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10. Important Pests and Diseases of Millets

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Abstract:

Millets, nutritionally valuable coarse cereals, are traditional crops widely grown in diverse agro climatic regions, particularly in the semi-arid areas of Africa and Asia. These crops are crucial for the livelihoods of small-scale farmers in these areas. Although millets are among the most resilient crops, they are vulnerable to many pests and diseases. These include seedling pests like shoot flies and stem borers, foliage pests such as hairy caterpillars, cutworms, armyworms, grasshoppers, ash weevils, and flea beetles, sucking pests like shoot bugs, aphids, and spider mites, ear head pests like grain midges, ear head bugs, and head caterpillars, soil-dwelling insects such as white grubs and termites, and storage pests. Additionally, millets face threats from nematodes and various diseases like downy mildew, smut, blast, fungal and bacterial leaf blight, banded sheath blight, wilt, rust, anthracnose, grain mold, ergot disease, and viral diseases. This overview outlines the symptoms for detection and management strategies to safeguard the millets.

Keywords:

Coarse cereals, Downy mildew, Ergot, Stem borers, White grub.

10.1 Introduction:

A class of grasses with tiny seeds called millets is cultivated worldwide for human and animal feed. They are a varied collection of small grains grown primarily in dry, semi-arid to sub-humid, drought-prone agroecosystems under a variety of harsh climatic circumstances. The most commonly grown millets in India are sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), and finger millet (*Eleusine coracana*). These are a better option than wheat and rice since they are devoid of gluten and have an excellent supply of proteins, carbohydrates, vitamins, and minerals.

The main places where millets are grown are China, India, and a few nations in East and West Africa. When it comes to the production of all millets, India leads the world with 41% of global production. Millets are resistant to pests and diseases compared to main cereal crops, but they are unable to eradicate these threats, which eventually results in losses of between 15% and 20% in India (Gahukar & Jotwani, 1980). To lessen the enormous losses in the quality and quantity of these millets, focused and ongoing efforts are thus needed to control these pests and diseases.

10.2 Insect Pests of Millets:

Table 10.1: List of Insect Pests of Millets at Different Growth Stages

Sr. No	Stage of the Crop	Insect Pests Associated with Crop
1	Seedling stage	• Shoot files • Stem borers
2	Vegetative stage	• Hairy Caterpillar • Cutworms • Armyworms • Grasshoppers • Ash weevils • Flea beetles • Sucking pests (Aphids and mites)
3	Reproductive stage (Ear head Pests)	• Grain midge • Ear head Bug • Head Caterpillar
4	Storage pests	• Angoumois grain moth • Rice weevil • Lesser grain borer

10.2.1 Shoot Flies:

***Atherigona* spp:** These shoot flies harm a variety of millets, resulting in dry fodder and grain production losses. It infests sorghum, maize, ragi, bajra, and other grasses.

Atherigona Approximata: It is common on pearl millet in many Indian states, lowering grain output by 12–46% and producing dry fodder by 57% in India. As it appears from weeks 1 to 6 following germination, it is regarded as a seedling pest. In August, the fly population increases. The fly is tiny, around 3.4 mm long, dark grey, and resembles a housefly.

It deposits its white, cigar-shaped eggs singly on the underside of the leaves. As soon as the maggot hatches, it penetrates the seedling and destroys the growth point, which causes the leaf to wilt and then dry up in the center, giving the appearance of a dead heart. When it comes to pearl millet, it results in dead hearts in the early seedlings and chaffy grains in the fully-grown panicles.

10.2.2 Stem Borers:

Spotted Stem Borer, *Chilo Partellus*: It attacks, crops such as rice, sugarcane, finger millet, pearl millet, and sorghum. The medium-sized, straw-colored moth deposits its eggs in large clusters on the leaf's underside, close to the midrib. Larva from the second week following sowing until crop maturity, infects the crop. Younger plants exhibit the dead hearts sign as a result of an early symptom. The larvae then tunnel deeply into the stem, creating a large amount of stem tunneling.

White Stem Borer *Saluria Inficita*: It is a specific insect pest of ragi found in south India. The adult is a medium-sized, dark brown moth with a faint white stripe running along each forewing's costal margin. It deposits its eggs in clusters close to the leaf blade's tip. The larvae attack the tillers' base and close to the soil, resulting in dead hearts.

Ragi Stem Borer *Sesamia Inferens*: Sorghum, maize, rice, wheat, sugarcane, bajra and ragi, barley, and guinea grasses are among its diverse host range. The adult moth has pale pink wings that are streaked with dark brown, and white wings on the back.

It deposits its hemispherical, creamy-white eggs between the host plant's leaf sheath and stem, giving rise to pale yellow larvae with a pinkish-purple hue and a reddish-brown head. The larvae exhibit gregarious behavior, gathering within the leaf whorls and feeding on the core leaves, which results in the characteristic "pinhole" symptom that eventually develops into a dead heart. White ear head symptoms, or empty panicles, are caused by attacks that occur during the panicle initiation stage.

10.2.3 Hairy Caterpillars:

The medium-sized red hairy caterpillar *Amsacta albistriga* has a yellow band on its head and a yellow streak along the costal margin of its white forewings, whereas in *A. moorei* the headband and the streak are red. Masses of cream-colored or bright yellow eggs are placed on the soil or on young foliage.

The larvae hatch in 3–4 days and begin to feed gregariously and voraciously, causing the plants to completely lose their foliage (Verma, 1981).

Larvae become ashy brown in around ten days and gradually move from plant to plant, feeding extensively before migrating from one field to another.

Black hairy caterpillar, *Estigmene lactinea* has red markings on its head, body, and wings. On the leaf surface, creamy white eggs are placed, which hatch into black hairy larvae that scrape the green material of the developing leaves.

Armyworms and Cutworms:

Caterpillars of *Mythmina seperata* defoliate ragi, maize, bajra, and sorghum. The adults are brownish, with black spots located in the center of the forewing. Larvae burrow into the ground during the day and come out to feed at night, especially in the nursery. It leaves the leaf tissue skeletonized by removing the green matter. *Spodoptera exigua* larvae cause significant damage to ragi nurseries by feeding on leaves and severely defoliating the plants.

Grasshoppers:

All millets are devastatingly affected in India by *Hieroglyphus nigrorepletus*, *H. banian*, *Colemania spheneroides*, and *Chrotogonus* spp. (Acrididae: Orthoptera). The adults and nymphs feed on the leaf, resulting in small notches. When the infection is severe, the entire leaf is defoliated, giving the field a grazed appearance.

Flea Beetle:

Chaetocnema Pusaensis is dark blue in color, the adult beetle has an expanded hind femur and is primarily observed attacking finger millet, creating holes in the leaves and weakening the young plants.

Ash weevils:

Ash weevils *Myllocerus maculosus*, *M. viridanus*, *M. subfasciatus*, and *M. discolor* are brownish-white adults with black dots on their dorsal wings. They emerge in the summer and lay pale yellow eggs in the ground, which hatch into creamy white grubs in three to five days. Adult grubs feed on leaf blades, causing notching on leaves, while juvenile grubs attack roots, causing areas of withered plants.

Aphids:

In Southern India, the ragi root aphid, *Tetraneura nigroabdominalis* Sasaki occasionally cause problems for the plant. They infect the root system, and the infestation lasts until the flowers appear. Aphids feed on plant sap, causing the crop to seem stunted and withering. The winged or wingless green aphid, *Rhopalosiphum maidis* can be found in dark blue green colonies deep within the center leaf whorl, on stems, or in panicles. The plant's sap is sucked by both adults and nymphs, resulting in yellowish mottling of the leaves with necrosis on the marginand it also generates a lot of honeydew, which is used by molds to grow secondary growth. The mosaic virus is spread by aphids.

Mites:

Spider mite, *Oligonychus indicus* feeds on sorghum, maize, rice, and millets. Sorghum mite adults are dark crimson or maroon. Moreover, the nymphs, which live beneath the web on the underside of the leaves, are likewise somewhat reddish. The largest population occurs following the emergence of the panicle.

Female and immature stages feed on the foliage. The lower surface of the functional leaves turns pale yellow at first, but then turns reddish or brownish tan as they absorb the plant sap. On the underside of the severely affected leaves, there are dense webbing deposits that have the potential to invade and web the sorghum panicle also.

Sorghum Midge, *Stenodiplosis Sorghicola* and Pearl Millet Midge, *Geromyia Penniseti*:

These dipterans target wild graminaceous plants such as sorghum and pearl millet. The adult fly is tiny and delicate, with a bright orange abdomen and two translucent wings. It deposits its eggs in florets, from which fully developed, dark orange-colored maggots emerge and begin to severely damage the ovaries or attack the growing grains, resulting in chaffy panicles. White pupal cases with exit holes that protrude from the chaffy grains are thought to be significant symptom.

Earhead Bug, *Calocoris Angustatus:*

The female, which is green with a brown border lays blue cigar-shaped eggs in the center of the florets or on the glumes. By feeding on the earheads, the adults and nymphs harm them. When the grains are milky, they drain the sap from them. The affected grains become chaffy, turn black, and become poorly filled.

10.2.4 Soil Insects:

In several parts of central India, the pearl millet crop has been devastated by white grub, *Holotrichia consanguinea*. The white, muscular, C-shaped grubs that attack the roots of seedlings causes the initial damage and the seedling will completely wither in a week. Stunting and lodging of fully grown plants are observed, resulting in a decrease in the number of plants in individual patches. The life cycle begins with eggs, which hatch in 1-3 weeks and mature into grubs in 8–22 weeks.

Termites like *Odontotermes* spp., *Microtermes* spp., and *Macrotermes* spp. are polyphagous pests that infect maize, pearl millet, sorghum, finger millet, wheat, sugarcane, and upland rice.

In arid and semi-dry conditions, termites are prevalent, and damage as soon as seeds are sown continues during the growth season. Worker caste targets the roots of different crops, interfering with the vascular system's ability to carry nutrients and water, which kills the plant and causes the wounded plants to collapse.

10.2.5 Storage Insects:

Angoumois grain moth infestation, *Sitotroga cerealella* is also often observed in fields. Larvae consume the seed, lowering the grain's quality, viability, and quantity. *Sitophilus oryzae*, the rice weevil, and *Rhizopertha dominica*, the lesser grain borer frequently occurs in millet that has been stored (Kishore and Sharma, 1974), and can result in losses of 15–25% (De Lima, 1981).

10.3 Diseases of Millets:

Table 10.2: List of Diseases of Millets and Its Causal Organisms

Sr. No	Disease	Scientific Name
1	Sorghum grain smut	*Sporisorium sorghi*
2	Sorghum loose smut	*Sporisorium cruenta*
3	Sorghum long smut	*Tolyposporium ehrenbergii*
4	Sorghum head smut	*Sporisorium reilianum*
5	Kodo millet head smut	*Sorosporium paspali-thunbergii*
6	Finger millet grain smut	*Melanopsichium eleusinis*
7	Foxtail millet grain smut	*Ustilago crameri*
8	Pearl millet grain smut	*Tolyposporium penicillariae*
9	Blast of Finger millet, Pearl millet, Barnyard millet, and Proso millet	*Pyricularia grisea*
10	Foxtail millet blast	*Pyricularia setariae*
11	Sorghum leaf blight	*Exserohilum turcicum*
12	Finger millet seedling blight	*Helminthosporium nodulosum*
13	Finger millet leaf blight	*Xanthomonas axonopodis pv. coracanae*
14	Foxtail millet leaf blight	*Pseudomonas avenae*
15	Pearl millet leaf blight	*Pantoea stewartii subsp. indologenes*
16	Banded Sheath Blight of Finger millet, Foxtail millet, Barnyard millet, Proso millet, and Kodo millet,	*Rhizoctonia solani*
17	Finger millet wilt	*Sclerotium rolfsii*
18	Sorghum Rust	*Puccinia purpurea*
19	Pear millet Rust	*Puccinia substriata var. indica*
20	Kodo millet rust	*Puccinia substriata*
21	Finger millet rust	*Uromyces eragrostidis*
22	Foxtail millet rust	*Uromyces setariae-italiae*
23	Sorghum anthracnose	*Colletotrichum graminicola*
24	Sorghum, Pearl millet, Finger millet mold	*Fusarium spp., Curvularia lunata, Alternaria alternate, Phoma sorghina, Bipolaris spp., Aspergillus spp*
25	Sorghum ergot	*Claviceps sorghi*
26	Pearl millet ergot	*Claviceps fusiformis*
27	Sorghum leaf spot	*Bipolaris sorghicola*
28	Sorghum grey leaf spot	*Cercospora sorghi*

Sr. No	Disease	Scientific Name
29	Sorghum zonate leaf spot	*Gloeocercospora sorghi*
30	Pearl Millet zonate leaf spot	*Gloeocercospora sorghi*
31	Pearl millet *Bipolaris* leaf spot	*Bipolaris setariae*
32	Pearl millet *Cercospora* leaf spot	*Cercospora penniseti*
33	Pearl millet *Curvularia* leaf spot	*Curvularia penniseti*
34	Proso millet leaf spot	*Bipolaris panici-miliacei*
35	Finger millet brown spot	*Drechslera nodulosum*
36	Foxtail millet leaf spot	*Cochliobolus setariae*
37	Sorghum bacterial leaf spot	*Pseudomonas syringae pv. syringae*
38	Pearl millet leaf spot	*P. syringae*
39	Finger millet leaf spot	*Xanthomonas eleusinae*
40	Pearl millet downy mildew	*Sclerospora graminicola*
41	Sorghum downy mildew	*Peronosclerospora sorghi*
42	Finger millet downy mildew	*Sclerophthora macrospora*

10.3.1 Downy Mildew:

Pearl millets can exhibit downy mildew even in their very early stages of development. On the upper surface of the second leaf, it begins to cause chlorosis in streaks. Only the fine downy growth on the opposite side of these streaks is visible. As time went on, the chlorotic sections of the leaves turn brown, causing the leaves to tear along their veins.

The disease is sometimes referred to as "Green ear" or "Crazy top" because nodal buds and inflorescence at the heading stage produce lateral shoots and twisted leafy structures that give the plant a bunchy look (Shetty *et al*., 2016; Singh, 2018b). However, the distinctive white, cottony growth is rarely observed in finger millet. According to Das *et al*. (2016), the disease turns the heads partially or totally into green, narrow, leafy structures, which results in total sterility.

10.3.2 Smut:

Grain Smut: It is the most damaging disease affecting sorghum. When millets develop grain smut, the grain is replaced by an unclean, grey, oval or cylindrical spore sac (sorus) that is 4–12 mm in diameter. Except for the columella, a hollow hard tissue in the center of the column, the sorus is filled with spore powder (Singh, 2018a). It has been discovered that the sorghum grain smut spores can survive for up to 13 years.

Loose Smut: Plants affected with loose smut flower earlier than healthy plants and have thin, stunted stalks. Every spikelet in a panicle becomes malformed. The fungal structure that resembles a membrane burst shortly after the head appears, and the spikelet left empty.

Long Smut: When sorghum is grown for a long time, the sorus is covered in a very thick membrane that can be pale or dull yellow in color. In comparison to long smuts, the sora of covered and loose smuts are somewhat shorter (4.0 cm).

Head Smut: The characteristic panicle that emerges from the boot leaf of millets is replaced by a sorus that is entirely encased in a greyish-white membrane in the head smut (Kumar *et al*., 2008). In kodo millet the panicle may not emerge from the flag leaf adequately, which would result in a significant yield loss (Sangappa *et al*., 2018). Eventually, millions of spores are released when the membrane bursts.

10.3.3 Blast:

Blast symptoms might appear on the finger, peduncle, leaf, or seedling, depending on the stage of development of finger millet. In addition to elliptical or diamond-shaped lesions on leaves with chlorotic rings surrounding them, water-soaking is one of the hallmark symptoms of leaf blasts. Under favorable conditions, the spots enlarge, and coalesce, and the leaf blades acquire a blasted appearance (Das, 2017; Jeevan *et al*., 2021). A prolonged lesion of black color, one to two inches below the ear, is generally the first indication of a neck blast. It is the most serious stage of the illness, causing large losses in grain weight and quantity and increased spikelet sterility (Nagaraja *et al*., 2007).

10.3.4 Leaf Blight:

Long, oval, necrotic lesions are one of the signs of sorghum leaf blight. The lesion typically has a straw-colored center and a dark brown border. In the cultivar of tan color, the edge is not visible. The size and shape of the lesions may vary depending on the level of host resistance. When a leaf has a vulnerable genotype, the lesions enlarge and group together to form brown or purple-grey necrotic regions. Initially, the lower or older leaves exhibit the symptoms. The surface of the necrotic lesions appears dark gray or black due to the pathogen's production of spores, especially in moist weather (Das and Rajendrakumar, 2016).

Bacterial Leaf Blight:

Xanthomonas axonopodis pv. coracanae is the cause of finger millet leaf blight, which was first identified in Gujarat, India, and later moved to Uganda, Africa. The initial signs are translucent, water-soaked, angular lines from pale yellow to dark greenish-brown parallel to the lamina's midrib. Subsequently, the hyaline stripe develops into a broad, 2-4 cm diameter yellowish lesion that eventually turns brown. If the infection is severe, especially in the early stages, the leaves turn brown and wither away.

In addition, the plants prematurely wilt and turn yellow. Plants can become infected at any stage of their growth. Water-soaked lesions on the tips of leaves that extend toward the base along a defined boundary are the symptoms of pearl millet leaf blight. Subsequently, the affected plants exhibit widespread necrosis and the classic symptoms of leaf blight (Ashajyothi *et al.*, 2021).

Banded Sheath Blight:

Banded sheath blight commonly affects little millets. Oval to irregular, light grey to dark brown lesions on the bottom leaf and leaf sheath is its defining feature. Next, the lesion's edges start to turn a thin reddish brown, having a whitish core. Subsequently, the spots became dispersed across the leaf lamina. When the correct circumstances are present, lesions spread swiftly and group together to cover a sizable portion of the leaf sheath and lamina. At this point, the symptom is described by a series of bands across the leaves that are colored copper and give them a banded appearance. Severe cases appear as irregular to oval, dark brown to purplish necrotic lesions on peduncles, fingers, and glumes. On and around the lesions, mycelia development and sclerotia are seen (Patro *et al.*, 2021).

10.3.5 Wilt or Foot Rot:

The affected area of finger millet foot rot is only two to three inches above the ground. At first, the diseased base appears to be soaked in water, with time, this appearance turns brown, then dark brown, and the impacted section of the stem starts to shrink. In this area, little, roundish, white, velvety sclerotia entities that resemble mustard seeds coexist with an abundance of white cottony fungal growth. Ultimately, as the leaves become parched, drooping, and dull, the plant prematurely dries up. Before they die, the sick plants remain green and distorted. On the surface of lesions, small, round, dark-colored sclerotia form (Raguchandar, 2015a).

10.3.6 Rust:

On both sides of the lower leaves, reddish-brown pustules are the initial signs of sorghum rust. Typically, an infection affects the top half of the leaf more severely than the bottom. As the disease gets worse, the infection spreads to the younger leaves. A collection of nearby pustules may combine to create a larger spot on the foliage. When viewed from a distance, sick leaves may wither away early, giving the plants an unhealthful appearance. Pustules can form on any part of the plant, including the stem, peduncle, and midrib. The pathogen develops two distinct types of spores in the pustules on sorghum uredospore and teliospore. The initial sign of pearl millet rust on a leaf is round to oval reddish-orange pustules. Before spreading to both surfaces of the leaf, pustules first develop on the distal half of the leaf. When fully developed pustules rupture, rust spores are discharged. There may be further symptoms on the stem and other plant parts. Plants with a lot of rust, seem reddish-brown. Additionally, prone to rust include finger millet, kodo millet, tiny millet, and foxtail millet. Small, fragmented pustules ranging in color from cinnamon to dark brown and arranged in a line on the upper surface of the upper leaves are the symptoms.

10.3.7 Anthracnose:

The earliest signs of anthracnose on a leaf are small, straw-colored, elliptic to circular dots with a wide border. The lesion edge might be red, orange, blackish purple, or tan, depending on the pigment in the cultivar. Adjacent spots can come together to resemble a blighted leaf. A black dot-like acervulus is often seen in the center of the necrotic patch, and this is the characteristic diagnostic indication for leaf anthracnose.

In addition to the leaf, the midrib, the spikelet's tissues, and the leaf sheath on the stalk might all exhibit the symptom. This is sometimes referred to as stalk rot or red rot. Circular cankers growing on the outside are signs of red rot in the inflorescence, in particular. A reddish staining, either continuous over a broad region or more commonly discontinuous, gives the impression of a marbled or ladder-like stem when an infected stem is split apart (Lebeau *et al*., 1951).

10.3.8 Grain Mold:

A significant disease of sorghum is grain mold, which can also sporadically be seen on finger millet and pearl millet. The first obvious signs of sorghum show on the tissues of the spikelet's as fungal growth on the anthers and filaments coloration. Infected plants produce blast florets. The color of the fungal bloom on grain can range from lustrous black to pinkish, grayish, or white. Grain sprouting can occasionally be induced by internal fungal invasion. The symptoms of mature grain manifest as fungal growth on the grain surface that might be pink, orange, grey, white, or black in color. Compared to white-grain sorghum, colored-grain sorghum has less noticeable grain discoloration. Fungal development initially begins at the hilar end and then spreads to the pericarp surface. When there is high humidity, highly infected grains crumble when little pressure is applied, and this is known as "seed rot," or "premature kernel rot" (Das *et al*., 2020). Grain mold on finger millet is visible as dark to black discoloration of the grains, while on pearl millet it appears as pinkish or whitish fungal development on mature grains. Another name for it is head mold (Tifton, 2016).

10.3.9 Ergot Disease:

The first noticeable sign of an ergot infection is the exudation of sticky droplets that resemble honeydew from infected flowers. A droplet may be seen on one, many, or all of the florets in a panicle, depending on the severity. In ten to fifteen days, these drops become quite rigid. The grain is replaced by dark brown to black, seed-sized or larger structures with pointed apexes that emerge from the florets (Thakur and King, 1988a). A fungus that has become infected creates something called a sphacelium. wart-like fungalgrowth known as a sclerotium progressively grows in place of the grain. Honeydews often stimulate the growth of saprophytic fungus, causing the leaf surface to turn black. Pearl millet ergot sclerotia have an elongated or spherical shape, range in color from pale pink to dark brown or black, and have a brittle or hard texture.

10.3.10 Fungal Leaf Spot:

- **Sorghum Target Leaf Spot:** On sorghum, leaf spots are round to cylindrical, purple to crimson, and have an irregular edge. The centers of the spots are colored like straw. When spots unite, large lesions may result.
- **Pearl Millet Bipolaris Leaf Spot:** It is a disorder that affects pearl millet. It appears as minute brown flecks or spots that vary in shape from round to square to rectangle.
- **Finger Millet Brown Spot:** Lesions may develop into clusters. Lesions are often tan or greyish-brown in color, with a border of dark brown that is more or less evident.

- **Grey Leaf Spot:** The characteristic symptoms are shown by brown to dark brown spots on the leaf or sheath. The neck and fingers could become infected. An early infection may be the cause of seedling blight. Grey leaf spots on sorghum initially appear as small, rectangular lesions that are surrounded by veins. The spots enlarge with time and create asymmetrical blotches.

On pearl millet, it resembles an oval lesion with rows of black conidiophores scattered across its pale tan to grey or white centers, encircled by dark brown edges. Stems may sustain lesions. When it comes to finger millet, the symptoms usually appear on the older leaves first and then spread to the younger ones. Initial symptoms appear as reddish-brown dots surrounded by a yellow halo. Eventually, several of these dots come together to form bigger lesions that have a burned appearance. Rain causes the fungus to sporulate and grow in the center of the area, giving it the appearance of a brown spot.

Zonate Leaf Spot: The symptoms of zonate leaf spot on sorghum are characterized by bands that alternate with zones colored like straw, resembling a bull's-eye target. Around the leaf edge, the dots usually form in semi-circular patterns. Lesions appear as wet patches with dark brown edges and tan centers on pearl millet. Larger spots develop into roughly semi-circular blotches that take up over half of the leaf's width.

Curvularia Leaf Spot: Blotches resemble concentric rings of alternating tan and brown colors. The rectangular lesions which first appear as little yellow-brown dots on leaves, can affect pearl millet. Lesions get brown in the middle but retain yellow around the margins. Lesions are more common on the margins of leaves (Schwartz and Gent, 2005).

Bacterial Leaf Spot:

Bacterial leaf spots are seen on the leaves of sorghum, finger millet, and pearl millet. Small, elliptical dots with a straw-colored center and a black rim are the initial symptoms of sorghum, over time, the spots merge to form wide bands. Linear dots can be observed on the veins and both sides of the leaves of finger millet. Spots begin as vivid yellowish brown, but they soon become dark brown. In the advanced stage, the leaf tears apart as it splits along the streak. There could be an effect on the entire leaf canopy. The peduncle occasionally has noticeable stripes, even though the bacteria primarily harm the leaves.

10.3.11 Viral Diseases:

Table 10.3: List of Viruses and Their Transmission

Sr. No	Virus	Transmission
1	Maize stripe virus	*Peregrinus maidis*
2	Maize mosaic virus	*Peregrinus maidis*
3	Maize dwarf mosaic virus	*Rhopalosiphum maidis*
4	Maize streak virus	*Cicadulina chinai*
5	Ragi mottle streak virus	*Cicadulina bipunctella, C. chinai*

- **Sorghum Stripe Disease:** The development of continuous, yellow stripes or bands between the veins of afflicted leaves, which progress constantly from the base to the tip of the leaves, is the hallmark of sorghum stripe disease, also known as chlorotic stripe stunt. Depending on the infection stage, impacted plants may appear stunted, with a range of heights. Many times, infected plants do not force open their earhead.
- **Sugarcane Mosaic Virus:** The infection manifests as systemic mosaic symptoms, necrotic red streaks, temperature-dependent red leaves, and general sorghum necrosis. Further identification of the virus revealed that it was an Indian strain of the sorghum red stripe virus (SRSV-Ind).
- **Ragi Mottle Streak Virus:** When the plants are 4–6 weeks old, the infection shows up as regular dark-green spots along the leaf veins. Chlorosis and streaks on leaves are common. The symptoms are of the mottle variety and show up as white patches on the lower leaves. Plants that are affected frequently have small ears and stunted growth (Kumar and Singh, 2010).
- **Maize Mosaic Virus:** The formation of thin, erratic, chlorotic striations between leaf veins and the plant's slowed growth are symptoms. As the condition worsens, the lesions get necrotic. Plants that were initially afflicted eventually die without developing an earhead. Plants in later stages of disease may have earheads with or without grain.

10.4 An Integrated Approach for Management of Pests and Diseases in Millets:

10.4.1 Cultural Control:

a. Weeds are both collateral and alternative hosts, providing a haven for numerous diseases and pests that act as a source of inoculums. According to Kumar and Singh (2010) a prompt removal of them aids in the control of diseases like ergot, downy mildew, and viral infections.
b. One month before planting, extensive ploughing will reveal the insect's juvenile stages, giving predators food (Prasad *et al.*, 2015). Additionally, this will lessen the inoculum of soil-borne illnesses like smut, downy mildew, charcoal rot, and a few bacterial and fungal leaf diseases.
c. To reduce the damage caused by head, midge, and shoot bugs as well as to reduce the opportunity for airborne disease spores to find a susceptible host, timely/early sowings of cultivars with a similar maturity should be employed.
d. Crop rotations involving non-host crops can also aid in lowering soil-borne disease inoculum and pest infestations, whether monophagous or oligophagous. To mitigate the effects of rust and stem borers, sorghum can be interplanted with lablab, pigeon pea, or cowpea.
e. To handle smut diseases, farmers need to be informed. Utilizing clean cultivation methods, such as collecting smutted heads in fabric bags and heating them to kill the virus, will reduce the inoculum for the next year and limit incidence.
f. The application of nitrogenous fertilizer sparingly lowers the prevalence of shoot fly and stem borers, blast, downy mildew, and charcoal rot diseases. Maintaining a healthy plant population and spacing is important, however, if a location has previously been known to have shoot fly infestations, we should proceed to reduce the

loss by using a 1.5-times greater seed rate and postponing thinning to preserve the ideal plant stand.

10.4.2 Mechanical Control:

a. To monitor, attract, and eradicate adult moth pests such as june beetles, adult stem borer, and grain midges, light traps can be left out until midnight. Male *Helicoverpa* sp. moths are drawn to the sex pheromone trap at 12/ha during the blooming and grain hardening stages. This can be achieved by employing fishmeal traps treated at a rate of 12/ha with insecticides until the crop is 30 days old.
b. Ergot infection from infected seeds is decreased by mechanically removing sclerotia from seeds by washing them in water containing 30% salt.

10.4.3 Biological Control:

The application of *Pseudomonas chlororaphis* SRB127 talc formulation to seeds decreases the occurrence of charcoal rot and increases seed weight. For tiny millets, bio-control agents, particularly *Trichoderma* and *Pseudomonas* strains, are helpful in treating sheath rot, foot rot, and grain mold (Kumar, 2013). Neem cake applied at a rate of 80 kg/acre to suppress nematodes. To manage the lepidopteran pests, apply 400 g/acre of *Bacillus thuringiensis*.

10.4.4 Chemical Control:

Downy mildew and smuts are reduced when seeds are treated with fungicides such as ridomyl-MZ at 6 g/kg or sulfur at 4 g/kg. For the treatment of blast, use foliar spray of carbendazim at 0.1% or tricyclazole at 0.06% depending on need. Ergot and gall midges are reduced when panicles are sprayed with fungicides (0.1% Bavistin, 0.2% Tilt, or 0.2% Mancozeb) and insecticides (cypermethrin 25 EC @ 0.5 ml/liter) during flowering (Upamanya et al., 2019).

Thiamethoxam 70 WS @ 3 g /1 kg seed treatment lessens shoot fly and stem borer damage to the seed. Carbofuran 3G granules reduce shoot fly and stemborer attacks when sprayed in whorls at 8–12 kg ai/ha. Imidacloprid spraying at a rate of 1.5 milliliters per liter successfully lowers the viral diseases and vector population. Chlorpyriphos mixture at 20% EC.

In addition to irrigation water, 4 L/ha or 50 kg of soil uniformly distributed over 1 ha of standing crop would lower the population of termites and white grubs, respectively.

10.5. Conclusion:

The International Year of Millets is being observed in 2023. The Indian government has implemented several programs aimed at raising millet production and consumption. Since millets are C_4 crops, they may be able to support agriculture through future climate circumstances. Conversely, the primary cereals of the C_3 group will be in jeopardy.

Millets are not an exception to the rule that the biggest production costs are incurred in managing pests and illnesses. Thus, it is important to employ preventative, early detection, and proactive management measures to limit the spread of these threats and the associated losses.

10.6. References:

1. Ashajyothi M, Balamurugan A, Shashikumara, Pandey N, Agarwal DK, Tarasatyavati CC, Varshney RK and Nayaka SC. 2021. First report of pearl millet bacterial leaf blight caused by *Pantoea stewartii* subspecies *indologenes* in India. *Plant Disease* 105(11): 3736.

2. Das IK. 201. Millet Diseases: Current Status and Their Management. *Millets and Sorghum: Biology and Genetic Improvement* 291–322.

3. Das IK and Rajendrakumar P. 2016. Disease Resistance in Sorghum. *Biotic Stress Resistance in Millets* 23–67. https://doi.org/10.1016/B978-0-12-804549-7.00002-0 6.

4. Das IK, Aruna C and Tonapi VA. 2020. Sorghum Grain Mold. ICAR-Indian Institute of Millets Research. https://www.millets.res.in/pub/2020/Sorghum_grain_mold_2020.pdf 7.

5. Das IK, Nagaraja A and Tonapi VA. 2016. Diseases of Millet-a ready reckoner. ICAR-Indian Institute of Millets Research. https://doi.org/10.1007/978-1-4757-5221-2_9.

6. De Lima CPF. 1981. Africa: assessment and control of losses in stored food. Span (UK) 24(3): 104–107. https://doi.org/10.3/JQUERY-UI.JS

7. Gahukar RT and Jotwani MG. 1980. Present Status of Field Pests of Sorghum and Millets in India. *International Journal of Pest Management* 26(2), 138–157.

8. Kishore P and Sharma GC. 1974. Note on relative susceptibility of seeds of promising bajra (*Pennisetum typhoides*) hybrids and varieties to insect attack in storage. *Seed Research* 12, 90– 92.

9. Kumaar B, Kumar J and Petikam S. 2008. A first record of head smut in barnyard millet from mid hills of Uttarakhand. *Journal of Mycology and Plant Pathology* 38(1), 142– 143.

10. Kumar, Bijender. 2013. Management of finger millet (*Eleusine coracana*) grain mold or seed blackening. *Indian Phytopathology* 66(3), 319–321.

11. Kumar, Bijendra and Singh KP. 2010. Important small millet diseases in India and their management. *In Microbial Diversity and Plant Disease Management.* https://www.researchgate.net/publication/327011510_Important_small_millets_diseases_in_In dia_and_their_management.

12. Nagaraja A, Jagadish PS, Ashok EG and Krishne Gowda KT. 2007. Avoidance of finger millet blast by ideal sowing time and assessment of varietal performance under rain fed production situations in Karnataka. *Journal of Mycopathological Research* 45(2), 237–240. https://www.semanticscholar.org/paper/Avoidance-of-finger-millet-blast-byideal-sowing-of-Nagaraja-Jagadish/4e28636283222f6e6062389599e8bd1573b.

13. Patro TSSK, Praveen B, Palanna KB and Das IK. 2021. Banded leaf and sheath blight (*Rhizoctonia solani*): An emerging malady in cultivation of nutricereals. *Plant Disease Research* 36(1), 11–17. https://doi.org/10.5958/2249-8788.2021.00001.00002.0

14. Prasad GS, Bhagwat VR and Babu KS. 2015. Insect Pests of Millets and their management. *Indian Farming* 65, 46–49.
15. Raguchandar T. 2015. TNAU Agritech Portal: Crop Protection: Agricultural crops: Cereals: Ragi diseases: Foot rot or wilt.
16. Sangappa D, Ronanki C, Kumar R and Tonapi VA. 2018. Kodo millet, 1–2. ICAR-Indian Institute of Millets Research.
17. Schwartz HF and Gent DH. 2005. Millet-*Curvularia* leaf spot. https://bugwoodcloud.org/bugwoodwiki/CurvulariaLeafSpot-Millet.pdf
18. Shetty HS, Rai NS, Kini KR, Bishnoi HR, Sharma R, Rajpurohit BS, Mahala RS, Yadav HP, Gupta, SK and Yadav OP. 2016. Downy Mildew of Pearl Millet and its Management. In All India Coordinated Research Project on Pearl Millet, Indian Council of Agricultural Research, Mandor, Jodhpur – 342304
19. Singh RS. 2018a. Disease caused by Basidiomycota (Ustilaginales). In Plant diseases (10th ed., 400–453). Medtech.
20. Singh RS. 2018b. Diseases caused by Plasmodiomycetes and Mastigomycotina. In Plant diseases (10th ed., 148–254). Medtech.
21. Thakur RP and King SB. 1988. Ergot disease of pearl millet. In Information Bulletin nO. 24. Patancheru, A.P. 502 324. India. International Crops Research Institute for the Semi- Arid Tropics. http://oar.icrisat.org/957/1/RA_00164.pdf
22. Tifton GA. 2016. Pearl Millet Diseases - Fungal: USDA ARS. United States Department of Agriculture. https://www.ars.usda.gov/southeast-area/tifton-ga/crop-genetic and-breeding-research/docs/pearl-millet-diseases-fungal/
23. Upamanya GK, Brahma R, Choudhury M, Deka P and Sarma R. 2019. Response of Different Varieties of Finger Millet Against Diseases and Evaluation of Efficacy of Fungicides Against Leaf Blast. *International Journal of Recent Scientific Research* 10(12): 36655– 36658.
24. Verma SK. 1981. Field efficiency of insecticides and antifeedants against advanced stage larvae of *Amsacta moorei* Butler. Annals of arid zone.