Pearl millet (Pennisetum glaucum) (Poales: Poaceae) is a crop native to Africa. Pearl millet is usually grown without irrigation or fertilizers. This crop is grown in well-drained soils and is well-adapted to poor, dry, and infertile soils; therefore, it is critically important for food security in some of the world’s hottest, driest cultivated areas where soils are tough. Due to its high adaptability, pearl millet is becoming an increasingly important crop. Pearl millet is the most widely cultivated millet and India and Africa are its largest producers. It is mostly grown in the drier areas of India and Sahelian Africa. Other countries where pearl millet is grown include the United States and Puerto Rico. The short-cycle cultivars (85–95 days to maturity) are the most widely cultivated compared to long-cycle (120–130 days maturity) cultivars and can be grown under irrigation in rotation with higher-value crops. Pearl millet can tolerate higher temperatures but does not tolerate long consecutive dry periods. This crop is grown in well-drained soils and is well-adapted to poor, dry, and infertile soils; therefore, it is critically important for food security in some of the world’s hottest, driest cultivated areas where soils are tough.

Integrated pest management (IPM), an environmentally sound and economical approach to pest control, was developed in response to pesticide misuse in the 1960s. Pesticide misuse has led to pesticide resistance among prevailing pests, a resurgence of non-target pests, loss of biodiversity, and environmental and human health hazards. The IPM Innovation Lab has developed and tested robust IPM packages, holistic suites of IPM recommendations and practices for the production of vegetables and other crops. Farmers who use IPM packages in planting, production, and throughout the supply chain see enhanced profitability in their crops. The recommended practices in IPM packages cover economically significant pest species over a wide range of cropping systems across the tropical world, resulting in benefits to human health and the environment.
DISEASES

Foliar and stem diseases

Cercospora leaf spot

This fungal disease causes small, dark lesions with grey centers on leaves. Lesions can also be present on stems, and in rainy weather, spores also become visible. High temperatures coinciding with periods of high humidity increase this disease incidence. To manage this disease, resistant varieties, weed management, crop rotation, sanitation are practiced.

Rust

This is a foliar fungal disease and symptoms include small yellow or white raised spots on upper and lower leaf surfaces. More spots occur on the lower side of the leaves and at later stages spots become bigger and red-brown surrounded by a yellow halo. Rust spores survive in crop residue in soil and spread through the wind. To manage the disease, disease-resistant varieties are available. Overhead irrigation increases incidence of this disease.

Pearl Millet Downy Mildew

Mildew is a fungal disease of foliage. The symptoms include chlorosis at the base of a leaf that then extend towards the tips of the leaves. White powdery development also occurs on the leaves. Inflorescences of infected tillers have the characteristic green-ear symptoms where the grain is replaced by whip-like vegetative structures. When infected at the early stage, plants may die. This fungus infects the growing point of each tiller when the leaf and panicle tissues are being formed. Primary infection is from oospores that live in the soil or crop debris. Secondary infection is from the spores produced in the honeydew. Once the stigmas have been pollinated, they rapidly wither and are no longer available as the infection route for the ergot fungus. Heavy rain at flowering time washes down pollen, extending the period at which the stigmas are available for infection as well as providing ideal conditions for germination and sporulation of the ergot fungus. Host plant resistance, pollen management, avoidance, and sanitation are the best way to manage this problem.

Milliano (Hypocreales: Clavicipitaceae)

Ergot is a fungal disease of inflorescences and symptoms include the appearance of viscous creamy-pink exudations on the flowering heads. Later, it forms a hard-brown spiky structure called sclerotia. These sclerotia contain alkaloids that are toxic for humans. Ergot also reduces grain yields. Initial infection is from spores produced from sclerotia in the soil or crop debris. Secondary infection is from the spores produced in the honeydew. Once the stigmas have been pollinated, they rapidly wither and are no longer available as the infection route for the ergot fungus. Heavy rain at flowering time washes down pollen, extending the period at which the stigmas are available for infection as well as providing ideal conditions for germination and sporulation of the ergot fungus. Host plant resistance, pollen management, avoidance, and sanitation are the best way to manage this problem.

Smut

Symptoms of this inflorescence disease include the development of sori on the ears. These sori appear as saccs and are initially green and later on turn dark brown or black. Spores are released from the sori when the crop is threshed and then get mixed with seeds of non-infected florets, and are the source of infection for the subsequent crop. Resistant cultivars are available.
Insect pests

Photos (From left): • Pink stem borer • Green bug • Lema planifrons damage

Oleage and stem pests

Stem borers
Pearl millet stem borer [Coniesta ignefusalis Hampson (Lepidoptera: Crambidae)]
Potted stem borer [Chilo partellus, Swinhoe, Chilo sacchariphagus Boer (Lepidoptera: Crambidae)]
Pin stem borer [Sesamia inferens Walker, Sesamia calamistis Hampson (Lepidoptera: Noctuidae)]
Sit stem borer [Saluria LQ0FL Walker (Lepidoptera: Pyralidae)]

The stem borer complex causes major damage to pearl millet in all growing areas. Some species are prominent in Africa and some in the Indian subcontinent. These borers attack plants from 4 weeks old through grain maturity. In general, after egg hatching, early instar larvae enter the leaf whorl and feed on soft tissues. Due to this feeding damage, leaves show pinhole damage after they unfold. Afterward, larvae move out of the whorl, bore upward in the developing stalk, feed on the meristem, and the leaf whorl dries up, causing dead heart. Later instar larvae bore into tunnels. The most prominent stem borer in Africa is Coniesta ignefusalis Hampson. It late maturing material. The dead heart and stand loss, while the second and third cause lodging, disruption of the vascular system and inhibition of grain formation. Yield losses range from 15% to total crop failure due to C. ignefusalis. Stem borers become problematic in spring and summer plantings when temperatures and insect reproduction rates are high. Stem borer complex could cause yield loss to pearl millet crop. Use of pheromone bait traps to monitor adult stem borers is recommended. Control measures should be taken as soon as stem borers are detected. Management strategies include use of resistant varieties and neem products early in the season before the larvae bore into the stem of the plant. Use of natural enemies Trichogramma spp., (Trichogrammatidae) and Telenomus spp. (Platygastridae) (egg parasitoids), Habrobracon (Bracon) hebetor Say (Braconidae) (larval parasitoid) can manage stem borers. Tetrastichus atriclavus Waterston (Eulophidae) (larval parasitoid) managing populations of C. ignefusalis. Also, use of biopesticides, Bacillus thuringiensis Berliner, Metarhizium anisopliae, and Beauveria bassiana (Bals.-Gv.) Vuill. [Atherigona approximata] (Diptera: Mecidae)

This is a major seedling pest, especially in the Indian subcontinent. In India, it causes 50% grain loss and 60% dry fodder yield loss during cold weather. It attacks seedlings and boot leaf stage of pearl millet and damages the earhead. It causes dead hearts in young plants and Increasing seed rate and seedlings at time of thinning is helpful in managing this pest. Not much is known in terms of biological management.

Lea beetles
[Leptatoma planifrons Weise (Coleoptera: Chrysomelidae)]

They feed on leaves of seedlings by scraping their chlorophyll portions, resulting in light-colored spots, bleached appearance of leaves. Infestations are sporadic and associated with prolonged period of drought.

Grasshoppers
[Kraussaria angulifera] Krauss, Oedaleus senegalensis

Both species cause major yield loss in pearl millet by feeding on the foliage and stem. By chewing they cause mechanical damage to the plant and the entire plant dies. Entomopathogenic fungus Metarhizium anisopliae and Beauveria bassiana can manage grasshoppers.

Aphids are polyphagous insects that suck sap, colonize in large numbers and secrete honeydew. Honeydew induces sooty mold on plants, hindering photosynthetic capacity. They produce several generations in a season. Both nymphs and adults suck sap from young leaves and whorls and cause yellowing, distortion of leaves, wilting, and death of plants. Damaged plants produce...
Earhead pests

Pearl millet head-miner
[Heliocheilus albipunctella (Lepidoptera: Noctuidae)]

This pest causes damage to earheads of pearl millet in the Sahelian region of Africa. Larvae feed on panicle and prevent grain formation. Young larvae perforate glumes and later instars cause characteristic damage in form of spiral mines by cutting floral peduncles. Depending on climate, soil type, crop cultivar, plant density, plant growth stage, dispersal, and abundance of natural enemies, pest level varies. Late planting or maturing varieties to avoid moth flight period coinciding with vulnerable stages of head development, light traps, resistant and tolerant varieties, and the egg parasitoid Trichogrammatoidea armigera Nagaraja (Hymenoptera: Trichogrammatidae) and larval parasitoid, Habrobracon hebetor Say (Hymenoptera: Braconidae) are effective in managing this pest.

Grain midge
[Geromyia penniseti Felt (Diptera: Cecidomyiidae)]

Grain midge feeds on developing grain and form white pupal cases attached to tips of spikelets. Due to feeding, glumes become empty. Early attack results in complete withering of ovary while late attack may cause lesions on formed seeds. Plants have a blasted appearance. The life cycle is completed in 2 weeks and 4 or 5 generations may occur in a single season, with successive generations overlapping. Parasitoids Tetrastichus sp. (Hymenoptera: Eulophidae) and H. hebetor, and predatory bug Orius sp. (Hemiptera: Anthocoridae) are effective in managing this pest.

Blister beetles
[Psalydolytta fusca Olivier, Psalydolytta vestita Dufour, Decapotoma D*QL YOL YHU & ROHRSWHUD 0HRLGDH&DQGFKD BU bees (Rhyhinpta infuscatia %UXPHLVWHU&ROHRSWHUD Rutelinae)]

Blister beetles are common in Africa, feed on pollen, and GLUHFWOIDDFWJUDLOQLQH stamens, resulting in formation of empty spikelets.

Soil inhabiting

White grub [Holotrichia consanguinea %ODQFKDUG&ROHRSWHUD Scarabaeidae]

White grub is a pest of pearl millet in India. Larvae feed on roots, causing seedlings to wither and die, and patches RIGHDVGHGOLQJLQWKHWHOU become visible. Pesticide applications are recommended in areas with high pressure and during outbreaks.

Other threats

Millet beetle (Pachnoda interrupta Olivier) & ROHRSWHUD6FDUDEDHG

Downy mildew
(Plasmodpora penniseti Kenneth & Kranz (Pleosporales: Pleosporaceae))

Drechslera leaf spot
(Drechslera dematioidea (Bubák & Wróbl.) Subram. & J aín) (Pleosporales: Pleosporaceae)

Exserohilum leaf blight
(Exserohilum rostratum=Setosphaeria rostrata Leonard) (Pleosporales: Pleosporaceae)

False mildew
(Beniowskia sphaeroidea) (Kalchbr. & RRHODVRQ,QFHUWDH sedis)

Myrothecium leaf spot
(Myrothecium roridum 7RGH+SRFUHDHOV Stachybotryaceae)

Phyllachora leaf spot
(Phyllachora penniseti Syd.)

Bipolaris leaf spot
(Bipolaris setariae Sawada) (Pleosporales: Pleosporaceae)

Phyloplastica leaf blight
(Phyllosticta penicillariae) (Botryosphaeriales: Botryosphaeriaceae)

Pyricularia leaf spot
(Pyricularia grisea=Magnaporthe grisea=+) (Magnaporthales: Magnaporthaceae)
Other threats (continued)

**Rhizoctonia blight** (Rhizoctonia solani Kühn, Rhizoctonia zeae) & DQWKDUHOODOHV & HUDDREDVLGDLDFHDH

**Smut** (Moesziomyces penicillariae) (Schröt.) Vánky (Ustilaginales: Ustilaginaceae)

**Southern blight** (Sclerotium rolfsii = Athelia rolfsii X U J L. L PEU (Atheliales: Atheliaceae)

**Top rot** (Fusarium verticillioides = Fusarium moniliforme)

**Zonate leaf spot** (Gloeocercospora sorghi) (Sacc.) Nirenberg + SRFUHDOHV1HFWULDFHDH

**Seedling blight** (various fungi)

**Head mold** (various fungi)

**Striga or Purple Witchweed** ([Striga hermonthica] Orobancheae)

**IPM TECHNIQUES**

- Use clean seeds.
- Select insect/disease-resistant varieties.
- Treat seeds with Trichoderma/ Pseudomonas to protect them from soil-borne diseases.
- Set up pheromone traps for stem borers to monitor and to take up timely interventions.

- If pesticide applications are necessary, apply biopesticides e.g. Metarhizium anisopliae, Metarhizium rileyi, Beauveria bassiana, Bacillus thuringiensis, NPV (nuclear polyhedrosis viruses), nematode (Steinernema carpocapsae), and botanical insecticides (e.g. neem).

- Release of egg parasitoids, Trichogramma spp, Trichogrammatoida armigera and Telenomus spp and larval parasitoid Habrobracon hebetor for control of lepidopteran pests.

**FOR MORE INFORMATION**

The Feed the Future Innovation Lab IDU, QWHJUDWHG3HVWHDQDJHPHQW, 30/GHYHORSVXX VDLQDE0HDQG economical pest control methods to improve livelihoods for farmers worldwide. The program's work is based in seven countries and is engaged with scientists, extension agents, students, and farmers in the tropical and subtropical world.

7KH,30/LVIXQGHGE186$/HDG award number: AID-OAA-L-15-00001) and housed at Virginia Tech in Blacksburg, Virginia.

& RQWDFW

Anamika Sharma & Rangaswamy 0XQLDSSDOQ, 30, QORQY DWLRQ/DE & HQWHUIRU, QWHUQDWQLRDQOSVHVDUFE Education, and Development & $1" Virginia Tech 526 Prices Fork Road %ODFTENEXVUJ% _UPXQL #YWHGX ZZZFLUSHGWHGX,30, /

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