# Pest Management in Pigeonpea

Compiled by

Faujdar Singh and D.L. Oswalt

## Skill Development Series no. 12

ICRISAT
Human Resource Development Program
International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1992

# Management Procedures for Evaluation of Pearl Millet and Sorghum Grain Quality

Compiled by

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## Human Resource Development Program

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## Contents

## Introduction

The term pest is derived from the Greek word 'pestis' which means to 'annoy'. Precisely any organism that annoys human beings is a pest. Therefore, pests includes insects, fungi, bacteria, viruses, and nematodes that harm plants or human beings.

## Insect Pests of Pigeonpea

Pigeonpea is attacked by over 200 species of insects (Reed and Lateef 1990). Most of these insects are sporadic in their distribution, so they are not regarded as pests. Reed et al. (1989) compiled the list of pigeonpea insects and classified them as pests of roots and stems, pests of foliage, and pests of flowers and pods. The damage caused by the insect pests to pods significantly reduces the crop yield. The major pests of economic importance are discussed here.

# MP 1. Insects Attacking Roots and Stems of Pigeonpea

The insects attacking roots and stems of pigeonpea are listed in Table 1 (Reed et al. 1989).

**Table 1. Insects attacking roots and stems of pigeonpea.**

| Name/spp | Distribution | Symptoms on plant |
|---|---|---|
| **A. Insects attacking roots** | | |
| 1. Nodule damaging fly *Rivellia angulata* Hendel | India, Africa | The larvae penetrate the nodules and make them hollow by feeding. The plants show yellowing and reduced growth. |
| 2. Termites *Odontotermes* spp *Microtermes* spp | Throughout tropics and subtropics | Wilting of young plants, sometimes produces a hole in the stem just below the soil surface. *Microtermes* spp tunnels into stem and root. Stems attacked by *Odontotermes* spp are covered with earth below while termites feed upon the stem surface. |
| **B. Insects attacking stem** | | |
| 1. Jewel beetles *Sphenoptera indica* Laporte & Gory | India | Larvae tunnel into the stem above and below the ground level. Wilting and death of attacked young plants. |
| 2. Stem weevils *Alcidodes fabricii* (Fabricius) *Alcidodes collaris* (Pascoe) | Central and South India | Girdling on the young plants by adults results in wilting, drying of plants, and stem breakage. |
| 3. Stem flies *Ophiomyia phaseoli* (Tryo) *O. centrosematis* (Meijere) | Africa, Asia, and Australia | Wilting of young plants. |

## Control Measures

1. In general root and stem insects are not very serious in pigeonpea. Therefore, unless heavily infested, control measures are not economical.

2. Seed treatment with aldrin or hexachloride (BHC®, Lindane®) prevents termite attack.

3. Systematic soil insecticides (phorate) control stemflies.

4. Soil application of phorate (Thimet®) 3% @ 25 kg $ha^{-1}$ at sowing time.

# MP 2. Foliage Feeding Insects — Jassids, Aphids, and Mites

Pigeonpea foliage is attacked by jassids, aphids, and mites (Reed et al. 1989). These are listed in Table 2.

**Table 2. Foliage feeding pests of pigeonpea.**

| Name | Distribution | Symptoms |
|---|---|---|
| 1. **Jassids** | | |
| *Empoasca fabae* (Harris)<br>*E. kerri* Pruthi<br>*Jacobiasca lybica* (de Beryen) | America and Caribbean<br>India<br>Africa | The attacked leaflets become cup shaped and yellow at the edges. Severely infected leaflets turn brown-red followed by defoliation and stunting. |
| 2. **Aphids** | | |
| *Aphis craccivora* Koch | Asia and Africa | Colonization on young stem leaflets and pods. Twisting of seedlings and young leaflets, wilting under severe infection. |
| 3. **Eriophyid mites** | | |
| *Aceria cajani* Channabasavanna | India | Transmit sterility mosaic disease, infected plants develop light green or chlorotic leaves on a mosaic pattern. Infected plants do not produce flowers or pods. |
| 4. **Red spider mites** | | |
| *Schizotetranychus cajani* Gupta<br>*Tetranychus* spp | India and eastern Africa | Yellow or white spots on upper surface of leaflets. Partial defoliation due to high infestation. Mites can be seen with the naked eyes on the lower surface of leaflets. |

## Control Measures

1. Mild infestation by these insects does not require any chemical control.

2. Under heavy infestation, spray with dimethoate (30% EC @ 1.0 L $ha^{-1}$ or endosulfan (35% EC @ 2.0 L $ha^{-1}$). This will control jassids, aphids, and mites.

# MP 3. Foliage Feeding Insects—Flies, Bugs, and Bees

The flies, bugs, and bees attacking pigeonpea are listed in Table 3 (Reed et al. 1989).

**Table 3. Foliage feeding flies, bugs, and bees of pigeonpea.**

| Name | Distribution | Symptoms |
|---|---|---|
| **1. White fly** | | |
| *Bemisia tabaci* (Genn) | America, Europe, Africa, Australia, and Asia | White fly is a vector of a virus causing yellow mosaic disease. |
| **2. Bud-sucking bugs** | | |
| *Campylomma* spp | India | Deformation of the leaves and abortion of flower buds due to sap sucking by bugs. |
| *Creontiades pallidus* (Rambir) | | |
| *Eurystylus* spp | | |
| *Taylorilygus vosseleri* (Poppius) | | |
| **3. Leaf-cutter bees** | | |
| *Megachile* spp | Widely distributed throughout the tropics | Leaflets are neatly cut in a semicircular fashion. |

## Control Measures

These insects have not been recorded as being significant to merit any control measures.

# MP 4. Foliage Feeding Insects—Weevils, Beetles, Defoliators, and Webbers

The main foliage feeders, weevils, beetles, and leaf-feeding lepidoptera larvae are given in Table 4 (Reed et al. 1989).

**Table 4. Leaf-feeding weevils, beetles, and lepidoptera larvae which attack pigeonpea.**

| Name | Distribution | Symptoms |
|---|---|---|
| **Leaf-damaging weevils** | | |
| *Myllocerus undecimpustulatus* Faust | India | Adults chew leaflets at the margin causing ragged effect. Larvae live in the soil, and mainly feed on roots. |
| *Namatocerus* spp | Africa | |
| *Phyllobius* spp | India | |
| *Systates* spp | Africa | |
| **Beetles** | | |
| *Epilachna* spp | India and Africa | The beetles eat leaves. Some of these are not seen because they feed only during the night and hide during the day. |
| *Cheilomenes* spp | | |
| *Podagrica* spp | | |
| *Oxycetonia versicolor* | | |
| *Holotrichia* spp | | |
| *Adoretus* spp | | |
| **Lepidopteran defoliators** | | |
| *Amsacta* spp | Polyphagous, widely distributed in Asia and Africa | Larvae feed on the leaves and inflorescence. |
| *Spilosoma obliqua* (Walker) | | |
| *Chrysodeixis chalcites* Esper | | |
| *Acanthoplusia orichalcea* (F.) | | |
| **Leaf webbers** | | |
| *Grapholita (Cydia) critica* Meyr. | India | Infestation starts at the seedling stage and may persist to the reproductive stage. Leaflets are webbed and larvae feed within the web. The web often includes the terminal bud. Further growth of the shoot is prevented. A small brown larva folds individual leaflets. It produces white or light brown patches on the folded leaflets. A green larva rolls the leaflets from the tips. |
| *Leguminivora ptychora* Meyr. | | |
| *Maruca testulalis* (Meyr) | | |
| *Anarsia ephippias* (Meyr) | | |
| *Aproaerema modicella* Dev. | | |
| *Caloptilia soyella* van Dev. | | |

## Control Measures

1. Leaf-damaging weevils, leaf-and-flower damaging beetles and lepidopteran defoliators do not cause sufficient damage to pigeonpea to merit separate control measures.

2. Insecticides such as endosulfan, or monocrotophos (36% EC @ 1.6 L $ha^{-1}$) effectively control when damage is severe.

## MP 5. Insects of Flowers and Buds—Thrips, Beetles, and Weevils

Pigeonpea flowers and buds that are severely affected by thrips, beetles, and weevils are listed in Table 5 (Reed et al. 1989).

**Table 5. Pasta of pigeonpea flowers and buds—thrips, beetles, and weevils.**

| Name | Distribution | Symptoms |
|---|---|---|
| **1. Thrips** | | |
| *Megalurothrips usitatus* (Bagnall) | India, Africa | Severe infection causes shedding of buds and flowers. |
| **2. Blister beetles** | | |
| *Mylabris pustulata* Thunberg | India | Adult beetles feed on flowers severely. |
| *Coryna* spp | Eastern Africa | |
| **3. Bud weevils** | | |
| *Indozocladius asperulus* (Faust) | Peninsular India | Larvae feed and pupate inside the flower buds, which become hollow. |
| **4. Pod weevils** | | |
| *Apion clavipes* Gerstaecker<br>*A. benignum* (Faust) | Northwest India and eastern Africa<br>southern India | Larvae damage the green seed in pods, adults emerge by cutting their way. The beetles chew and make small holes in leaflets and flowers. |
| **5. Pod sucking bugs** | | |
| *Anoplocnemis* spp<br>*Riptorters* spp<br>*Clavigralla gibbosa*<br>*Piezodorus* spp<br>*Dolicoris indicus* Stal. | Africa, Asia<br>Africa, Asia<br>India<br>Southeast Asia,<br>India | These bugs suck the sap of developing seed through the pod wall. The seed become shriveled with dark patches. Seeds lose germinability and become unfit for human consumption. |

## Control Measures

1. Thrips, bud weevils, pod weevils being minor pests, normally require no control measures. In case of heavy infestation, sprays of insecticides such as endosulfan or dimethoate are useful to control these insects.

2. Blister beetle damage is severe when small plots of pigeonpea are grown in isolation. Its attack is severe at the flowering stage (August to October in southern India). The beetles can be controlled manually by hand picking and killing or collecting them with an insect net followed by killing. Insecticides are not very effective against blister beetles but synthetic pyrethroids are useful.

3. Pod weevils and pod-sucking bugs can be controlled by sprays of dimethoate or monocrotophos, and by the use of synthetic pyrethroids.

# MP 6. Insects of Flowers and Pods—Pod Borers

This is the most dangerous group of insects causing yield losses in pigeonpea. Pod borers attacking pigeonpea are listed in Table 6 (Reed et al. 1989):

**Table 6. Pod borers attacking pigeonpea.**

| Name | Distribution | Symptoms |
|---|---|---|
| 1. **Pod borers** | | |
| *Helicoverpa armigera*[1] (Hubner)<br>*H. punctigera* (Wallengren)<br><br>*Heliothis vlrescens* F.<br>*Helicoverpa zea* (Boddie) | Throughout tropics and sub-tropics<br>Australia<br><br>USA | They destroy buds, flowers, and pods. When flowers and pods are not available they feed upon leaflets, leaving the veins. Larvae enter into the pod by making a hole and they eat developing and partially mature seed. |
| 2. **Lablab pod borer** | | |
| *Adisura atkinsoni* (Moore) | Southern India | The larvae bore into buds, flowers, and green pods. |
| 3. **Cowpea pod borer** | | |
| *Maruca testulalis*[1] (Geyer) | Throughout tropics and sub-tropics | The larvae web leaves, buds, and pods together and feed inside. |
| 4. **Plume moths** | | |
| Exelastis atomosa (Walsingham)<br>Sphenarches anisodactylus Wlk. | Widely in Asia and eastern Africa | The larvae chew into the bud, flowers, and pods. Small holes can be seen in the buds and tender pods. |
| 5. **Lima bean pod borer** | | |
| *Etiella zinckenella* Treitschke | Widely distributed in tropics and semi-arid tropics | Larvae are present in mature and dried pods. The infestation is maximum at the end of the pigeonpea season when temperatures are high. Faecal granules are found inside the damaged pods. |

1. Most important pests

## Control Measures

1. Sprays of insecticides such as endosulfan and synthetic pyrethroids control pod borers, lablab pod borers, cowpea pod borers, and plume moths. Insecticides should be applied soon after the eggs hatch.

2. The lima bean pod borer can be controlled by a systemic insecticide, namely dimethoate (30% EC @ 1.0 L $ha^{-1}$)

# MP 7. Pod Flies, Pod Wasps, and Bruchids

The important pod flies, pod wasps, and bruchids of pigeonpea are listed in Table 7.

**Table 7. Import pod flies, pod wasps, and bruchids of pigeonpea.**

| Name | Distribution | Symptoms |
|---|---|---|
| **1. Pod flies** | | |
| *Melanagromyza obtusa*[1] Malloch; *M. chalcosoma* Spencer | Major pest in Asia and Australia | No external symptom until the fully grown larvae chew and make holes in the pod walls. They leave a 'window' for emergence of flies after pupation in pod. Damaged seeds are of no value. |
| **2. Pod wasps** | | |
| *Tanaostigmodes cajaninae* La Salle | India | Attacked locules of young pods remain undeveloped. They feed inside the pod and make an exit hole for the emerging wasp which is smaller than that of the pod fly. |
| **3. Bruchids** | | |
| *Callosobruchus maculatus* (F.) | Common world-wide in field and store. | Attack nearly mature and dried pods. Attack is conspicuous by the round hole and white eggs on the pod wall. |
| *C. analis* (F.); *C. chinensis* (L.) | Common in stores | In store, eggs on the seed surface and round holes with the 'flap' on the seed coat. |

1. Most important pest.

## Control Measures

1. Systemic insecticides such as dimethoate and monocrotophos (36% EC @ 1.0 L $ha^{-1}$) effectively control larvae inside pods.

2. Follow proper crop rotation and avoid growing genotypes of different duration in a mixture or adjacent area. This will reduce the availability of pods over a long period and prevent several generations from developing sequentially.

3. Bruchids can be controlled by harvesting the pods at maturity, sun-drying the seed (low moisture 6%) and storing in beetle-proof containers. Fumigation of store at regular intervals prevents insect infestation. A coating of edible oils or of inert clays can prevent further development of bruchids in the stored seeds (Reed et al. 1989).

# MP 8. Screening Technique for *Helicoverpa armigera*

## Screening in a Net House

Pigeonpea screening for resistance to *Helicoverpa* under a net house failed (Lateef and Reed 1981). This was done in a large net house with the release of laboratory-bred *Helicoverpa* moths. The moths were found resting for most of the time on the net and egg-laying was nonuniform and indiscriminate. Plants looked etiolated and took more time to pod-set and maturity. Therefore an open-field screening technique was proposed.

## Open-field Screening

To screen germplasm accessions in nonreplicated plots this technique was proposed (Lateef and Reed 1981). The infector rows are sown 2 weeks before the test materials. These are a mixture of susceptible cultivars of different maturity groups. The infector rows are sown every 10th row of test genotypes.

The desirable genotypes are evaluated in replicated trials, each with a narrow maturity range and a susceptible check. Advance testing should be done in a balanced lattice square design with 16 or 9 entries. This design increases the efficiency of screening by reducing the coefficient of variation which tends to be high due to spatial and temporal variation in pest attack.

The screening procedure involves the following steps:

| | |
|---|---|
| First year | Screening of germplasm and breeding material in nonreplicated conditions. Here one row of an infector check is sown after every five test rows. The plot (row) is 1.5 m. |
| Second year | Conduct a replicated experiment, 2 rows of 4 m length, including a check, every 5th row and 2 replications of each maturity group for observations and selection. |
| Third year | Separate the material according to maturity group. Test these materials in a replicated trial (3 replications) under sprayed and nonsprayed conditions. |
| Fourth year | Test the promising selections in a balanced lattice square design. A minimum of four replications under each sprayed and nonsprayed condition with susceptible checks. |
| Fifth year | Test for confirmation of previous year results and multilocational testing. |

# MP 9. System of Scoring Insect Damage on Pods of Pigeonpea

The scoring system for insect pest damage should have reliability and repeatability. Therefore, it is important to include the known susceptible checks when entomology experiments are conducted. Lateef and Reed (1985) suggested comparing the percentage of pod damage at maturity of the test entries with that of the checks. The test entries are graded using the formula of Abbott (1925).

$$\text{Pest resistance rating (\%)} = \frac{\text{P.D. rating of check} - \text{P.D. rating of test entry} \times 100}{\text{P.D. rating of check}}$$

Where P.D. = Mean of pod damaged (%)

There is not always a good correlation between pod damage and yield loss. For this reason it is important to record yield as well as pod damage, and use both factors when evaluating germplasm.

The pest resistance percentage is converted to a 1 to 9 rating scale as described below.

| Pest resistance (%) | Resistance / susceptibility Rating | |
|---|---|---|
| 100 | 1 | ↑ Increasing resistance |
| 75 to 99 | 2 | |
| 50 to 75 | 3 | |
| 25 to 50 | 4 | |
| 10 to 25 | 5 | |
| -10 to 10 | 6 | Equal to check |
| -25 to -10 | 7 | Increasing susceptibility ↓ |
| -50 to -25 | 8 | |
| -50 to less | 9 | |

This scale is useful for pod fly damage also when a selected insect susceptible check entry is grown. The same check cannot serve the purpose for both the insects as there is negative association between *Helicoverpa* damage and pod fly damage.

# MP 10. Development of Sex Pheromone Traps

A pheromone is a substance secreted externally by an organism causing a specific reaction in a receiving organism of the same species. This is a semichemical which is involved in the interaction between organisms (Nordlund 1981). Pheromones are useful for monitoring the insect population and its suppression via traps. *Helicoverpa* males readily respond to synthesized pheromones.

Pawar et al. (1984) described various types of traps used by entomologists for pest management in sorghum, pearl millet, groundnut, pigeonpea, and chickpea. Research at ICRISAT Center proved that pheromone traps were useful to control *Helicoverpa* moths in pigeonpea. The standard pheromone trap for pigeonpea is described (Pawar et al. 1988).

## Material for Pheromone Trapping

1. **Synthetic pheromone.** Among the synthetic products a mixture of 97% (2)-11-Hexadecenal and 3% (2)-9-Hexadecenal attract more male moths to the traps than virgin females (Pawar et al. 1988).

2. **Dispenser.** A white rubber septa loaded with 1 mg of pheromone mixture is attractive to *Helicoverpa armigera* moths even after 3 months of continuous field exposure. However, the septa needs to be replaced after 4 weeks exposure (Pawar et al. 1988).

3. **Trap design.** The trap is developed by using an aluminum plate in the fabricated dry funnel (diameter 21 cm) which is fixed by a nut and bolt to support the strut with a gap of 5 cm between plate and funnel. The funnel is covered with a polyethylene bag of 21 cm x 45 cm size wired below it in which the moths could move downward to be trapped (Fig. la). Pawar et al. (1988) reported that dry funnel traps are much easier to maintain, and catches in these could be easily recorded and removed. They also reported modification of the standard trap by inserting a perforated small yellow funnel (diameter 15 cm) around the pheromone (Fig. lb). This funnel is secured to an aluminum plate after the placement of the pheromone source below the plate. The white colored traps were found more efficient at ICRISAT Center than red, yellow, green, black, or orange.

   The trap is placed 2-3 m above the ground in the crop canopy with the help of a pole bent 90°.

   To kill the trapped moths an insecticide is placed in glass vials in the polyethylene bag.

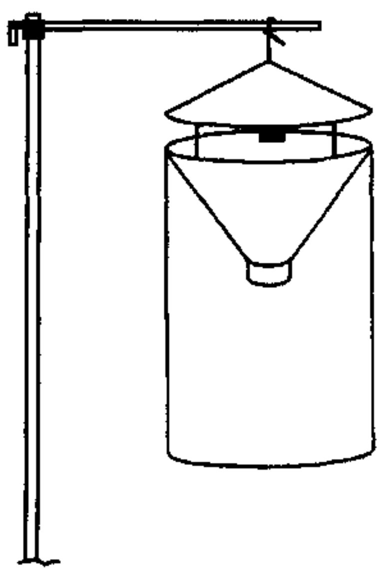

**Figure la.** COPR dry funnel trap: a yellow plastic funnel (diameter 17 cm) with a hood of the same material at clearance of 2.5 cm.

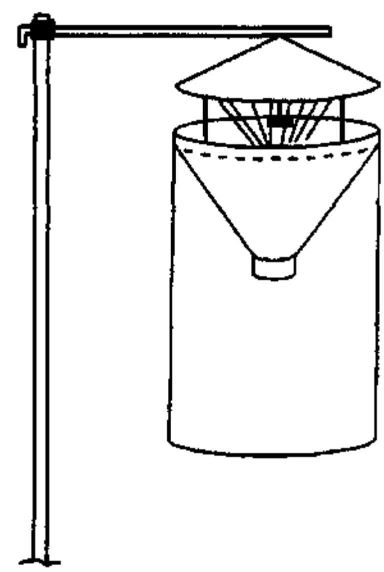

**Figure lb.** ICRISAT standard trap modified by inserting a perforated small yellow funnel (diameter 15 cm) around the pheromone.

(Source: Pawar et al. 1988)

# MP 11. Determination of an Economic Threshold for Insecticide Application

Pest-management strategies depend on accurate and reliable estimates of pest population densities. Economic thresholds are established for a pest based on season, crop maturity, weather, treatment history, cost of control, value of crop, and natural enemy population.

Stern et al. (1959) defined the injury level as the lowest density that causes economic damage, justifying the cost of control. It is the density at which the value of the gain potential equals the cost of control. This can be expressed as:

$$(1) \quad T = \frac{C \times 10^6}{P \times E}$$

Where T = Threshold of larvae $ha^{-1}$
C = Cost of control ($ $ha^{-1}$)
P = Value of commodity ($ $t^{-1}$)
E = Consumption per larva (g)

The above equation (1) satisfies the situation where the amount spent on pest control simply equals the value of the potential losses. This becomes unacceptable to the farmer as he is interested in a profitable cost:benefit ratio. Therefore, formula (1) was modified (Headley 1975) as:

$$(2) \quad T = \frac{C \times 10^6}{P \times E} \times BC$$

where BC = Benefit : Cost

Likewise, depending upon the potential yield loss caused by a particular instar or larval density of infestation (D) $plant^{-1}$ can be calculated as suggested by Twine and Kay (1982) in sorghum.

$$(3) \quad D = \frac{C \times BC \times 10^6}{Y \times P \times N}$$

Where D = Density of infestation $plant^{-1}$
C = Cost of control ($ $ha^{-1}$)
BC = Benefit : Cost
Y = Reduced yield (g) $plant^{-1}$ by each larva
P = Value of commodity ($ $t^{-1}$)
N = Number of plants $ha^{-1}$

In pigeonpea 1 larva $plant^{-1}$ or 3 eggs $plant^{-1}$ have been considered as the threshold level for the application of insecticides in research plots. A sampling procedure and the number of samples depends on the plot size, growth of plant, and facilities available. In small plots of 1 row a single plant may be sufficient whereas in big plots 10–15 samples are taken.

Suppose the cost of a control is $ 35 $ha^{-1}$, and it has a cost benefit ratio of 1:2, with a value of pigeonpea of $ 350 $t^{-1}$, and with 300 000 plants ha"$^1$, the threshold would be:

C = $ 35; P = $ 350; E = 1.6 g; BC = 2:1; N = 300 000

$$D = \frac{35 \times 2 \times 1\ 000\ 000}{1.6 \times 350 \times 300\ 000} = 1.25 \text{ larvae } plant^{-1}$$

# MP 12. Cultural Control of Pigeonpea Insects

To effectively control pests the use of pesticides may be necessary. However, the following practices may be useful in suppressing the pest population (Chandra et al. 1983).

1. Deep plowing of the field in summer.

2. Sowing early or at the normal time. Late sowing results in more pest infection and damage.

3. Avoid close spacing or high population density (unit area$^{-1}$) as it attracts more pests.

4. Ratoon crop and volunteer plants of pigeonpea are major sources of pest carry-over. They need to be destroyed.

5. Blister beetle, grey weevils, brown bug, leaf tier, and hairy caterpillars can be manually controlled on a limited scale by hand picking, shaking, bagging or catching in nets .

6. The insecticide application is essential at the appropriate time to discourage a pest population increase, especially at the initiation of flowering and at pod formation.

# MP 13. Nature and Action of Insecticides

The insecticides can be broadly classified based on (A) chemical nature, and (B) mode of action (Oudejans 1982).

## A. Classification Based on Chemical Nature

Chemically insecticides belong to inorganic or organic compound groups.

1. **Inorganic compounds.** These are derived from naturally occurring elements and do not contain carbon. Many of them are persistent and several, including arsenic, mercury, and thallium, are cumulative poisons. Minerals used most often are arsenic, boron, copper, lead, mercury, sulfur, tin, and zinc. Most of the inorganic compounds have been replaced by the synthetic organics.

2. **Organic compounds.** These are man-made or extracted pesticides consisting of carbon, hydrogen and one or more other elements such as chlorine, oxygen, sulfur, phosphorous and nitrogen. The main organic groups are:

   a) Botanical compounds or "natural insecticides". These are derived from plant materials. These insecticides tend to be less stable and short-lived. These have good knockdown qualities and low mammalian toxicity, with the exception of nicotine. Examples are Nicotine from *Nicotiana tabacum* (leaves), and Pyrethrum from Chrysanthemum *cinerariaefolium* (flowers).

   b) Organophosphorous compounds. These are synthetic organic materials and can be either contact or systemic poisons. Most of these have a short residual activity, which is desirable in keeping down residues on food crops. Repeated applications are often necessary. Some examples are: azinphos-methyl, chlorpyrifos, demephion, diazinon, endothion, fensulforthion, isoxathion, leptophos, malathion, menazon, mephosfolan, methamidiphos, methidathion, mevinphos, monocrotophos, naled, omethoate, oxydemeton-methyl, parathion, parathion-ethyl, parathion-methyl, phenthoate, phorate, phosalone, phosfolan, phosmet, phosphamidon, phoxim, pirimiphos-ethyl, pirimiphos-methyl, profenofos, pyrazophos, quinalphos, ronnel (fenchlorphos), schradan, sulfotep, temephos, tetrachlorvinphos, thiometon, thionazin, triazophos, trichlorfon, trichloronate, vamidothion.

   c) Carbamate compounds. These are closely related in biological action. Most members of the group have short residual activity. Three classes of compounds are commercially useful:

      1. Methylcarbamates of phenols; aminocarb, carbaryl, isoprocarb (MIPC), methiocarb, mexacarbate, promercarb.
      2. Methylcarbamates of oximes; aldicarb, methomyl, oxamyl, oxycarboxin.
      3. Methylcarbamates and dimethylcarbamates of hetrocyclic compounds; carbofuran, pirimicarb.

      The carbamate group also includes the herbicides propham and chlorpropham.

   d) Organochlorine compounds. These are synthetic organic materials that act mainly as contact and stomach poisons. The majority of the organochlorines have a long residual effect. The tendency of many of them to build up in natural food chains creates a hazard to fish and wildlife populations and has brought about a drastic reduction in their use. Some organochlorines are listed below.

      aldrin, benzenene hexachloride (BHC, HCH), chlordane, chlordecone, chlordimeform, chlorfenson, dicofol, dieldrin, dienochlor, endosulfan, endrin, heptachlor, lindane (gamrna-BHC), methoxychlor, pentachlorophenol, perthane (ethylane), proclonol, toxaphene.

e) Pyrethroids. The chemical structure of synthetic pyrethroid is patterned after pyrethrins (or rethrins) which are botanical insecticides extracted from chrysanthemum flowers. Like pyrethrins, the pyrethroids show a higher efficacy against insects and a lower toxicity to mammals than other insecticide groups. However, they have quick knockdown effects with low persistence and act mainly as contact insecticides.

The complicated chemical structure of pyrethroids makes their cost of manufacture high. But due to low dose rates $ha^{-1}$ their use is still competitive. Some pyrethroids are -

allethrin, bioallethrin, bioresmethrin, cismethrin, cypermethrin, deltamethrin, fenvalerate, permethrin, phenothrin, prothin, resmethrin, tetramethrin.

3. **Fumigants** that are rapidly absorbed through the skin and spiracles are formaldehyde, methyl bromide, ethylene dibromide, carbon disulfide, phosphine, and naphthalene. These are useful to control storage insects, domestic pests, and rodents.

4. **Insect growth regulators** are synthetic organic chemicals, designed to mimic the action of hormones normally found in every insect. When an insect is exposed to these chemicals, normal development is interrupted and the insect dies without becoming a reproducing adult. Examples are diflubenzuron, kinoprene, methoprene.

5. **Mineral oils** have been used to control insects and spider mites in orchards. Only light applications of refined, emulsified paraffinic oils are safe as "summer oil" treatments. "Winter washes" of cruder and more aggressive paraffinic petroleum oils have a greater efficacy against eggs of spider mites and capsides. But these are tolerated only by dormant or deciduous orchards in winter: dinitrocresol, superior oil (Volck oil). These oils act primarily by impairing the insect's respiratory system.

6. **Microbial compounds** such as fungi, protozoa, bacteria, and viruses are produced by man as a formulation. These pathogens infect or poison the insect and cause its death. For example, *Bacillus thuringiensis* has found widespread commercial use against lepidopterous caterpillars. Dried spores, which are nontoxic to human beings and animals are easily produced. The spore contains a protein. This rapidly paralyzes the gut of the larvae and causes cessation of feeding a few minutes after ingestion. Nuclear polyhedral viruses also have potential for insect control. They are specific and highly virulent and can survive for years due to their inert protective coating. Production of these viruses involves rearing them on living insects.

## B. Classification Basad on Moda of Action

Once on or inside a pest organism, an insecticide may act on one or more of the life processes by causing death, sickness or a change in the behavior, growth, metabolism, or reproductive capabilities of the pest.

o Stomach toxicants enter a pest's body through the mouth and are absorbed into the body through the digestive tract.

o Contact toxicants generally enter a pest's body through contact with treated surfaces such as leaves. These poisons act upon the nervous and respiratory system of the pest.

o Fumigants are volatile and generally enter a pest's body in a gaseous state through the respiratory system.

- **Systemic toxicants** are applied to leaves, stems, fruit, or to the roots and are absorbed by the plant. Once inside the plant, they move through the plant's vascular system and the pests acquire the translocated insecticide during feeding.

- Suffocation results from applying materials, usually oils, which clog the breathing mechanism of a pest.

## The Concept of Plant Diseases

Any change in one or more physiological processes that obstructs plants in utilizing energy is a disease. A disease usually causes a progressive and continuous disturbance of cellular activities that eventually manifest as 'symptoms'.

### Pathogens and Parasitism

A living organism (plant or animal) which produces a disease in plants is a 'pathogen'. This includes fungi, bacteria, nematodes and even viruses which are in fact not considered as living organisms.

A parasite is a plant or animal living in close association with and at the expense of some other living organisms (the host) from which it derives its food. If such an organism cannot complete its life cycle without the host, it is called an 'obligate' parasite.

A pathogen must cause a disease. A parasite may or may not cause a disease. Therefore, all pathogens are parasites, but all parasites are not pathogens.

A parasitic pathogen obtains its food in a way that

- the host remains alive, but shows symptoms such as a growth in the form of galls or warts (biotrophes);

- the host is poisoned and completely killed by toxins produced by the parasite (pertotrophes). When the host is partially destroyed it is bio-pertotrophe;

- the parasite feeds on dead, decaying or living organic matter (necrotrophes). An organism which feeds only on dead organic matter is known as a saprophytic parasite.

If the pathogen is present externally on a plant or seed it is 'contaminated'. When the pathogen starts to affect the internal system of plant, it is 'infected'. When infection is purposely induced to test the sensitivity of a pathogen, it is 'inoculated'.

An organism transmitting pathogens is called a Vector', for instance the eriophyid mite is the vector of sterility mosaic virus (mycoplasma) in pigeonpea.

### Symptoms of Plant Diseases

#### General symptoms

- Discoloration of leaves, fruits, sap vessels in blast, or woody tissue.

- Wilting is caused by insufficient uptake of water to replace the water loss from plant cells owing to metabolic processes and evaporation. The plant cells loose their firmness (turgor) causing stem and leaves to wilt.

- **Necrosis** is due to rot or decay of tissues. General necrosis is called rotting or decay, it occurs on fleshy organs such as bulbs and tubers and sometimes on roots and stems. There may be wet rots, dry rots, soft rots, hard rots, etc. Local necrosis results in local lesions such as leaf spots, fruit spots and anthracnoses. They vary in their shape, color, size or pattern.

- **Stunting and dwarfing** caused by many virus and fungal diseases, damaged root system, shortage or excess of water and nutrients and excessive acidity, or alkalinity of the soil.

- **Hypertrophy** (enlargement of cells) results in tumor-like galls, deformations, witches brooms, club roots, swollen shoots, or excessive growth of tillers. Hypertrophic symptoms caused by fungi, bacteria, viruses, and insects may also induce swelling or leaf galls. Herbicides such as 2,4-D, cause cell enlargement, accelerated cell division, and sometimes distortions and galls on certain crops.

- Secretion of gums such as ergot.

- Fruitification of a fungus, such as tree mushrooms or other fruiting bodies.

## Main Categories of Plant Diseases

### Nonparasitic diseases

- Hereditary, noninfectious; diseases caused by genetic defects, such as chlorophyll deficiency or necrotic genes.

- Nonhereditary, noninfectious; diseases and injuries caused by

  - excess or deficiency of growth factors
  - agroclimatic conditions
  - pollution of air, soil, or water
  - pesticide application

- Nonhereditary, infectious; diseases caused by viruses.

### Parasitic diseases

- Caused by a plant or animal living at the expense of its host such as fungi, bacteria, seed plants (striga), or nematodes.

# Diseases of Pigeonpea

Pigeonpea is attacked by over 100 pathogens including fungi, bacteria, viruses, nematodes and mycoplasma-like organisms (Nene et al. 1989). However, only a few of them cause economic loss. Comprehensive literature is available on pigeonpea disease resistance screening techniques (Nene et al. 1981) and disease management (Reddy et al. 1990). Therefore, this section will briefly discuss selected diseases, their distribution, and symptoms. The pigeonpea diseases can be classified in two groups. The diseases that cause substantial loss to crop are wilt, sterility mosaic, phytophthora blight, and leaf spots. The diseases that cause less economic loss are collar rot, dry root rot, phoma stem canker, alternaria leaf spot, powdery mildew, rust, bacterial leaf spot, stem canker, cercospora leaf spot, and yellow mosaic.

# MP 14. Major Diseases of Pigeonpea

The major diseases of pigeonpea, their distribution, and symptoms are listed in Table 8a and 8b (Reddy et al. 1990). Their control measures are discussed in MP 17.

**Table 8a. Major diseasea of pigeonpea.**

| Disease/<br>Causal organism | Distribution | Symptoms |
|---|---|---|
| **Wilt**<br>*Fusarium udum* Butler | Important in India and eastern Africa, widely distributed | Loss of turgidity in leaves and slight interveinal clearing. Foliage yellowing and chlorosis. Browning of xylem extending from root to stem. Brown or dark purple bands on the stem surface. After removing the bark browning or blackening of the wood. |
| **Sterility mosaic**<br>transmitted by *Eriophyid* mite *Aceria cajani* Clannabasvanna causal organism not confirmed | India, Myanmar, Nepal, Sri Lanka, Thailand, and Bangladesh | Bushy and pale green appearance of infected plants. Reduced leaf size, increase in tertiary branches from leaf number of secondary and axils. Complete or partial cessation of reproductive structures. |
| **Phytophthora blight**<br>*Phytophthora drechsleri* Tucker f. sp. cajani | India, Australia | Infected seedlings at emergence show a crown rot symptom, topple over and dry. Older seedlings show water-soaked lesions on leaflets which become necrotic. Brown dark lesions on main stem, branches, and petioles. The lesions usually girdle the stems causing drying of portions above lesions. Finally stems break due to wind. |

**Table 8b. Major diseases of pigeonpea outside India.**

| Disease/<br>Causal organism | Distribution | Symptoms |
|---|---|---|
| **Cercospora leaf spots**<br>*Cercospora cajani*[1] Henning<br>C. *indica*<br>C. instabilis | Asia, eastern Africa, Caribbean | Small,brown, circular spots on leaves which coalesce when they increase in size. Severe defoliation due to dropping of infected leaves. |
| **Witches' Broom** | Australia, Bangladesh, Costa Rica, Puerto Rico, Taiwan, USA | Prolific and clustered branching of the plant. Pale green leaves with reduced size. The flowers fail to develop beyond the bud stage and affected plants fail to set pod. |

1. Most Important

# MP 15. Minor Diseases of Pigeonpea

The minor diseases of pigeonpea, their distribution, and symptoms are listed in Table 9a and 9b (Reddy et al. 1990).

**Table 9a. Minor fungal diseases of pigeonpea.**

| Disease | Distribution | Symptoms |
|---|---|---|
| Collar rot<br>Sclerotium rolfsii Sacc. | India, Puerto Rico, USA, Venezuela | High seedling mortality during the initial 6 weeks after sowing. Whitish mycelia and sclerotial bodies present at the collar region. |
| Dry root rot<br>Rhizoctonia bataticola (Taub.) Butler<br>Macrophomina phaseolina (Tassi) | India<br>Jamaica, Trinidad | Rotting of root and basal stem with fungal sclerotia visible under the bark. Drying of plants under drought stress. |
| Phoma stem canker<br>Phoma cajani (Rangel) Khune and Kapoor | Brazil, India | On adult plants - appearance of brown, cankerous lesions which have gray center and dark brown margins, may coalesce and girdle the stem. |
| Alternaria leaf spot<br>Alternaria tenuissima (Kunze ex. pers.) Wiltshire | India | Initially small necrotic spots on leaves, which increase in size and become dark and light brown concentric rings with a wary outline and purple margin. At later stages the lesions coalesce. |
| Powdry mildew<br>Oidiopsis taurica (Lev.) Salmon. | Ethiopia, India, Malawi, Kenya, Zambia | Affected leaves turn yellow and show twisting and crinkling. |
| Rust<br>Uredo cajani Syd. | South America, India, Caribbean region | Dark brown uredial pustules on leaves and leaf-drop is common. |

**Table 9b. Minor bacterial and mycoplasma diseases of pigeonpea.**

| Disease | Distribution | Symptoms |
|---|---|---|
| Bacterial leaf spot canker<br>Xanthomonas campestris pv. cajani | Australia, Panama, Puerto Rico<br>Sudan | Small brown lesions on leaves and stem surrounded by yellow halo. Lesions often coalesce and form larger ones. On stem and branch, rough, cankerous dark brown lesions of various shapes and sizes. Severe infected plants may dry prematurely or break at infection sites. |
| Yellow mosaic | India, Jamaica, Nepal, Sri Lanka | Yellow, diffused spots scattered on leaf lamina. At later stages affected leaflets show broad yellow patches alternating with the green. It reduces leaf size. |

# MP 16. Nematodes Attacking Pigeonpea

The nematodes causing diseases in pigeonpea, their distribution, and symptoms are listed in Table 10 (Reddy et al. 1990; Sharma et al. 1992).

**Table 10. Nematodes attacking pigeonpea.**

| Name | Distribution | Symptoms |
|---|---|---|
| Cyst nematode *Heterodera cajani* Koshy | India, Egypt | Pearly-white bodies of females on the root of 30 to 35 days old infected plants. These females turn brown at maturity. Nematode infection delays flowering and pod formation and can cause 30% reduction in plant biomass and seed yield. |
| Reniform nematode *Rotylenchulus reniformis* Linford & Oliveira | 38 countries of tropical and subtropical world | Soil-covered egg masses on roots appear dirty. Root - mass of infected plants is smaller than normal plants, foliage is light green to yellow. |
| Root-knot nematode *Meloidogyne* spp<br>*M. incognita* Kofoid and White<br>*M. javanica* (Treub) Chitwood<br>*M. arenaria* (Neal) Chitwood<br>*M. hapla* Chitwood<br>*M. acronea coetzee* | Australia, India Malawi Trinidad, USA<br><br>Brazil, Puerto Rico Zambia and Zimbabwe | Stunting, suppressed growth, chlorosis, reduced leaf size and plant vigor.<br>Development of galls on the root.<br>Root-knot nematode infection increases Fusarium wilt incidence. |

## Control Measures

1. Application of aldicarb, carbofuran, fensulfothion, and phorate to the soil (1.5-3.0 kg a.i. $ha^{-1}$).

2. Soil solarization reduces nematode infection. Crop rotation with rice for 2-3 years reduces populations of nematodes.

3. Seed treatment with 2% carbofuran and benfuracarb help to reduce infection of cyst and root knot nematodes.

# MP 17. Losses and Control Measures for Wilt, strrility Mosaic, Blight, and Leaf Spots of Pigeonpea

## Wilt

### Losses

Depending upon the stage of occurrence, wilt may cause 100% loss at the pre-flowering stage; 67% and 30% when it occurs at maturity and the preharvest stage respectively (Kannaiyan and Nene 1981).

### Control

o Follow a proper crop rotation, grow pigeonpea only after a gap of 2-3 years in the same field. Remove the crop debris from the field after harvest. Treat the seed with thiram @ 3 g $kg^{-1}$. This will help to control most of the fungal diseases of pigeonpea.

o Intercropping of pigeonpea with sorghum reduces the disease incidence.

o Cultivation of wilt resistant or tolerant long-duration varieties (NP(WR)15, C 11, or BDN 1) or medium-duration variety (ICP 8863) are recommended.

## Sterility Mosaic (SM)

### Losses

Early infected crops (first 45 day) show almost complete sterility and yield loss up to 100%. Late infected plants show partial sterility (Reddy and Nene 1981).

### Control

o Cultivation of resistant genotypes. A variety like NP (WR) 15 is moderately tolerant to sterility mosaic (SM). The variety Bahar is resistant to sterility mosaic, but highly susceptible to wilt. ICPL 151, an early variety, has tolerance to SM (Reddy et al. 1989).

o Seed dressing with a higher dose of carbofuran 3 g $kg^{-1}$ seed protects pigeonpea from SM infection up to 45 days after sowing (Reddy et al. 1990). Rathi (1979) reported seed treatment with 10% aldicarb protects the crop till maturity.

o Application of carbofuran 3% @ 1.2 kg a.i. $ha^{-1}$ and aldicarb @ 1.5 kg a.i. ha"[1] to the soil at sowing time protects pigeonpea against SM for 75 days after sowing (Reddy et al. 1990).

o Spraying of acaricides — tetradifion (Tedion®) at 0.1% concentration effectively control of eriophyid mites and prevents SM infection (Reddy et al. 1990).

## Phytophthora Blight

### Losses

Early infection at the seedling stage (15 days after emergence) gave 100% incidence while it was only 25% in 120 day plants (Mishra and Shukla 1986a).

### Control

- Cultivation of resistant genotypes; ICPL 161, METH 12, Composite 1, ESR-6, Pant A3, Pant A 83-14 (Singh et al. 1985); KPBR 79-1 and KPBR 5786 (Mishra and Shukla 1986b) are the best to control this disease.
- Treat the seed with metalaxyl (4 g $kg^{-1}$ seed) and two sprays of metalaxyl 25 WP (@ 500 ppm) at 30 and 45 days after sowing (DOAS).
- Avoid waterlogging in the pigeonpea field.
- Crop rotation.

## Cercospora Leaf Spot

### Losses

Yield losses in infected fields are reported up to **85%** (Onim 1980).

### Control

Spray benomyl or mancozeb (Benlate®) @ 5 g $L^{-1}$ a.i. or 3 g $L^{-1}$ at regular interval in case of severe infection (Onim 1980) .

# MP 18. Resistance Screening Techniques for Pigeonpea Diseases

The resistance screening techniques for each diseases (wilt and phytophthora blight) have been described by Nene et al. (1981). This can be done in the sick plot developed for each disease in the field or pot screening using artificially inoculated sick soils. The sterility mosaic screening involves leaf stapling and infector-hedge techniques. In the stapling technique infected leaves from diseased plants are taken and stapled on to the young leaves of test rows, one diseased leaflet per primary leaf. In the infector-hedge technique, a hedge of the susceptible cultivar is grown 4 months in advance and inoculated with sterility mosaic. The disease spreads from the hedge to the test lines. Alternatively, spreader rows of susceptible genotypes are grown at least 4 months in advance in the field (Nene et al. 1981). For practical purposes it is better to develop multiple sick plot for screening all the three diseases with suitable checks. This helps in identifying the combined resistance/tolerance to wilt, phytophthora blight, and sterility mosaic in the same genotype. The procedure involves the following steps (Nene et al. 1981).

## A. Development of a multiple disease sick plot

1. Develop a wilt sick plot by incorporating chopped stubbles of wilted plants from other field. Grow a sole crop of highly wilt susceptible genotypes in this plot.

2. By the end of the season, there should be a minimum of 10% wilted plants. Chop off the tops of the living plants to allow them to ratoon. Many ratooned plants will show wilt after the new flush.

3. Incorporate the stubbles and whole crop by chopping them into the soil. This will increase the level of fungus inoculum and make the soil sick.

4. Repeat the step '2' and '3' in the next season. By the end of the second season more than 80% wilt incidence may occur in this field when susceptible genotypes are grown. If the wilt incidence is less, repeat step '2' and '3' for one more season.

5. After establishment of a wilt sick plot, use the spreader row or infector-hedge technique for sterility mosaic screening. For phytophthora blight screening use the stem-inoculation or diseased debris technique in the same sick plot.

6. The stem inoculation technique involves procurement of a pure culture of phytophthora blight from infested plants. Multiplication of the culture on pigeonpea-flour agar in petri dishes or autoclaved V-8 juice agar. Preparation of a suspension and spraying 15 to 30 day old seedlings (Nene et al. 1981). The diseased debris technique involves spreading of diseased plant material after sowing.

## B. Growing test material in a multiple sick plot

The test material is grown along with the susceptible checks for each disease, such as genotype HY-3C (resistant to wilt and sterility mosaic but susceptible to phytophthora blight), BDN-1 (resistant to wilt and tolerant to blight, and susceptible to sterility mosaic). The genotype ICP 2376 is resistant to mosaic and blight, and susceptible to wilt. All these checks should be grown after two to eight test rows.

## C. Rating scales

For easy scoring, a 9-point scale is suggested (Nene et al. 1981). Interpretation of the scale gives 1 resistant, 3 moderately resistant, 5 tolerant, 7 moderately susceptible, and 9 susceptible (Table 11). Test lines with ratings of 1-3 are considered acceptable and 7-9 as not acceptable for breeding programs. Materials with ratings 3-5 can be further screened for improvement through selfing resistant plant progenies.

**Table 11. Rating scales for wilt, blight, and sterility mosaic of pigeonpea screening.**

| Rating | Wilt | Blight | Sterility mosaic |
|---|---|---|---|
| 1 | No symptom on any plant | No symptom on any plant | No symptom on any plant. |
| 3 | 10% or less plant mortality | Symptoms on 10% or fewer plants | Symptoms on 10% or fewer plants |
| 5 | 11-20% plant mortality | Symptoms on 11-20% plants | Ring spots on most plants but, disappearing with age; no sterility |
| 7 | 20-25% plant mortality | Symptoms on 20-50% plants | Mild mosaic symptoms on most plants causing partial sterility |
| 9 | 51% or more plant mortality | Symptoms on 51% or more plants | Severe mosaic on most plants; almost complete sterility |

# MP 19. Fungicides and their Use to Control Plant Diseases

The term 'fungicide' refers to chemicals capable of preventing or eradicating diseases caused by fungi. The word 'fungicide' originated from the Latin words 'fungus' and caedo'. Caedo means "to kill". Thus a chemical capable of killing fungi is a fungicide (Nene and Thapaliyal 1987). Fungicides are not effective in preventing or eradicating virus and bacterial diseases, because virus diseases are transmitted by insects, mites, or nematodes. It is possible to control them by using insecticides, miticides, or nematicides to eradicate these vectors.

## A. Classification of Fungicides by Chemical Nature (Oudejans 1982)

1. **Systemic fungicides.** These chemicals are absorbed by roots or leaves of a plant and taken into the vascular system. These toxicants are rapidly transported via the sapstream in vessels towards the foliage and the apical point. Systemic fungicides provide good protective effects. Most of them also provide curative effects against pathogens. Some systemic fungicides are:

| **Common name** | **Trade name** |
|---|---|
| o oxathiins: | |
| carboxin | Vitavax® |
| oxycarboxin | Plantvax® |
| o benzimidazoles: | |
| benomyl | Benlate®, Fundazol® |
| carbendazim | Bavistxn®, Delsene®, Derosal® |
| fuberidazol | Voronit® |
| thiabendazole | Tecto® |
| thiophanate-methyl | Cercobin M®, Mildothane®, Topsin M® |
| o Pyrimidins: | |
| bupirimate | Nimrod® |
| dimethirimol | Milcurb® |
| ethirimol | Milstem® |
| o acylalanines: | |
| furalaxyl | Fongarid® |
| metalaxyl | Apron®, Ridomil® |
| o phosphor compounds: | |
| ditalimfos | Dowco 199®, Laptran® |
| pyrazophos | Afugan®, Curamil® |
| o thiocarbamates: | |
| propamocarb | Previcur N® |

2. **Antibiotics.** These substances are produced by microorganisms. They have the capacity to inhibit, in very dilute concentrations, the growth of other microorganisms or even to destroy them.

   Antibiotics have a systemic action similar to systemic fungicides, after absorption they are transported through the xylem vessels towards the foliage and apical points. Antibiotics kill the invading pathogen within the hosts system and provide temporary protection against infection.

   An antibiotic used in agriculture that has fungicidal and bactericidal action is streptomycin (Agrimycin 100®, Plantomycin®).

Antibiotics that have fungicidal action are:

| | |
|---|---|
| blastcidin-S | Bla-s® |
| griseofulvin | Fulvicin®, Grisovin®, Grisetin® |
| kasugamicin | Kasumin® |
| pimaricin | Delvolan® |

## B. Nonsystemic Fungicides

### Sulfur fungicides

1. **Inorganic sulfur** is mostly formulated as wettable powders, pastes, or flowables, which contain sulfur particles of 0.2-10 microns in diameter. Although its toxic efficacy is limited, sulfur is a safe and cheap fungicide; it is "cost effective" even at high rates. It is useful for control of powdery mildews. Lime sulfur is a combination of rocklime and sulfur.
2. **Organic sulfur compounds.** Among the most effective and popular fungicides in current use are the derivatives of dithiocarbamic acid (a sulfur-containing acid). In combination with metallic salts such as zinc salt, ferric salt, and manganous salt, these organic sulfur compounds offer a particular affectivity, better stability and less phytotoxicity than elemental sulfur. Some dithiocarbamate fungicides are:

| | |
|---|---|
| maneb ......... | Dithane M-22®, Manzate®, Plantineb®, Polyram M®, Trimangol® |
| metham-sodium ... | Karbation®, Sepiram®, Vapam® |
| mancozeb ....... | complex of zinc (2.5% Zn) and maneb (20% Mn); Manzeb®, Dithane M-45®, Manzate 200®, Sandozebe® |
| metiram ........ | zineb + polyethylene thiuram disulphide complex; Carbatene®, Polyram®, Combi®, Thioneb® |

## c. Copper Fungicides

One of the early discoveries was the fungicidal effect of bordeaux mixture (a watery solution of copper sulphate mixed with a lime slurry). Bordeaux mixture, with about 12% copper, is a safe fungicide with low mammalian toxicity. It controls a wide range of diseases such as downy mildews and late blight of potatoes. The product has been largely replaced by "fixed coppers". In this a copper compound of low-solubility is packed in a form that is stable in storage and readily dispersible in water. The copper compound is usually a basic cupric salt. Such products are less phytotoxic than bordeaux mixture, but their fungicidal efficacy tends also to be lower. Copper oxychloride, formulated as a 50% wettable powder or 10-25% dust, is the most widely used compound against Phytophthora diseases.

Products containing yellow cuprous oxide instead of basic cupric salts are also effective fungicides.

### Fixed coppers

| | |
|---|---|
| copper oxychloride .... | Cobox®, Coprantol®, Cupramar®, Cupravit-forte®, Cuprox Vitigran® |
| copper sulphate ....... | Blue Vitriol® |
| cuprous oxide ......... | Oleocuivre®, Perenox®, Yellow-Cuproxide® |
| cuprobam .............. | tricopper dichloride dimethyl dithiocarbamate |

## D. Other Inorganic Fungicides

Many heavy metal compounds have a strong toxic effect and are used for the control of plant diseases. Zinc, chromium, and nickel are used in inorganic form. Mercury is used in both inorganic and organic compounds. Tin is used as inorganic compounds only.

Inorganic nickel salts, such as nickel acetate (Ruston®) and nickel chloride, are water soluble. These demonstrate a certain curative and systemic action against rust diseases of wheat.

## E. Organomercury Fungicides

Organomercury compounds are more often used and generally more toxic to fungi than inorganic mercury salts. They have a disinfecting and protective action and often considerable volatility. These characteristics make the organomercury fungicides very well suited for seed treatment. Organomercury fungicides for restricted use include following:

2-methoxyethyl
mercury silicate . . . . Ceresan Universal Trockenbeize®
phenylmercury acetate . . . . Agrosan®, Antimucin®, Ceresan Universal®

### Organotin compounds

Organic compounds of tin are salts, which are both toxic and phytotoxic. The most widely used tin-fungicides are:

fentin acetate . . . . . . . . . Brestan®, Hoe 2824®, Suze®
fentin chloride . . . . . . . Aquatin®, Hoe 2872®, Tinmate®
fentin hydroxide . . . . . . Du-Ter®, Suzu H®, Telustan®, Tinicide®

Triphenyl tin (fentin) salts demonstrate good control of leaf spot diseases in beets and blights in potatoes.

### Chloronitrobenzene compounds

quintozene . . . . . . . . . . . . . Brassicol®
tecnazene . . . . . . . . . . . . . . Folosan®, Fusarex®

### Dinitroalkyphenols

binapacryl . . . . . . . . . . . . Acricid®, Morocide® (strong acaricidal action)
dinocap . . . . . . . . . . . . . . . Arathane®, Capryl®, Karathane®

### Heterocyclic nitrogen compounds

captafol . . . . . . . . . . . . . . Difolatan®, Haipen®
captan . . . . . . . . . . . . . . . . Altan®, Orthicide®, Trimegol-50®
dichlofluanid . . . . . . . . . Elvaron®
folpet . . . . . . . . . . . . . . . . . Folpan®, Phaltan®
tolylfluanid . . . . . . . . . . Euparen M®

### Morpholina compounds

dodemorph . . . . . . . . . . . . . BAS 238F®, Meltatox®
tridemorph . . . . . . . . . . . . BAS 220®, Calixin®

### Dicarboximide compounds

iprodione . . . . . . . . . . . . . Rovral®
procymidone . . . . . . . . . . . Sumilex®, Sumisclex®
vinclozolin . . . . . . . . . . . Ronilan®

**Other compounds**

| | |
|---|---|
| chlorothalonil | Bravo®, Daconil® |
| dichlofluanid | Elvaron®, Euparen® |
| dithianon | Deland®, Thynon® |
| dodine | Carpene®, Curitan® |
| etridiazol, echlomezol | Aaterra®, Terrazole® |
| fenarninosulf | Le San® |
| formaldehyde | Formalin® |
| phosethyl-Al | Aliette® |
| guazatine | Panoctine® |
| quinomethionate | Morestan® |

## Classification of fungicides by mode of action

Fungicide sprays are of two types, eradicants or protectants (Oudejans 1982).

1. **Eradicant sprays.** Although few plant diseases can be eradicated from a plant once they are well established, some can be controlled. The fungicides having curative action; include benomyl, dichlone, dodine, liquid lime-sulfur, fenpropimorph, metalaxyl, propicinazol, and triadimefon.

2. **Protectant sprays** provide a film of fungicide over the surface of plants and seeds that kills fungi spores upon germination. This type of fungicide is applied as a spray or dust to prevent leaf spot of foliage, blight diseases of flowers, blemishes, and harvest rot of fruits and vegetables. Examples captan, maneb, and thiram.

The advantages of eradicant sprays are that they are applied only after infection has occurred. However, as the eradicants fungicides are few in number and not always effective, the protectant fungicides have a vital role to play in controlling fungi.

Sometimes more protectant sprays are applied when anticipated wet weather fails to arrive.

# MP 20. Concept of Integrated Pest Management (IPM)

There are three main ways to control pests (Oudejans 1982).

- **Prevention**— keep a pest away from becoming a problem,
- **Suppression**— reduce pest numbers or damage to an acceptable level.
- **Eradication**— destroy or remove a pest completely from a target or area.

The pests are controlled either by natural forces or by applied control practices.

## Natural control

This is due to collective action of environmental factors, physical, and biotic. These factors maintain pest populations within certain limits over a period of time. The natural control include climatological factors, natural enemies (parasites and predators), and availability of food and space.

## Applied control

A whole range of practices have been developed or modified by man to control pests when natural control fails. These include cultural, mechanical, physical, biological, genetic, regulatory, and chemical control.

- **Cultural control** includes cultivation practices that are employed to make the environment less suited for the reproduction and growth of certain pest species (soil tillage, time of sowing and harvesting, water management, and crop rotation), sowing resistant varieties, and the sowing of 'trap crops'. Sanitation in storage areas, farm yards, and fields are regarded as first steps in preventing pests.

- **Mechanical control** includes collection of pests by hand and destroying them. Exclusion of pests by wire fences or screens are common practices with high value or small area crops.

- **Physical control** refers to methods of mechanical removal or destruction of pests using physical factors such as heat, cold, humidity, energy, and sound.

- **Biological control.** In an undisturbed ecosystem, insects and weeds are to a great extent controlled by their natural enemies. In a disturbed ecosystem pests can be controlled by releasing more predators and parasite insects, mites, and fungi.

- **Genetic control** can be either by breeding crop plants resistant to pest attack or pests themselves can be subjected to genetic intervention with the introduction of mass-reared individuals with a selected phenotype.

  Genetic manipulation of pest species has resulted in "autocidal" control such as the "sterile male" technique. This involves the introduction of the artificially reared insects carrying sterile sperm into natural populations. They are usually dominant genetic mutations that are lethal or conditionally lethals. These individuals, when they mate in competition with the normally wild population will introduce factors causing the death of portions of this population and thus reduce their numbers.

- **Regulatory control.** The spread of pests from an infested area to a new area is often caused by the movement of commodities or equipment contaminated with pest animals or pathogens. Quarantine laws have been enacted and enforced in many countries to overcome this problem.

- **Chemical control.** The use of pesticides has become a necessity and accepted practice in pest management. They provide a rapid, effective and economical means of controlling the majority of crop pests.

- **Integrated peat control.** It involves combining various control methods in a planned approach. The aim is either to reduce a pest population or keep it at or below a level of economically acceptable damage.

Thus integrated control does not necessarily include chemical control. However, chemical control involving the use of pesticides is one of the most effective tools available provided it is practiced with judgement and care (Oudejans 1982).

## Integrated Pest Management (IPM)

Examining components of the term 'integrated pest management' may help in understanding its meaning (Oudejans 1982).

A pest is an organism causing harm to man or his property. Pests include insects, nematodes, rodents, weeds, fungi, bacteria, and viruses. Management implies the direction of the pest situation by a judicious use of various methods of control to decrease the harm caused by the pest to an economically acceptable level.

Integrated means bringing together of individual control methods into a whole operation that takes due care of a sound environment. Integrated also implies that combined control operation should be compatible, with complex farm production units and its social, physical, and economic conditions.

Therefore, "integrated pest management" considers any and all combinations of various techniques for the management of pest problems such as those caused by plant vigor, mechanical injuries, weeds, insects, diseases, rodents, and animals within the context of the farming system (Oudejans 1982).

The components of IPM are explained in the flow chart (Fig. 2) based on the information given by Ghose (1989).

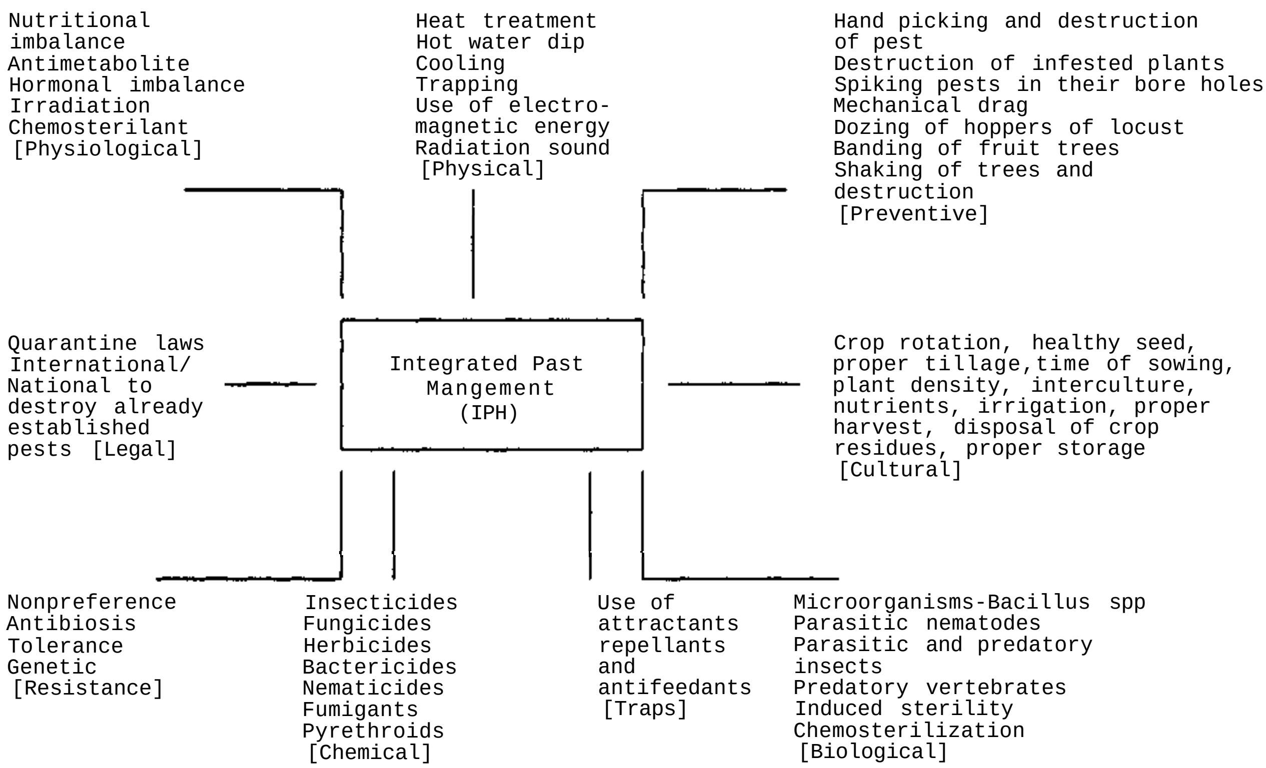


**Figure 2. Flow chart of Integrated Pest Management (IPM) system**

(Source: Ghose 1989)

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## Evaluation

**Select the most appropriate answer and check the correct answer at the end of the booklet.**

1. An organism causing annoyance to human being is a/an
   a) insect. b) animal. c) pathogen. d) pest.

2. Pigeonpea is attacked by over ____ species of insects.
   a) 50 b) 100 c) 150 d) 200

3. Insects attacking roots of pigeonpea are
   a) jewel beetles and weevils. b) nodule damaging fly and termites.
   c) jassid and aphids. d) eriophyid mites.

4. The scientific name of pigeonpea nodule damaging fly is
   a) *Ophiomyia phaseoli.* b) *Odontotermes* sp.
   c) *Rivellia angulata.* *d) Sphenoptera indica.*

5. The scientific name of aphid is
   a) *Empoasca fabae.* b) *Aphis* craccivora.
   c) *Aceria cajani.* d) *Schizotetranychus cajani.*

6. White fly is
   a) *Campylomma* spp. b) *Megachile* spp.
   c) *Bemisia tabaci.* d) none of the above.

7. Wilting of young plants and sometime holes in the stem just below the soil surface may be caused by
   a) nodule damaging flies. b) termites.
   c) jewel beetles. d) stem weevils.

8. Sterility mosaic disease is transmitted by
   a) jassids. b) aphids.
   c) eriophyid mites. d) spider mites.

9. Pigeonpea yellow mosaic is transmitted by
   a) eriophyid mites. b) whiteflies.
   c) bud sucking bugs. d) leaf cutter bees.

10. At seedling and reproductive stages terminal leaflets are webbed and larvae feed within webs and prevent further shoot growth. This may be caused by
    a) *Myllocerus undecirnpustulatus.* b) *Epilachna* spp.
    c) *Amsacta* spp. d) *Grapholita critics.*

11. Under severe infection shedding of buds and flowers are caused by
    a) blister beetles. b) bud weevils,
    c) thrips. d) pod weevils.

12. The vector of pigeonpea yellow mosaic disease is
    a) whitefly. b) bud-sucking bugs,
    c) leaf cutter bees. d) eriophyid mites.

13. Leaf damaging weevils
    a) chew the leaflets at the margin causing ragged effect and larvae feed on roots.
    b) eat the leaves during night.
    c) feed leaves and inflorescence.
    d) web the leaflets and feed within.

14. The scientific name of blister beetle is
    a) *Megalurothrips usitatus.* b) *Indozocladices asperulus*
    c) *Mylabris pustulata.* d) *Apion clavipes.*

15. Adult blister beetles
   a) feed and pupate inside the flower.
   b) causes shedding of buds and leaves.
   c) severely feed on flowers.
   d) damage the immature seeds in pods.

16. The sap of developing seeds is sucked through the pod wall by
   a) thrips.
   b) blister beetles.
   c) pod-sucking bugs.
   d) pod weevils.

17. The insects that do not require control measures in pigeonpea unless infestation is heavy are
   a) jewel beetles, stem weevils, and stem flies.
   b) aphids, jassids, and spider mites.
   c) leaf damaging weevils and beetles.
   d) all the above.

18. Insects that destroy buds, flowers, and pods, and when flowers and pods are not available they feed upon leaflets leaving the veins and the larva enter into the pod by making a hole and eat developing and partially mature seed are
   a) blister beetles.
   b) lablab pod borers.
   c) cowpea pod borers.
   d) pod borers.

19. The most effective way to control blister beetle in a small area is to
   a) use an insecticide.
   b) use synthetic pyrethroids.
   c) hand pick.
   d) use biological controls.

20. The larvae webbing leaves, buds, and pods together, then feeding inside the webs are of
   a) *Helicoverpa armigera.*
   b) *Maruca testulalis*
   c) *Exelastis atomosa.*
   d) *Etiella zinckenella.*

21. Sprays of endosulfan and synthetic pyrethroids can control
   a) pod borers, lablab pod borers, cowpea pod borers, and plume moth.
   b) pod weevils and sucking bugs.
   c) leaf damaging weevils and leaf-and-flower damaging beetles.
   d) all the above.

22. The plants attacked by insect show no external symptoms till the fully grown larvae chew and make holes in the pod walls leaving a window for the emergence of flies after pupation inside the pod. These are the symptoms of damage caused by
   a) *Melanagromyza obtusa.*
   b) *Tanaostigmodes cajaninae.*
   c) *Callosobruchus maculatus*.
   d) all the above.

23. To control the larvae of pod flies inside pods an effective insecticide is
   a) endosulfan 35% EC @ 2.0 L $ha^{-1}$.
   b) monocrotophos 36% EC @ 1.0 L $ha^{-1}$.
   c) aldrin 5% @ 25 kg $ha^{-1}$.
   d) all the above.

24. The most important pests of pigeonpea are
   a) jewel beetles, stem weevils, and stem flies.
   b) jassids, aphids, and red spider mites.
   c) whitefly, bud sucking bugs, and leaf-cutter bees.
   d) pod borers, cowpea pod borer, and pod flies.

25. Harvesting at optimum maturity followed by quick drying (6% moisture), storage in beetle proof containers, and fumigation at regular interval prevents pigeonpea from
   a) pod flies and pod wasp.
   b) bruchids.
   c) pod borers.
   d) pod-sucking bugs.

26. The best way to screen for *Helicoverpa armigera* is
a) in a net house. b) in a laboratory.
c) in an open field. d) all the above.

27. In pigeonpea insect resistance (%) is recorded on a scale of
a) 1 to 3. b) 1 to 5. c) 1 to 7. d) 1 to 9.

28. In the above scale the entry equal to a resistant selection is
a) 3. b) 4. c) 5. d) 6.

29. A chemical substance causing a specific reaction in a receiving organism of the same species is
a) a chemical. b) an insecticide.
c) a pheromone. d) a hormone.

30. A mixture of 97% (2)-11-Hexadecenal and 3% (2)-9-Hexadecenal which attracts male moths to the traps is
a) a synthetic pheromone. b) a trap.
c) a fumigant. d) an insecticide.

31. The placement of a pheromone trap should be
a) below the crop canopy. b) 2 m above the crop canopy.
c) at the crop canopy height. d) at the ground level.

32. The compounds derived from naturally occurring elements that do not contain carbon are
a) organic compounds. b) inorganic compounds.
c) botanical compounds. d) organophosphorus compounds.

33. The synthetic organic materials that act mainly as contact and stomach poisons are
a) organic compounds. b) organophosphorus compounds.
c) organochlorine compounds. d) pyrethroids.

34. The pesticides that are rapidly absorbed by the lungs such as formaldehyde are called
a) pyrathroids. b) fumigants.
c) growth regulators. d) botanical compounds.

35. Any change in one or more physiological processes which obstructs plants to utilize energy is
a) an insect. b) a disease.
c) a physiological disturbance. d) a pathogen.

36. A living organism (plant or animal) that produces a disease in plants is
a) an organism. b) disease.
c) pathogen. d) none of the above.

37. A plant or animal living in close association with and at the expense of some other living organism (the host) from which it derives its food is a
a) pathogen. b) parasite.
c) host. d) none of the above.

38. A parasite that cannot complete its life cycle without a host is
a) an obligate parasite. b) a facultative parasite.
c) a mycoplasma. d) none of the above.

39. When a parasitic pathogen obtains its food and the host remains alive, but shows symptoms such as the growth of a gall it is a
a) biotrophe. b) pertotrophe.
c) necrotrophe. d) biopertotrophe.

40. An organism that feeds only on dead organic matter is
a) an obligate parasite. b) a saprophytic parasite.
c) a pertotrophe. d) none of the above.

41. When a pathogen is present externally on a plant or seed it is
- a) contaminated.
- b) infected.
- c) inoculated.
- d) a vector.

42. An organism transmitting a pathogen is called a
- a) pathogen carrier.
- b) host.
- c) vector.
- d) none of the above.

43. When a plant cell lose its firmness (turgor) resulting due to insufficient uptake of water to replace the water lost owing to a loss by metabolic processes and evaporation it is
- a) necrosis.
- b) stunting.
- c) dwarfing.
- d) wilting.

44. The major diseases of pigeonpea are
- a) collar rot and root rot.
- b) phoma and stem canker.
- c) powdery mildew and rust.
- d) wilt, sterility mosaic, phytophthora blight, and leaf spots.

45. The minor diseases of pigeonpea are
- a) collar rot, dry root rot, and phoma.
- b) stem canker, alternaria leaf spot, and rust.
- c) powdery mildew, bacterial leaf spot, and yellow mosaic.
- d) all the above.

46. Pigeonpea wilt is caused by
- a) *Eriophyid mite.*
- b) *Fusarium udum.*
- c) *Cercospora cajani.*
- d) none of the above.

47. Phytophthora blight in pigeonpea is caused by
- a) *Cercospora cajani.*
- b) *Phytophthora drechsleri.*
- c) *Phytophthora megasperma.*
- d) *Phytophthora parasitica.*

48, Sterility mosaic is transmitted by
- a) aphids.
- b) jassids.
- c) eriophyid mite.
- d) wind.

49. Loss of turgor, yellowing of foliage, browning of xylem, and presence of brown or dark purple bands on the stem surface are characteristic symptoms of
- a) phytophthora blight.
- b) wilt.
- c) root rot.
- d) stem rot.

50. Bushy and pale green pigeonpea plants with reduced leaf size and complete or partial cessation of reproductive structures are caused by
- a) wilt.
- b) phytophthora.
- c) sterility mosaic.
- d) leaf spot.

51. Pigeonpea seedlings showing crown rot symptoms. Brown dark lesions on main stems, branches, and petioles. Lesions girdle the stems resulting in drying of portion above lesions and breaking of stem. These are symptoms caused by
- a) wilt.
- b) sterility mosaic.
- c) phytophthora blight.
- d) cercospora leaf spot.

52. Small brown circular spots on leaves which coalesce when they increase in size and dropping of infected leaves are symptoms of pigeonpea
- a) wilt.
- b) sterility mosaic.
- c) phytophthora blight.
- d) cercospora leaf spot.

53. Prolific and clustered branching of the plants, pale green leaves of small size, reduced flower development causing nonsetting of pods are symptoms of
- a) wilt.
- b) sterility mosaic.
- c) witches broom.
- d) cercospora leaf spot.

54. Rotting of root and basal stem with visible sclerotia under the bark and drying of plants under drought stress are symptoms of
    a) dry root rot. b) collar rot.
    c) phoma stem canker. d) alternaria leaf spot.

55. Appearance of brown, cankerous lesions with a gray center, and brown margins on adult plants which may coalesce and girdle the stem are symptoms of
    a) collar rot. b) dry root rot.
    c) phoma stem canker. d) alternaria leaf spot.

56. Small necrotic spots on leaves that increase in size and become dark and light brown concentric rings with a wary outline and purple margin are the symptoms of
    a) phoma stem canker. b) alternaria leaf spot.
    c) dry root rot. d) collar rot.

57. Dark brown uredial pustules on leaves and leafdrop is due to
    a) rust. b) bacterial leaf spot.
    c) powdery mildew. d) alternaria leaf spot.

58. Small brown lesions on leaves surrounded by a yellow halo which often coalesce and form larger ones are symptoms of
    a) rut. b) bacterial leaf spot.
    c) cercospora leaf spot. d) alternaria leaf spot.

59. Yellow diffused spots scattered on leaf stamina, affected leaves showing broad yellow patches alternating with green color, and reduced leaf size are symptoms of
    a) sterility mosaic. b) powdery mildew.
    c) yellow mosaic. d) rust.

60. Pearly white bodies of nematodes on the root of 30-35 day-old plants that turn brown at maturity are symptoms of
    a) reniform nematode. b) cyst nematode.
    c) root knot nematode. d) none of the above.

61. Soil covered egg masses on roots and feeding of adults, results in the reduction of root development that maybe caused by
    a) cyst nematode. b) reniform nematode.
    c) root knot nematode. d) none of the above.

62. Stunting of plants, suppressed growth, chlorosis with reduced leaf size, and reduced plant vigor are the symptoms of
    a) cyst nematode. b) reniform nematode.
    c) root knot nematode. d) root rot.

63. The severe infection of wilt at the preflowering stages and maturity can cause damage (%)
    a) 15-20 and 20-30 respectively. b) 100 and 67-30 respectively.
    c) 30-40 and 40-20 respectively. d) 50-60 and 30-40 respectively.

64. Sterility mosaic disease can damage early infected crop of pigeonpea (first 45 days) up to
    a) 20%. b) 30%. c) 40%. d) 100%.

65. Early infection of pigeonpea phytophthora blight can damage crop up to
    a) 20%. b) 30%. c) 50%. d) 100%.

66. The sterility mosaic screening technique involves
    a) creating a multiple disease sick plot.
    b) growing infector rows.
    c) advancing the susceptible selections by growing infector rows and leaf stapling.
    d) burying the crop debris.

67. The stem inoculation technique is useful to infect with
a) wilt. b) phytophthora.
c) sterility mosaic. d) rust.

68. Wilt, blight, and sterility mosaic diseases are scored on a scale of
a) 1 to 3. b) 1 to 5. c) 1 to 7. d) 1 to 9.

69. A chemical capable of preventing or eradicating disease caused by fungi is
a) a chemical. b) a pesticide.
c) a fungicide. d) an insecticide.

70. The fungicide that is absorbed by the roots or leaves of a plant and is taken into the vascular system is
a) a systemic. b) an eradicant.
c) a non systemic. d) an antibiotic.

**Correct responses to the questions.**

1. d); 2. d); 3. b); 4. c); 5. b); 6. c); 7. b); 8. c); 9. b);
10. d); 11. c); 12. a); 13. a); 14. c); 15. c); 16. c); 17. d);
18. d); 19. c); 20. b); 21. d); 22. a); 23. b); 24. d); 25. b);
26. c); 27. d); 28. d); 29. c); 30. a); 31. c); 32. b); 33. c);
34. b); 35. b); 36. c); 37. b); 38. a); 39. a); 40. c); 41. a);
42. c); 43. d); 44. d); 45. d); 46. b); 47. b); 48. c); 49. b);
50. c); 51. c); 52. d); 53. c); 54. a); 55. c); 56. b); 57. a);
58. b); 59. c); 60. b); 61. b); 62. c); 63. b); 64. d); 65. d);
66. c); 67. b); 68. d); 69. c); 70. a).