late (September), or in the postrainy season on the plains of north-eastern India. Seed infection has only been reported from Puerto Rico.

Symptoms. Symptoms develop as small, circular, necrotic spots on leaves (Fig. 31) that develop quickly forming typically concentric rings. The lesions appear on all aerial plant parts including flowers, flower buds and pods (Fig. 32). They cause blighting of leaves, and severe defoliation and drying of infected branches. The fungus sporulates well under warm, humid conditions.

Figure 31. Necrotic spot on leaf.

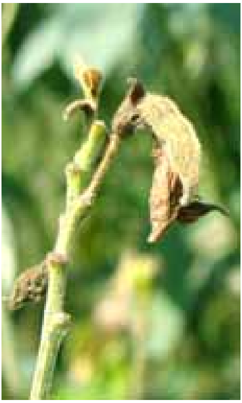

Figure 32. Drying of flowers and flower buds

Phyllosticta Leaf Spot

Phyllosticta cajani Sydow

Distribution. Brazil, India, Jamaica, Puerto Rico, Sri Lanka, and Trinidad and Tobago.

Epidemiology. A problem in warm, humid climates; the disease usually appears in July and persists throughout the cropping season. Serious epidemics can develop during October in the north-eastern plains of India. Mean temperatures ranging from 20 to 30°C with a mean humidity range of 73-80% favor severe outbreaks.

Symptoms. Round, necrotic spots, up to 10 mm in diameter, appear on the leaves. These lesions have wavy dark brown margins with gray centers; they contain characteristically concentric rings of pycnidial bodies (Fig. 33). In severe infections desiccation and defoliation occur.

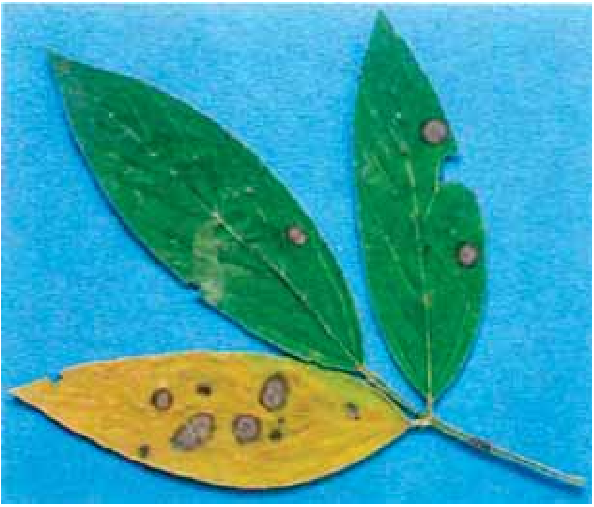

Figure 33. Necrotic leaf spots with pycnidial bodies.

Fusarium Leaf Blight

Fusarium semitectum Berkley & Rav.

Distribution. India and Puerto Rico.

Symptoms. A problem on pigeonpea crops in the north-eastern hills of India, disease symptoms appear as dark brown, circular to elliptical lesions, 2-10 mm in diameter, on the leaves. These lesions originate on leaf margins, and coalesce to form dark brown patches. Infected leaves become yellow and dry prematurely. When the weather is humid, white mycelia with abundant conidia appear on the blighted leaves.

Rust

Uredo cajani Sydow

Distribution. Bermuda, Colombia, Guatemala, India, Jamaica, Kenya, Nigeria, Puerto Rico, Sierra Leone, Sri Lanka, Tanzania, Trinidad and Tobago, Uganda, and Venezuela.

Epidemiology. Disease severity increases with the onset of flowering. Dense planting and the formation of a closed canopy provide a microclimate favorable for disease development. Light rain, wind, and cloudiness encourage spore release, dispersal, and disease development.

Symptoms. Normally seen as dark brown raised pustules full of uredia on the lower leaf surfaces (Fig. 34). The infected leaves desiccate, and drop off. There is extensive defoliation when infections are severe.

Figure 34. Rust pustules on the lower leaf surface.

Halo Blight

Pseudomonas syringae pv. phaseolicola

(Burkholder) Young, Dye & Wilkie

(syn ***P. phaseolicola***)

Distribution. Australia, Ethiopia, and Zambia

Symptoms. The disease develops on leaves as dark brown angular necrotic spots 1 mm in diameter surrounded by large chlorotic halos 10 mm in diameter. Under humid conditions, these spots coalesce giving the leaves a blighted appearance. The symptoms are more commonly seen on the soft, young leaves of older and ratooned plants. Persistent rains and cloudy weather result in severe disease development.

Botrytis Gray Mold

Botrytis cinerea Persoon ex Fries

Distribution. Bangladesh, India, Nepal, and Sri Lanka.

Symptoms. Disease symptoms usually appear when plants are flowering, as dark gray fungal growths on the growing tips, flowers, and pods. Infected flowers (Fig. 35) drop, thus reducing pod set. The shed flowers and leaves

Figure 35. Dark gray fungal growth on flowers and pods.

Figure 36. Sporulating mycelium on shed flowers and leaves.

on the ground are covered with sporulating mycelium of the fungus (Fig. 36).

Marginal Leaf Burning

Symptoms. Starts with marginal chlorosis and progresses to the “burning” of the leaf laminae margins (Fig. 37), commonly observed late in the season. The problem is exacerbated by prolonged dry spells. The symptoms first start in lower leaves and progress upwards. They can be distinguished from those of fungal leaf blights by their systematic nature and the absence of chlorotic area between the dried and healthy portions of the laminae that are characteristic of symptoms caused by pathogens. The reasons for leaf burning are not well understood, but it could be due to soil salinity that results in a gradual accumulation of salts in the leaves.

Figure 37. Margins of leaf laminae showing burnt appearance.

Mosaics and Sterility

This section includes some diseases caused by viruses and mycoplasma-like organisms.

Sterility Mosaic

Pigeonpea sterility mosaic virus

Vector. Eriophyid mite ***Aceria cajan*i** Channabasavanna

Distribution. Bangladesh, India, Myanmar (Burma), Nepal, and Sri Lanka.

Economic importance. A serious problem in Nepal and India where it is estimated to cause annual pigeonpea grain losses worth US$282 million.

Epidemiology. A single eriophyid mite vector (Fig. 38, x 200) is sufficient to transmit the disease. The mites are very small but can be seen easily under a stereo binocular (40x) microscope. They can be wind borne up to 2 km from the source of inoculum. Both pathogen and the mite vector are specific to *Cajanus cajan* and its wild relative *C. scarabaeoides* var. *scarabaeoides* that is commonly found on wastelands and field bunds. Perennial and volunteer pigeonpeas, and the ratooned growth of harvested plants provide reservoirs of the mite vector and the pathogen. Disease incidence is high when

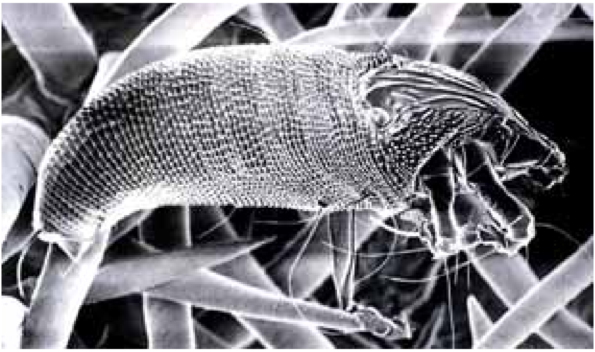

Figure 38. Eriophyid mite (magnified).

pigeonpeas are inter- or mixed cropped with sorghum or millets. Symptoms are suppressed during the hot summer months, but with monsoon rains they reappear on the new growth. Shade and humidity encourage mite multiplication, especially in hot summer weather.

Symptoms. In the field, the disease can be easily identified from a distance as patches of bushy, pale green plants (Fig. 39,40) without flowers or pods

Figure 39. Patches of bushy pale green plants in the field.

Figure 40. Bushy pale green plant.

(Fig. 41). The leaves of these plants are small and show a light and dark green mosaic pattern (Fig. 42). The mosaic symptoms initially appear as vein-clearing on young leaves (Fig. 43). When infection occurs at 45 days after emergence or later, only some parts of the plant may show disease symptoms, while the remaining parts appear normal (Fig. 43). Some pigeonpea varieties, eg, ICP 2376, exhibit ring spot leaf symptoms (green islands surrounded by chlorotic areas), these indicate localized sites of infection of the pathogen (Fig. 44), and such plants produce normal flowers and pods. Strains of sterility mosaic prevalent in the Indian state of Bihar and in Nepal cause severe internodal shortening of the branches and clustering of leaves. Sometimes these leaves become filiform.

Figure 41. Infected plants without flowers and pods.

Figure 42. Mosaic symptoms on leaf.

Figure 43. Vein clearing symptom on young leaves.

Figure 44. Infected leaf with ring spot symptom.

Yellow Mosaic

Mung bean yellow mosaic virus

Vector. White fly ***Bemisia tabaci*** Gennadius

Distribution. India, Jamaica, Nepal, Puerto Rico, and Sri Lanka.

Symptoms. Affected plants are conspicuous in the field, because of the green and golden yellow mosaic mottle symptoms on their leaves (Fig. 45). Sometimes the affected parts of the leaves become necrotic. Diseased plants are usually scattered in the field, and may produce fewer pods than normal, especially when infected early. Off-season and isolated sowings suffer more from the disease than does the main-season crop, because pigeonpea is not a preferred host of the white fly vectors; they only feed on the crop when forced to by the absence of other host plants.

Figure 45. Green and golden yellow mosaic mottle symptoms on leaves.

Witches' Broom

Candidatus Phytoplasma phoenicium

Vector. Leaf hopper ***Empoasca*** sp

Distribution. Australia, Bangladesh, Costa Rica, Dominican Republic, El Salvador, Haiti, Jamaica, New Guinea, Panama, Puerto Rico, Taiwan, Trinidad and Tobago, and USA.

Symptoms. Infection results in excessive proliferation and clustering of branches with small pale green leaves (Fig. 46). This gives the plant a 'witches' broom' appearance. Such plants rarely produce flowers and pods. Flowers, if produced appear in clusters with elongated pedicels. The whole or part of the plant may exhibit symptoms, depending on the intensity of the disease.

Figure 46. Clustering of branches with small pale green leaves.

Phyllody

Candidatus Phytoplasma species

Vector. Not known.

Distribution. India, Myanmar (Burma) and Thailand.

Symptoms. The disease can only be recognised at flowering. Diseased plants are scattered in the field and can be easily recognized because they are bushy with an axillary proliferation of phylloid flowers (Fig. 47). This disease, like yellow mosaic, is seen more frequently in off-season sowings than in main-season crops, but its incidence is still low. Phyllody differs from witches' broom, as in the former flowers are converted into leafy structures, while in the latter there are no flowers.

Figure 47. Floral proliferation.

Bracteomania

Genetic abnormality

Distribution. India

Symptoms. Affected plants are stunted with few branches, they produce solitary simple leaves with obtuse tips and long petioles attached to their stems, twigs, and floral shoots. Axillary flower buds proliferate into abnormal, clustered inflorescences (Fig. 48). The flowers of affected plants are sessile, small, bunchy, and tightly packed, giving the inflorescences a knotted appearance. Such flowers do not produce normal pods.

Figure 48. Floral proliferation.

Stunting

This section covers three kinds of nematode-induced diseases commonly characterized by stunting.

Root-knot

Meloidogyne incognita (Kofoid & White) Chitwood

Meloidogyne javanica (Treub) Chitwood

Meloidogyne arenaria (Neal) Chitwood

Meloidogyne acronea Coetzee

Distribution. Australia, Bangladesh, Brazil, Egypt, India, Kenya, Malawi, Nepal, Puerto Rico, Trinidad and Tobago, Uganda, USA, Zambia and Zimbabwe.

Economic importance. Yield losses of 8 to 35% have been reported from the Caribbean, Africa and southeast Asia.

Epidemiology. *Meloidogyne incognita* and *M. javanica* are the two most widely distributed root-knot nematode species in tropical, subtropical and warm temperature climates. They have a very wide host range and occur in an extensive range of soil types, but their association with crop damage is reflective of sandy soils or sandy patches within fields. Weed hosts help to maintain high populations of nematodes in fields. The severity of root knot disease increases in fields with combined infestations of *M. javanica* and *M. incognita.* Also, infection by these species increases the severity of Fusarium wilt infection.

Symptoms. Aerial parts show no characteristic symptoms, but reduced plant vigor (Fig. 49), delayed flowering in the whole or patches of a field and leaf yellowing are all indicative of nematode infestation. Root galls (knots) are the most characteristic symptom of infection, and can easily be seen with the naked eye (Fig. 50). When the galls are very small, examining roots for the presence of egg sacs is a useful way to confirm nematode infection.


Figure 49. Infected plants show stunted growth in the field.


Figure 50. Root galls.

Pearly Root

Heterodera cajani Koshy

Distribution. Egypt and India.

Economic importance. Yield losses as high as 30% have been reported as a result of infection. An initial population density of three juveniles cm^{-3} of soil can cause 25% reduction in plant biomass and yield.

Epidemiology. The host range of the cyst nematode *Heterodera cajani* is largely confined to species of the Leguminosae, but *Sesamum indicum* (Pedaliaceae) and *Phyllanthus maderaspatensis* (Euphorbiaceae) are non-legume hosts. *Heterodera cajani* is widespread in sandy loam soils in northern India and in black cotton soils in western and southern India. The nematode lives up to 45 cm deep in soil throughout the year. Summer fallowing reduces densities of *H. cajani* by 45% at 0-15 cm but does not affect densities at lower soil depths. Nematode infestation enhances the aggressiveness of *Fusarium udum* infection in wilt-susceptible pigeonpeas.

Symptoms. First noticed as poor and stunted plants evident 30-45 days after sowing (Fig. 51). If the roots of infected plants are carefully examined, many minute, pearl-like, white females of *H. cajani* can be seen attached to them (Fig. 52). These females can be seen with the naked eye, but are more clearly visible through a hand lens (10x). Nematode infestation can delay flowering and pod formation for more than a week.

Figure 51. Infected plants show stunted growth in the field.

Figure 52. Infected roots with pearl-like female nematodes.

Dirty Root

Rotylenchulus reniformis Linford & Oliveira

Distribution. Fiji, India, Jamaica, Puerto Rico, and Trinidad and Tobago.

Economic importance. Infestation severely affects pigeonpea production in Fiji, and is associated with variable crop growth in northern India, and on sandy and red soils (Alfisols) in western and southern India. Damage thresholds range from pre-plant nematode densities of 1.0 to 4.0 cm^{-3} of soil, depending on the soil type and climatic factors.

Epidemiology. This nematode attacks many crops in 38 subtropical and tropical countries. Its extensive host range includes several fruit, vegetable, legume, oilseed, millet, ornamental, and plantation crops. It can reduce the number of *Rhizobium* nodules a legume plant produces. Although, the wilt pathogen reduces the density of the nematode, wilt-susceptible genotypes die prematurely when the nematode and the fungus are both present in the soil. The nematode can survive in the absence of a host for more than 300 days without losing its infectivity, but summer fallowing reduces *R. reniformis* densities to 70% at 0-15 cm soil depth and 36% at 15-30 cm soil depth.

Symptoms. Infected plants generally grow less vigorously than healthy ones (Fig. 53), and have smaller root systems than healthy plants. If these plants are uprooted, egg masses covered with soil are found on their roots (Fig. 54). Infected roots appear dirty because soil particles adhere to the mucilaginous nematode egg sacs, and are not easily dislodged when the roots are shaken. If these roots are dipped in 0.25% trypan blue and rinsed in water, the nematode egg sacs are selectively colored blue while the roots are not stained. This technique can be used to identify reniform nematode infection without using a microscope.

Figure 53. Plants stunted due to dirty root disease.

Figure 54. Infected roots with egg masses.

Disease Management

Successful disease management requires integration of such practices as growing resistant or moderately resistant varieties, modification of sowing dates to avoid environmental conditions conducive to disease, use of crop hygiene and cultural practices known to reduce disease severity, and application of appropriate fungicides as soil fumigants, seed protectants and foliar sprays. Specific packages of practices have to be developed for each crop production system and environment, and socio-economic factors need to be considered. It is therefore not possible to prescribe any overall disease management practice, but the information provided in Tables 1-4 should be useful in putting together packages for particular situations.

Table 1. Sources of disease resistance.

Disease	Resistant varieties/lines
Fusarium wilt	ICP 9145, ICEAP 00020, ICEAP 00040, ICEAP 00053, ICEAP 00540, ICEAP 00550, ICEAP 00555, ICEAP 00556, ICEAP 00557 IPA 16 F, NDA2009-1, TS 3, JKM 189, AL 1, BDN 2, Birsa Arhar 1, DL 82, H 76-11, H 76 -44, H 76-51, H 76-65, ICP 9145, ICPL 267, Mukta, Prabhat, Sharda, TT 5, TT 6
Sterility mosaic	MA - 3 (Malviya Vikalp), ICP 7035, Bahar, Bageshwari, DA 11 , DA 13, ICPL 86, ICPL 146, ICPL 87051, MA 165, MA 166, PDA 2, PDA 10, Rampur Rahar
Phytophthora blight	Azad, Bandapaleru, *C. sericeus*, HPL 24-47, ICP 11376-5, ICP 12730, ICP 12751, ICP 12755, ICPL 20093, ICPL 20100, ICPL 20101, ICPL 20104, ICPL 20105, ICPL 20109, ICPL 20114, ICPL 20122, ICPL 20124, ICPL 20126, ICPL 20128, ICPL 20136, ICPL 93179, ICPL 99044, Hy 4, ICPL 150, ICPL 288, ICPL 304, KPBR 80-1-4, KPBR 80-2-1 (Field resistant)

Table 1 *Continued*

Disease	Resistant varieties/lines
Cercospora leaf spot	UC 796/1, UC 2113/1, UC 2515/2, UC 2568/1
Powdery mildew	ICP 9150, ICP 9177
Alternaria blight	DA 2, MA 128-1, MA 128-2, 20-105 (West Bengal)
Dry root rot	ICPLs 86005, 86020, 87105, 91028
Bacterial leaf spot and Stem canker	ICPs 12807, 12848, 12849,12937, 13051,13116,13148
Phoma stem canker	AL 133, AL 136, ICPL 148, ICPL 84018
Rust	Blanco, Todo Tempo No. 17
Phyllody	BDN 5, ICPL 83057, MRG 66
Halo blight	GW 3, ICPL 362
Phyllosticta leaf spot	EMC, ICPL 161, ICPL 269, ICPL 335, Pusa 33, Pusa 85
Root-knot	ICP 11289, ICP 11299
Dirty root	AGS 522, Basant, GAUT 82-75, GAUT 83-23, GAUT 84-22, ICP 12744, PDM 1

Table 2. Sources of multiple disease resistance.	
Diseases	Resistant varieties/lines
Wilt + Phoma stem canker + Phyllody + Halo blight + Phyllosticta leaf spot	ICPL 87, C 11
Wilt + Sterility mosaic + Phytophthora blight	ICPL 20135, ICPL 20125, ICPL 20115, KPBR 80-2-2-1, ICP 11975, ICPL 20096, ICPL 20099, AWR 74/16, KPBR 80-2-1, KPL 96053, ICPL 20127, ICPL 83024
Wilt + Sterility mosaic + Powdery mildew	ICP 7867
Wilt + Phytophthora blight + Halo blight	BDN 1
Sterility mosaic + Powdery mildew + Halo blight	Hy 3C, ICP 7035
Wilt + Sterility mosaic	ICPL 85063 (Laxmi), ICP 8863 (Maruti), ICP 11376-5, ICP 12755, ICPL 99044, ICP 9174, ICPL 227, ICPL 87119 (Asha), NPWR 15
Wilt + Halo blight	ICPL 81
Sterility mosaic + Alternaria blight	Pusa-9, ICPL 366
Sterility mosaic + Root-knot	ICPL 151 (Jagiti)

Table 3. Cultural practices for disease control.

Diseases	Suggested cultural practices
Fusarium wilt	• Collect and burn plant residues after harvesting • Do summer ploughing • Select a field with no previous record of wilt for at least 3 years • Select seed from disease-free fields • Grow pigeonpea intercropped or mixed with cereal crops, eg, sorghum • Rotate pigeonpea with sorghum, tobacco, or castor every 3 years • Uproot wilted plants and use them for fuelwood • Solarize the field in summer to help reduce inoculum
Sterility mosaic	• The spacing between the lines should be maintained at 30 to 40 cms • Weeds should be rouged out at their inception • Maintain timely sowing of the crop • Select a field well away from perennial or ratoon pigeonpeas • Destroy sources of sterility mosaic inoculum, ie, perennial or ratooned pigeonpeas • Uproot infected plants at an early stage of disease development and destroy them • Rotate crops to reduce sources of inoculum and mite vectors

Continued

Table 3 *Continued*

Diseases	Suggested cultural practices
Phytophthora blight	• Early or normal sowing • Practice ridge planting methods • Summer solarization and summer ploughing should be done • Select fields with no previous record of blight • Avoid sowing pigeonpea in fields with low-lying patches that are prone to waterlogging • Prepare raised seed beds and provide good drainage • Use wide inter-row spacing
Witches' broom	• Select fields away from perennial pigeonpeas affected with witches' broom • Pull out and destroy any infected plants to minimize secondary spread of disease • Avoid ratoon cropping
Cercospora leaf spot	• Select fields away from perennial pigeonpeas that are a source of inoculum • Select seed from healthy crops
Powdery mildew	• Select fields away from perennial pigeonpeas affected with the disease that are a source of inoculum • Sow late (after July) in India, to reduce disease incidence
Alternaria blight	• Avoid fields close to perennial pigeonpeas • Select seed from healthy crops • Sow early

Table 3 *Continued*

Diseases	Suggested cultural practices
Dry root rot	• Disease incidence can be reduced if the previous crop stubble is buried deep, and is allowed to decompose well before pigeonpea is sown • Select fields with no previous record of dry root rot • Avoid sowing late so that the crop escapes from drought and high temperatures at maturity
Collar rot	• Deep summer ploughing • Select well drained fields • Keep the fields free from un-decomposed organic matter • Sow when soil moisture is low • Select fields where cereal crops (such as sorghum) have not been grown during the previous season • Collect cereal stubble from the field and destroy it before sowing pigeonpea
Bacterial leaf spot and Stem canker	• Select well-drained fields • Select seed from healthy crops
Phoma stem canker	• Avoid fields with previous records of the disease • Remove infected plants to reduce the build-up of inoculum in the soil
Rust	• Avoid sowing pigeonpea close to bean fields • Rotate crops to reduce the chance of pathogen survival
Yellow mosaic	• Avoid sowing late to reduce disease severity • Uproot and burn infected plants if the disease appears on isolated plants in the field

Continued

Table 3 *Continued*

Diseases	Suggested cultural practices
Phyllody	• Select fields away from perennial pigeonpeas and sesamum
Anthracnose	• Avoid fields with previous blight records
Root-knot	• Select field with no previous record of nematode infestation • Rotate pigeonpea with wheat to reduce nematode populations • Solarize soil in summer to reduce nematode populations
Pearly root	• Select fields with no previous record of nematode infestation • Rotate crops with sorghum, maize, or pearl millet to reduce nematode populations • Solarize soil in summer to reduce nematode populations
Dirty root	• Select fields with no previous record of nematode infestation • Rotate crops with rice, maize, or groundnut to reduce nematode populations • Solarize soil in summer to reduce nematode populations

Table 4. Chemical control measures.

Disease	Chemical treatment
Fusarium wilt	• Spot drenching with Carbendazim @ 1g L^{-1} water • Seed dressing with Benlate T® (benlate 50% + thiram 50% mix) @ 3 g kg^{-1} seed
Sterility mosaic	• Seed dressing with 25% Furadan 3G® or 10% aldicarb@ 3 g kg^{-1} seed • Spraying acaricide or insecticides like Kelthane®, Morestan®, metasystox @ 0. 1% to control the mite vector in the early stages of plant growth
Phytophthora blight	• Seed dressing with RidomilMZ® @ 3 g kg^{-1} seed • Two foliar sprays of Ridomil MZ® at 15-day intervals starting from 15 days after germination
Witches' broom	• Spray insecticides (eg., metasystox @ 0.1%) to control the leaf hopper
Cercospora leaf spot	• Spray maneb (Indofil M 45®)@ 3 g L^{-1} water
Powdery mildew	• Spray wettable sulfur @ 1 g L^{-1} or triadimefon (Bayletan® 25% EC) @ 0.03%
Alternaria blight	• Spray maneb (Indofil M 45®)@ 3 g L^{-1} water
Collar rot	• Seed dressing with tolclofosmethyl (Rhizolex®), captan, orthiram @ 3 g kg^{-1} seed
Bacterial leaf spot and Stem canker	• Spray antibiotics like Streptocycline® (streptomycine and tetracycline) @ 100 μg L^{-1} at 10-day intervals

Continued

Table 4 *Continued*

Disease	Chemical treatment
Rust	• Spray maneb (Indofil M 45®) @ 3 g L^{-1} water
Yellow mosaic	• Spray insecticide (metasystox @ 1 g L^{-1}) to control the whitefly
Phyllody	• Spray insecticides such as metasystox to control the vector
Anthracnose	• Spray maneb (Indofil M 45®) @ 3 g L^{-1} water
Halo blight	• Spray antibiotics like Streptocycline® (streptomycine and tetracycline) @100 μgL^{-1}
Botrytis gray mold	• Spray Ronilan® or Daconil® @3 g L^{-1} water
Phyllosticta leaf spot	• Spray maneb (Indofil M 45®) @ 3 g L^{-1} water
Fusarium leaf blight	• Spray Benlate-T® @ 3 g L^{-1} water
Root-knot	• Soil application of chemicals such as aldicarb, carbofuran, fensulfothion, and phorate (2 to 6 kg ha^{-1})
Pearly root	• Same as for root-knot nematode
Dirty root	• Same as for root-knot nematode

Key to the Diagnosis of Major Diseases

1.	Plants die	*See* **2**
	Plants do not die	*See* **5**
2.	No external restricted lesions on main stem or branches	**Fusarium wilt**
	Collar rot with white mycelial growth	**Collar rot**
	Root rot	**Dry root rot**
	Brown chromatographic type lesions on wood at collar region	**Waterlogging**
	External lesions on main stem and branches without enlarged swellings	*See* **3**
	External lesions on main stem and branches with enlarged swellings	*See* **4**
3.	Lesions elongated, sunken, without discrete margin and galls on their margins	**Phytophthora blight**
	Lesions localized with discrete marginal acervuli	**Anthracnose**
	Lesions spindle-shaped with gray centers	**Macrophomina stem canker**
4.	Enlarged swellings	**Phoma stem canker**
5.	Lesions localized and cankerous	**Bacterial stem canker**
	Plant growth stunted, without any characteristic symptoms on foliage	*See* **6**

	Plant growth stunted with characteristic symptoms on foliage	*See* **7**
6.	Swelling (knots) on main and lateral roots	**Root-knot**
	Minute pearl like white females on roots	**Pearly root**
	Soil particles adhere to roots difficult to dislodge by shaking	**Dirty root**
7.	Clusters of closed buds in leaf axis	**Bracteomania**
	White powdery fungal growth on foliar parts	**Powdery mildew**
	Dark gray fungal growth on leaves, flowers, and pods	**Botrytis gray mold**
	"Burning" of the margins of leaf laminae	**Marginal leaf burning**
	Necrotic spots on foliage	*See* **8**
	Lesions on foliage	*See* **9**
	Mosaic, stunting, sterility	*See* **10**
8.	Necrotic spots circular to irregular	**Cercospora leaf spot**
	Necrotic spots small, circular, with pycnidia, and wavy margins	**Phyllosticta leaf spot**
	Necrotic spots large, circular to irregular, with Zonation	**Alternaria blight**
	Necrotic spots small, with chlorotic halos	**Bacterial leaf spot**

	Necrotic spots small, with chlorotic halo	**Halo blight**
9.	Small, dark brown raised pustules	**Rust**
	Large necrotic lesions on leaf margins	**Fusarium leaf blight**
10.	Green and golden mosaic symptoms on leaves	**Yellow mosaic**
	Light and dark green mosaic symptoms on leaves and sterility	**Sterility mosaic**
	Small leaves, axillary proliferation, and sterility	**Witches'broom**
	Phylloid flowers and sterility	**Phyllody**

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About ICRISAT

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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ISBN 92-9066-277-8 Order code: IBE 042 382-12