



Fig. 3 F. Scraping of leaf Fig. 3 G. Foliage damage Fig. 3 H. Whorl damage with excreta Fig. 3 I. Tassel damage Fig. 3 J. Ear damage

Integrated Pest Management Strategies

Sowing to six leaf stage

- Timely and uniform sowing over larger area.
- Ridge and furrow planting method to be followed.
- Application of recommended dosage of NPK as basal dose.
- Planting of 3-4 rows of napier grass/hybrid napier as trap crops.
- Intercropping of maize with legumes, viz., pigeonpea, cowpea, black gram, kidney bean etc. in 2: 1 to 4: 1 ratio.
- Erection of bird perches @ 10/acre to encourage natural FAW predation by birds.
- Installation of pheromone traps @ 4/acre soon after sowing and monitor moth catches.
- Adoption of clean cultivation to eliminate possible alternate hosts.
- Crushing of egg masses and larvae.
- Application of sand or soil mixed with lime in 9: 1 ratio into whorl of maize plants.
- First spray with 5% neem seed kernel extract (NSKE) or azadiractin, 1500 ppm (1 litre/acre) @ 5ml/litre after observation of one moth/trap/day or 5% FAW infestation on trap crop or main crop.
- If monitoring indicates more than one moth/trap/day release egg parasitoids, viz., *Telenomus remus* @ 4000/acre or *Trichogramma chilonis* @ 16,000/acre. Two releases of parasitoids at weekly interval should be done.
- At 5-10% infestation whorl application of *Bacillus thuringiensis v. Kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1 kg/acre) @ 5g/litre or SfNPV (600 ml/acre) @ 3ml/litre or entomopathogenic nematode (EPN-NBAIR H38) (4kg/acre) @ 20g/litre of water is recommended.
- If infestation is more than 10%, whorl application of any one of the recommended insecticides for FAW, viz., Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre; Spinetoram 11.7 % SC (100ml/acre) @ 0.5 ml/litre; Emamectin benzoate 5% SG (80g/acre) @ 0.4g/litre is recommended.

Seven leaf stage to flowering

- Monitoring of FAW using pheromone traps @ 4/acre should be continued
- Spray 5% NSKE or azadiractin, 1500 ppm (one litre/acre) @ 5 ml/l after observation of one moth/trap/day or 5% of fresh FAW infestation.
- If infestation is more than 10%, whorl application of *Bacillus thuringiensis v. Kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1 kg/acre) @ 5g/litre or SfNPV (600ml/acre) @ 3ml/litre or entomopathogenic nematode (EPN) (4kg/acre) @ 20g/litre of water is recommended.
- If infestation is more than 20%, whorl application of any one of the recommended insecticides for FAW, viz., Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre; Spinetoram 11.7 % SC (100ml/acre) @ 0.5 ml/litre; Emamectin benzoate 5% SG (80g/acre) @ 0.4g/litre is recommended.

Flowering to harvest

- Hand picking and destruction of larvae which bore into ears.

- Application of *Bacillus thuringiensis v. kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1kg/acre) @ 5g/litre or SfNPV (600ml/acre) @ 3ml/litre or entomopathogenic nematode (EPN) (4kg/acre) @ 20g/litre of water is recommended at 10% ear damage.

Caution upon release of egg parasitoids– Interval of minimum one week should be there between parasitoid release and application of neem or chemical insecticides.

4. Shoot fly [*Atherigona soccata* Rondani; *Atherigona naqvii* Steyskal; *Atherigona orientalis* (Schiner)] (Muscidae: Diptera)

The infestation of shoot fly, *Atherigona* spp. occurs in *spring* sown maize. Heavy plant loss is observed if sown during third week of February to first week of March. Hence, sowing within second week of February is advisable. Grain yield loss due to *A. soccata*, *A. orientalis*, *A. naqvii* is 21.28%, 20% and 27.93 - 45.04 %, respectively. Mild to moderate temperature (20-30°C) and high relative humidity favour multiplication of shoot fly.

Biology

Eggs of *A. soccata* (Fig. 4A) and *A. orientalis* are elongated like a small rice grain (1.3mm), milky white in colour with two wing-like projections and those of *A. naqvii* (Fig. 4B) are cylindrical with fine ridges on surface. The incubation period is 1-3 days. Larval period is 7-10 days with 3-4 instars. Full grown maggot is yellow in colour (Fig.4C). Pupation takes place inside the stem. The pupa is dark brown, barrel-shaped. The pupal period lasts for about a week. The adult (Fig. 4 D) lives for 3-4 days. The life cycle is completed within 3 weeks.



Fig.4A Egg of *A. soccata*



Fig. 4B. Egg of *A. naqvii*



Fig. 4C. Maggot



Fig. 4D. Adult fly

Nature of Damage/Symptoms

Atherigona spp. infests seedling stage of maize as it is the most vulnerable stage. Infestation starts from two days after germination. Its infestation can extend up to three weeks old crop, which is less vulnerable to the pest. Eggs are laid on the abaxial surface of basal leaves/ shoot/leaf sheath. Maggots bore into shoot while feeding gradually killing the growing point leading to withering of central shoot results in formation of dead heart, which is formed within two weeks of germination.

Management strategies

- Sowing must be completed by first fortnight of February.
- Seed treatment with imidacloprid 600 FS @ 6 ml/kg seed or Thiamethoxam 30 FS @ 8.0 ml per kg seed gives very good control of the insect. Treated seed should be used within 14 days of the treatment.
- Removal and destruction of dead hearts prevents further spread of the insect.

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Insect pests of maize and their management



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Maize (*Zea mays* L.) is the third most important cereal crop after rice and wheat being grown in tropical, sub tropical and temperate regions of the world. Even though the production of maize has increased from 1.73 mt (1950-51) to 31.51 mt, the productivity of maize (3.1 t/ha) is much lower than the world average (5.62 t/ha). Insect pests are one of the major factors responsible for low productivity. In the context of India the major insect pests of maize which cause economic damage are spotted stem borer [*Chilo partellus* (Swinhoe)], pink stem borer [*Sesamia inferens* Walker], shoot fly [*Atherigona* spp.] and a recent invasive pest, fall armyworm [*Spodoptera frugiperda* (J. E. Smith)]. These pests have been subjected to intensive studies due to their serious damage on maize production. The details on biology, nature of damage of potential insect pests and their management strategies including cultural and biorational measures have been outlined in this folder.

1. Spotted Stem borer [*Chilo partellus* (Swinhoe)] (Crambidae: Lepidoptera)

Spotted stem borer (*Chilo partellus*) is the most important insect pest during kharif/rainy season causing 26-80% yield losses in different agro-climatic regions of India.

Biology

Eggs are flat, oval, yellowish and are laid in overlapping clusters (Fig. 1 A). The larva is creamy pink to yellowish brown with 4 rows of dotted stripes along the back with reddish brown head. The larval period is completed in about 14-28 days. The pupal period varies from 7-10 days. Before pupation, the larva makes an exit hole in the stem and pupates inside the tunneled stem.

The forewing of adult female moth is brown-yellowish with darker scale patterns forming longitudinal stripes (Fig. 1 B). In male moths, hind wings are pale straw-colour, and in females, they are white. The life cycle is completed in about 5-6 weeks.

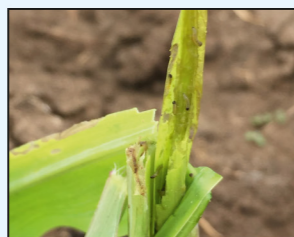
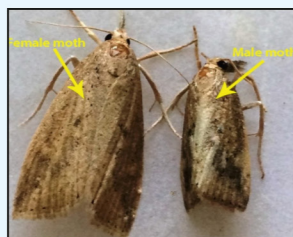


Fig. 1 A. *Chilo partellus* neonates hatching out from egg mass

Fig. 1 B. Female and male moths

Fig. 1 C. *Chilo partellus* larvae in leaf whorl

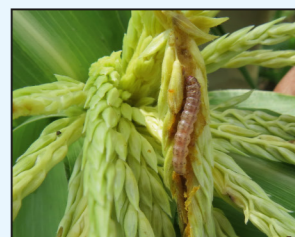


Fig. 1 D. Larva feeding on tassel

Fig. 1 E. Larva feeding on stalk

Nature of Damage/Symptoms

Female moth prefers 3-5 leaf stage maize for egg laying. The moth lay eggs preferably on lower surface of leaves. Eggs hatch in 3-4 days and the newly hatched larvae crawl inside the leaf whorl and feed in groups (Fig. 1 C). The larva also feed on tassel (Fig. 1D). Pin holes (Fig. 1F) and papery windows (Fig. 1G) are first symptoms of spotted stem borer attack. After a week onwards, larvae move out of whorl and bore upwards the developing stalk (Fig. 1 E). The leaf whorl dries resulting in 'dead heart' formation and often gives rise to tillers (Fig. 1 H).



Fig. 1 F. Pin holes



Fig. 1 G. Papery Windows



Fig. 1 H. Dead heart

Integrated Pest Management Strategies

- Destruction of the stubbles.
- Deep summer ploughing (not applicable to conservation agriculture).
- Planting of 2-3 rows of Napier grass as trap crop in field boundary.
- Inter-crop maize with cowpea in 2:1 ratio.
- Two releases of *Trichogramma chilonis* 8 cards/ha (1,50,000 parasitized eggs/ha) at 7 and 15 days after germination.
- Removal and destruction of dead hearts.
- Spraying of Chlorantraniliprole 18.5 SC @150ml/ha immediately when infestation reaches 10% of plants, i.e. 10% of plants show visible leaf feeding damage.

2. Pink stem borer, *Sesamia inferens* Walker (Noctuidae: Lepidoptera)

Pink stem borer (PSB) is the most important pest of rabi/winter maize distributed in almost all parts of India causing yield losses in the range of 25.7-78.9%. Mild winters and high relative humidity favours the multiplication of PSB.

Biology

Eggs are creamy white in colour, laid in bead-like pattern in 2-4 longitudinal rows inside the sheath of 1-2 lower leaves of young plants (Fig. 2 A). Egg laying is preferred at early stages of crop growth. Larva is light pink in color with a purplish tinge (Fig. 2 B). The larval period varies from 22-36 days depending on ambient temperature. Pupa is smooth, stout, ashy brown in colour with a tinge of purple on the head region (Fig. 2 C). Adult is medium sized, stout straw coloured moth with three coppery tinged shining scales with brown streaks. Forewings have three small black dots on the dorsal side and an intermediate brown strip. Hind wings are white in colour. Males are smaller than females. In males the antennae are pectinate while filiform in female moths (Fig. 2 D). The total life cycle takes from 40-53 days depending on prevailing temperature.

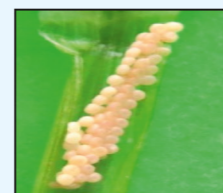


Fig. 2 A. Egg mass



Fig. 2 B. Larva

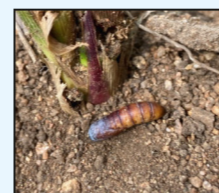


Fig. 2 C. Pupa



Fig. 2 D. Female and Male Moths

Nature of Damage/Symptoms

After hatching, pink stem borer larvae feed inside the leaf sheath in groups and feed on the epidermal layer of the leaf sheath preferably on first three leaf sheaths. Pin holes are the initial symptoms (Fig. 2 E) and later elongated oval holes appear on leaves (Fig. 2 F). The larva bores into the central shoot as a result, growing point dries up resulting in formation of dead heart in young plants (Fig. 2 G). The larva feed in groups (Fig. 2 H) forms circular shaped tunnels inside the stem and exit holes at the surface. Due to larval feeding, circular ring like cuts occur on lower inter nodes.



Fig. 2 E. Initial symptom



Fig. 2 F. Elongated oval holes on leaf

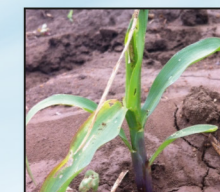


Fig. 2 G. Dead heart

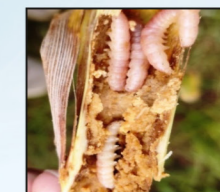


Fig. 2 H. Pink stem borer larvae in stalk tunnel

Management Strategies

- Collection and destruction of the stubbles.
- Deep summer ploughing (not applicable to conservation agriculture).
- Removal and destruction of dead hearts.
- Spraying of chlorantraniliprole 18.5 SC @150ml/ha when infestation crosses 10%, i.e. 10% of plants show visible leaf feeding damage towards stem of the plant.

3. Fall Armyworm [*Spodoptera frugiperda* (J. E. Smith)] (Noctuidae: Lepidoptera)

Fall armyworm (FAW) is an invasive insect pest causing serious damage to maize at all stages of its growth. It was first reported in India in May, 2018. Yield losses of about 73% have been reported due to fall armyworm infestation. Foliage feeding is often concentrated in the whorl of the plant. Infested plants show ragged appearance with abundant faecal matter on the leaves. Warm and humid conditions are favourable for multiplication of FAW.

Biology

Each egg mass contains 100-200 eggs in two to four layers (Fig. 3 A). The larvae are smooth-skinned, vary in colour from light tan or green to dull grey body with three creamy yellow dorsal and lateral lines. The larva contains reddish brown head with predominant white, inverted Y-shaped suture between the eyes. The larval stage contains 6 instars and larval period varies from 15-18 days depending upon prevailing temperature. On 8th and 9th abdominal segment at dorsal side, four large spots are arranged in a square shape on segment 8 and in trapezoid pattern on segment 9 (Fig. 3 B). Pupa is reddish brown in color. After 7-9 days, adults emerge from pupae (Fig. 3 C). The forewing of male moth consists of fawn coloured spot and a white patch at the apical margin of the wing (Fig. 3 D). Female moths are less distinctly marked ranging from uniform grayish brown to a fine mottling of grey and brown (Fig. 3 E). The total lifecycle completes in about 30-35 days which vary according to climatic conditions. The adult moth in a life span of 4-5 days can fly up to 500 km before oviposition.



Fig. 3 A. Egg mass



Fig. 3 B. Larva



Fig. 3 C. Pupa

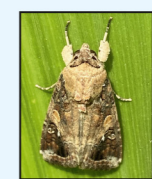


Fig. 3 D. Male moth



Fig. 3 E. Female moth

Nature of Damage/Symptoms

Early instars feed in and around the whorl by scraping and skeletonizing the upper epidermis of leaves leaving a silvery transparent membrane resulting into papery spots (Fig. 3 F). The damage results in pinhole symptoms on the leaves. The dispersal of early instar larva occurs by suspending in its silk known as ballooning. Later instars remain and feed inside the whorl. The damages by late instars (4th instar onwards) result in extensive defoliation of leaves and presence of large amounts of faecal pellets in the plant whorl (Fig. 3G, H). During reproductive stage the larvae damage tassels (Fig. 3 I) or may bore inside the corn ear and feed on kernels (Fig. 3 J), making control very difficult.