Training Manual for Training of Trainers Recognition and Management of Major Insect Pests of Large Cereals (maize and sorghum) and Beans

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Major insect pests of large cereals (maize and sorghum) and beans

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Large cereals (Maize and sorgum)

A large number of insect pests attack maize and sorgum both in the field and storage. Of these the recently introduced invasive fall armyworm (*Spodoptera frugiperda*), the maize stem borer (*Busseola fusca*) and the spotted stem borer (*Chilo partellus*) in the field and the maize weevils, *Sitophilus zeamais* and *Sitotroga cerealella*, in store constitute the major insect pest problems.

Fall armyworm

The fall armyworm (FAW; *Spodoptera frugiperda* (JE Smith); Lepidoptera, Noctuidae) is recently introduced invasive insect of maize and several species of plants. It is native to Americas and was first reported as present on the African continent in January 2016. Subsequent investigations have revealed the pest in nearly all of sub-Saharan Africa (SSA), where it is causing extensive damage, especially to maize fields and to a lesser degree sorghum and other crops.

The presence of FAW in Ethiopia was reported on 1st March 2017 from Southern Nation, Nationalities and Peoples' Regional State (SNNPR). Currently it has spread and conquered all regions of the country and reported in 417 districts from across the country. The speed with which it conquers the country highlights its adaptability, invasiveness and probably superior competitive ability over indigenous species. Out of 2.1 million ha of land currently under maize cultivation in Ethiopia 22.23% (650,000 ha**)** of the total maize planted has been infested with FAW. In general, without use of control options, the potential impact of FAW on the country wide maize yield lies between 1.23 and 3.1 million tons per year of total expected production of 7 million tons per year and with losses lying between US$ 292.6 and US$728.3 million per year of total expected value of US$ 1,580.2 million per year.

FAW Description and Life Cycle

The FAW life cycle is completed in about 30 days (at a daily temperature of ~28°C) during the warm summer months but may extend to 60-90 days in cooler temperatures. FAW does not have the ability to diapause (a biological resting period); accordingly, FAW infestations occur continuously throughout the year where the pest is endemic.

Egg Stage

The egg is dome shaped: the base is flattened and the egg curves upward to a broadly rounded point at the apex. The egg measures about 0.4 mm in diameter and 0.3 mm in height. The number of eggs per mass varies considerably but is often 100 to 200, and total egg production per female averages about 1,500 with a maximum of over 2,000. The eggs are sometimes deposited in layers, but most eggs are spread over a single layer attached to foliage. The female also deposits a layer of grayish scales between the eggs and over the egg mass. Duration of the egg stage is only 2 to 3 days during the warm summer months.

Larval stage

The FAW typically has six larval instars. Young larvae are greenish with a black head. The head turns a more orange color in the second instar. Head capsule widths range from about 0.3 mm (instar 1) to 2.6 mm (instar 6), and larvae attain lengths of about 1 mm (instar 1) to 45 mm (instar 6). In the second instar, but particularly the third instar, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. In the fourth to sixth instars the head is reddish brown, mottled with white, and the brownish body bears white subdorsal and lateral lines.

Elevated spots occur dorsally on the body; they are usually dark in color and bear spines. The face of the mature larva may also be marked with a white inverted "Y" and the epidermis of the larva is rough or granular in texture when examined closely. The best identifying feature of the FAW is a set of four large spots that form a square on the upper surface of the last segment of its body. Larvae tend to conceal themselves during the brightest time of the day. Duration of the larval stage tends to be about 14 days during the warm summer months and 30 days during cooler weather.

Pupal Stage

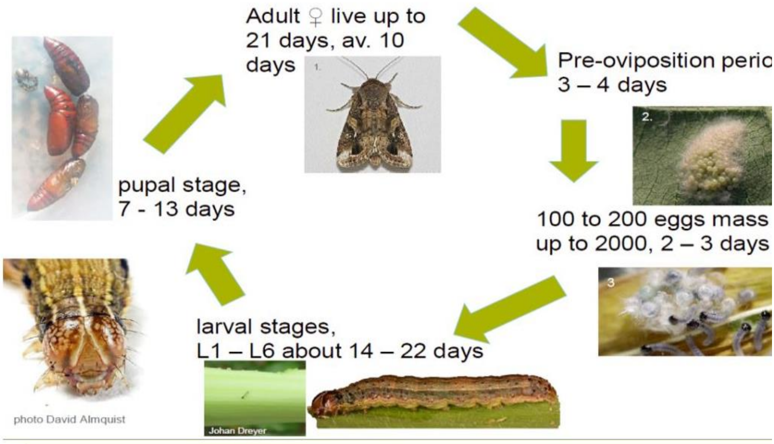
The FAW normally pupates in the soil at a depth 2 to 8 cm. The larva constructs a loose cocoon by tying together particles of soil with silk. The cocoon is oval in shape and 20 to 30 mm in length. If the soil is too hard, larvae may web together leaf debris and other material to form a cocoon on the soil surface. The pupa is reddish brown in color, measuring 14 to 18 mm in length and about 4.5 mm in width. Duration of the pupal stage is about 8 to 9 days during the summer, but reaches 20 to 30 days during cooler weather.

Adult Stage

Adult FAW moths have a wingspan of 32 to 40 mm. In the male moth, the forewing generally is

shaded gray and brown, with triangular white spots at the tip and near the center of the wing. The forewings of females are less distinctly marked, ranging from a uniform grayish brown to a fine mottling of gray and brown. The hind wing is iridescent silver-white with a narrow dark border in both sexes. Adults are nocturnal, and are most active during warm, humid evenings. After a preoviposition period of 3 to 4 days, the female moth normally deposits most of her eggs during the first 4 to 5 days of life, but some oviposition occurs for up to 3 weeks. Duration of adult life is estimated to average about 10 days, with a range of about 7-21 days.

A. Egg mass placed on stem (left) or leaf (right) at early stage of maize
B. Egg mass (left) and larvae hatching three days after oviposition (right)
C. Blackheaded larvae emerging out of egg mass
D. Larval growth stages (1 mm to 45 mm)
E. Distinguishing marks on medium to large-sized larvae
F. Reddish-brown pupa
G. Male moth with conspicuous white spot on tip of forewing



Life cycle of fall armyworm

Host Range

The FAW has a very wide host range, with over 80 plants recorded, but clearly prefers grasses.

The most frequently consumed plants are field maize and sweet maize, sorghum, Bermuda grass,

and grass weeds. When the larvae are very numerous they defoliate the preferred plants, acquire the typical "armyworm" habit, and disperse in large numbers, consuming nearly all vegetation in their path.

Damage

Larvae cause damage by consuming foliage. Young larvae initially consume leaf tissue from one side, leaving the opposite epidermal layer intact. By the second or third instar, larvae begin to make holes in leaves, and eat from the edge of the leaves inward. Feeding in the whorl of corn often produces a characteristic row of perforations in the leaves. Larval densities are usually reduced to one to two per plant when larvae feed in close proximity to one another, due to cannibalistic behavior. Older larvae cause extensive defoliation, often leaving only the ribs and stalks of corn plants, or a ragged, torn appearance. Window panes, “shot holes”, elongated ragged holes, whorl plugged with frass, injury to developing tassel, bored cob husks from side, cob husk leaves chewed upon, feeding on developing grains in cob are damage symptoms FAW exhibit on maize

Fall armyworm damage on various stages of maize

Management

Integrated Pest Management (IPM) which involves the use of agronomic practices to prevent occurrence or buildup of FAW population, biological control and the use of chemicals is crucial in the management of Fall armyworm. Scouting the field to determine the population of caterpillars and to assess plant damage is the most vital step in any IPM programme. Scouting must be done daily as soon as the plants have emerged from the soil. The different methods are highlighted below for 2 weeks and thereafter at least twice per week. The different methods are highlighted below.

Scouting

To detect presence of FAW moth, installing one pheromone trap per ha is necessary. When scouting the field for FAW damage, it is advisable to avoid the border rows by walking into the field about 5 meters. The scout then zigzags the field, stopping at 5 different locations. At each of these locations the scout assesses 10-20 plants looking for signs of FAW feeding. The percentage of damaged plants is recorded and the scout moves to the next check point. After assessing 5 locations in the field, the scout determines the percentage of damaged plants for the field. Action threshold for small holder farmers under African condition is 20% (10-30%) at early whorl stage and 40 (30-50%) at late whorl stage. Unless it is a low toxic product and supportive of biological control, pesticide application at tassel and silk stages is not recommended

Agronomic practices/Prevention

Avoid late or offseason planting.

Plant tolerant maize varieties (e.g. with hard husk cover to prevent the pest from penetrating)

Regularly weed to remove alternate hosts

Plough after infested fields are harvested

Ensure optimum use of fertilizer for strong maize plants able to compensate for damage done

Avoid planting new crop near infested fields

Do not move infested maize materials from one area to another; instead feed to livestock

Applying sand sawdust or soil in the whorl (with ash/lime)

Intercropping of maize with non-host crops like sun flower and bean

Use hands to squash the caterpillars or collect and drop caterpillars in hot water to drown them. Best picking time is early morning between 6:00 to 8:00 am and in the evening between 5:00 to 6:00 pm (when they still feed on leaves before they hid in whorls)

Chemical control

There are no registered insecticides for FAW control in Ethiopia to date. However, the insecticides Tracer (Spinosad), Coragen (Chlorantraniprole) and

Avaunt (Indoxcarb) have been found effective in controlling FAW in Ethiopia and other African countries. These insecticides are registered in Ethiopia for the control of other insect pests. For example, for the control of the tomato leaf miner, *Tuta absoluta*, on tomato. Other insecticides used for the control of Fall armyworm elsewhere include the pyrethroid insecticides cypermethrin, deltamethrin, lambda-cyhalothrin, the organophosphates Chlropyrifos, profenofos, etc. The use of broad-spectrum insecticide should be discouraged as much as possible because of their negative impacts on naturally occurring biological control agents.

Biological control

Numerous parasitic wasps, natural predators, and pathogens help to control the population of fall armyworms. The egg parasitoid *Telenomus remus* is frequently introduced to effectively control fall armyworm and other *Spodoptera* species. Natural levels of larval parasitism are often very high (20-70%). In Ethiopia, the braconid parsitoids Cotesia icipe and *Coccygidium luteum* with parasitism level ranging between 4.6 and 45.3% and a tachinid parasitoid *Palexorista zonata* with parasitism level ranging between 5.7 to 6.4 were found associated with FAW.

stem borers

The maize stem borer (*Busseola fusca*)

The African maize stalk borer is indigenous to and occurs throughout mainland sub-Saharan Africa. Maize and sorghum are its main crop hosts. The larval stage (caterpillars) cause damage to maize by feeding on young leaves from where they can enter the stems. This may kill the plant. In older plants their feeding can damage can reduce grain production.

Life history

Adult African maize stalk borer moths lay eggs in a row between the stem and leafs heath. Each female lays on average about 200 eggs over its short lifetime which lasts several days – its exact duration depends on temperature and other factors. Egg laying on maize is usually concentrated on plants that are less than 2 months old with the leaf sheath of the youngest unfolded leaf being the most attractive part of the leaves for females. The eggs hatch in 3-5 days and larvae move into the leaf whorls to feed. When older (third instar), they tunnel into the stems where they feed for 3-5 weeks before pupating within the tunnels that they have produced in the stems. The adult moth will emerge after a pupal period of 7-14 days from a hole that they produced before pupation. Adults mate soon after emergence. Under favourable conditions the life cycle can be completed in 7-8 weeks but during dry and/or cold weather the larvae can enter a period of suspended development (diapause) of 6 months or more in stems and other plant residues.

Eggs

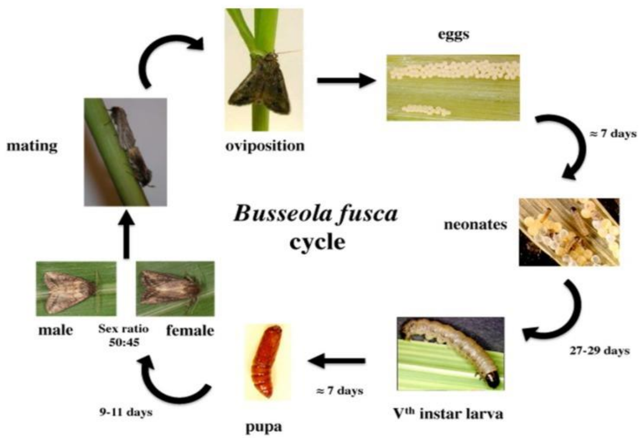
Eggs are creamy-white when laid but darken just before emergence. They are about 0.8-1mm in diameter. They are usually laid in batches of 30-100 under leaf sheaths.

Larvae

The larvae (caterpillars) lack conspicuous hairs or markings. They are usually creamy-white, in colour, often with a distinctive grey tinge but sometimes with a pink suffusion, which may cause them to be confused with the larvae of *Sesamia Calamistis* (the pink maize borer). The head capsule is dark brown and the prothorax is yellowish-brown. The caterpillars have prolegs along the abdomen.

Adults

The adult wing-span is 25-35 mm. Its forewings are light to dark brown with darker markings. The hind wings are white to grey-brown.



Life cycle of *Busseola fusca*

Host range

Primary hosts are crops particularly maize, and sorghum. Secondary crop hosts are pearl millet, finger millet and sugarcane. Wild hosts include many species of wild grasses such as: wild Sudan grass (*Sorghum verticilliflorum*), elephant grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*), Johnson grass (*Sorghum halepense*), *Hyparrhenia rufa* and *Rottboellia exaltata* .

Damage symptoms

First-instar larvae feed in the young terminal leaf whorls producing characteristic patterns of small holes and 'window-panes' (patches of transparent leaf epidermis) where tissues have been eaten away. Later they eat into the growing points, which may be killed so that the dead central leaves form characteristic dry, withered 'dead-hearts'. Older larvae tunnel extensively in stems, eating out long frass-filled galleries which may weaken stems and cause breakages. Larvae also tunnel into maize cobs and into the peduncles of sorghum and millet inflorescences and may seriously affect grain production.



Damage symptoms on the leaves of maize due to Maize stalk borer (left and central) and larvae tunneling inside maize stalk (right)

Management

Similar to the management of FAW, an IPM approach involving cultural, biological and chemical control is crucial.

Cultural practices

Intercropping maize with non-hosts crops like legumes (cowpea, beans) can reduce African maize stalk borer damage. Alternatively, maize can be intercropped with a repellent plant such as silver leaf desmodium

(*Desmodium uncinatum*) and a trap plant, such as Napier grass (*Pennisetum purpureum*), molasses grass (*Melinis minutiflora*) as a border crop around this intercrop to protect maize from stem borers. The trap plant draws the adult female away from the crop. More eggs are laid on the trap plant than on the crop but the larvae develop poorly or not at all on the trap plant. This practice is known as "push-pull".

Good crop hygiene through the destruction of maize residues by burning to get rid of the larvae and pupae within the stems, and removal of volunteer crop plants and/or alternative hosts, prevents carry-over populations. This helps in limiting the initial establishment of stem borers that would infest the next crop. Early slashing of maize stubble and laying it out on the ground where the sun's heat destroys the larvae and pupae within can also be utilised.

Biological-control

Many natural enemies of the African maize stalk borer have been reported but their impact is variable across regions, seasons and crops. Two of the most abundant natural enemies of the African maize stalk borer are the larval parasitoids *Cotesia sesamiae* and *Bracon sesamiae*. They locate the stem borers while the stem borers are feeding inside the plant stems lay eggs into them. Upon hatching the larvae of the parasitic wasp feed internally in the stem borer, kill it and then exit to spin cocoons. The ability of indigenous natural enemies to control this species is too low to prevent significant damage to maize. However, they can help control to reduce densities of the African maize stalk borer as part of an integrated pest management (IPM) approach that includes habitat management practices that conserve parasitoids and predators like ants and earwigs.

Chemical control

Chemical control can be achieved by applications of granules or dusts to the leaf whorl early in crop growth to kill early larval instars. This method has limited effectiveness once the larvae bore into the stem. Neem products (powder from ground neem seeds) are reportedly effective and may be applied to the leaf whorl in a 1:1 mixture with dry clay or sawdust. Use only pesticides registered for the control of the pest. List of pesticides registered for the control of this pest can b obtained from the Crop Protection directorate of the Ministry of Agriculture and livestock.

The spotted stem borer, *Chilo partellus*

The spotted stemborer is native to Asia and became established in Africa in the 1950s. It occurs at low to medium altitudes. The spotted stemborer attacks several grass species, both wild and cultivated (including maize, sorghum, pearl millet and rice). The larvae (caterpillars) eat through leaves when young and as they grow older, eventually bore into the stem causing it to break or die.

Life cycle

Eggs are laid in batches on leaf surfaces, usually close to the midrib. They hatch after 4-10 days.

Young caterpillars initially feed in the leaf whorl. Older caterpillars tunnel into stems, eating out extensive galleries, within which they feed and grow for 2-3 weeks. When larvae are fully grown, they pupate and remain inside the maize stem. After 7-14 days adults emerge from pupae and come out of the stem. They mate and lay eggs on maize plants again and continue damaging the crop. During the dry season, larvae may enter a state of suspended development (diapause) for several months and will only pupate with the onset of rains. Adults emerge from pupae in the late afternoon or early evening. They are active at night and rest on plants and plant debris during the day. They are rarely seen, during the day unless they are disturbed.

The whole life cycle takes about 3-4 weeks, varying according to temperature and other factors. Five or more successive generations may develop in favourable conditions. In regions where there is sufficient water and an abundance of host plants, the spotted stemborer can reproduce and develop all year-round.

Eggs

Are flat and oval (scale-like), creamy-white, about 0.8mm long, laid in overlapping batches of 10-80 eggs on the upper and underside leaf surfaces, mainly near the midribs.

Larvae

Spotted stem borer larvae (caterpillars) are creamy-white to yellowish-brown in colour, with four purple-brown longitudinal stripes and usually with very conspicuous dark-brown spots along the back, which give the larvae spotted appearance (hence the common name). When fully grown the larva has a prominent reddish-brown head. It has a prothoracic shield (a plate on the dorsal surface of the thorax) which is reddish-brown to dark-brown and shiny.

Pupae
Are up to 15 mm long, slender, shiny and light yellow-brown to dark red-brown in colour.

Adults
Are relatively small moths with wing lengths ranging from 7-17 mm and a wingspan of 20-25 mm. Forewings are brown-yellowish with darker scale patterns forming longitudinal stripes. In males, hind wings are a pale straw-colour, and in females, they are white.

Different life stages of spotted stem borer, *Chilo partellus*

Related species
In external appearance the spotted stemborer (*Chilo partellus*) resembles many other species of *Chilo* but can be distinguished from them by diagnostic characters of the male and female genitalia, which may require taxonomic expertise. In East Africa, it may be confused with the coastal stemborer (*Chilo orichalcociliellus*).

Host range
The spotted stemborer attacks several grass species, both cultivated and wild. Cultivated crop hosts include maize, sorghum, pearl millet, rice and sugarcane. Wild hosts include many species of wild grasses such as: elephant grass (*Pennisetum purpureum),* reeds *(Phragmites* species) and vossia (*Vossia cuspidate*).

Damage symptoms
Damage occurs as a series of small holes in lines (pin holes) in younger leaves and/or patches of transparent leaf epidermis (window panes) in older leaves. Holes in stem caused by larvae tunnelling into the stem can result in broken stems or drying and eventual death of the growing point of the maize (dead heart). Vegetative stage or before harvest. Younger plants less than two months old are more often attacked than older plants. Feeding by younger larvae takes place in leaf whorls. Older larvae tunnel into the stem, and may also eat into

the cob in older plants. Yield losses are variable across regions, seasons, plant species and varieties and management regime on farms. Yield losses may exceed 20% on maize and 50% on sorghum.


Early damage to maize by *Chilo partellus*

Pest Management

Similar to the management of FAW, an IPM approach involving cultural, biological and chemical control is crucial.

Cultural practices

Intercropping maize with non-hosts crops like cassava or legumes like cowpea can reduce spotted stemborer damage. Alternatively, maize can be intercropped with a repellent plant such as silver leaf desmodium (*Desmodium uncinatum*) and a trap plant, such as Napier grass (*Pennisetum purpureum*), molasses grass (*Melinis minutiflora*) as a border crop around this intercrop to protect maize from stemborers. The trap plant draws the adult female away from the crop. More eggs are laid on the trap plant than on the crop but the larvae develop poorly or not at all on the trap plant. This practice is known as "push-pull".

Good crop hygiene through the destruction of maize residues by burning to get rid of the larvae and pupae within the stems, and removal of volunteer crop plants and/or alternative hosts, prevents carry-over populations. This helps in limiting the initial establishment of stemborers that would infest the next crop. Early slashing of maize stubble and laying it out on the ground where the sun's heat destroys the larvae and pupae within can also be utilised.

Biological control

Biological control by two parasitic wasps, *Cotesia flavipes* and *Xanthopimpla stemmator*, that attack the spotted stemborer, has shown good results. *Cotesia flavipes* locates the stemborers while they are feeding inside the plant stems. The wasp lays about 40 eggs into a stemborer. Upon hatching the larvae of the parasitic wasp feed internally in the stemborer, and then exits and spin cocoons. *Xanthopimpla stemmator* operates similarly but attacks the pupae. Habitat management practices that conserve these parasitoids and predators like ants and earwigs can help in the control of the spotted stem borer.

Chemical control

Chemical control can be achieved by applications of granules or dusts to the leaf whorl early in crop growth to kill early larval instars. This method has limited effectiveness once the larvae bore into the stem. Neem products (powder from ground neem seeds) are reportedly effective and may be applied to the leaf whorl in a 1:1 mixture with dry clay or sawdust. Pesticides are poisons so it is essential to follow all safety precautions on labels.

Stored insect pests

A large number of insect pests attack sorghum and maize in the store. Of these the maize weevils, *Sitophilus zeamais* and *Sitotroga cerealella*, are regarded most important in Ethiopia.

Maize weevil (*Sitophilus zeamais*)

The maize weevil is a pest of stored maize, sorghum, wheat and others. Both adults and larvae feed on internally on maize grains and an infestation can start in the field (when the cob is still on the plant) but most damage occurs in storage. The origin of the maize weevil is not known but now it is found in all warm and tropical parts of the world.

Description

Adult maize weevils are 3 – 3.5 mm long, dark brown – black in colour and shiny and pitted with numerous punctures. The punctures on the thorax are in an irregular pattern while those on the elytra (wing cases) are in lines. The elytra also usually have four pale reddish-brown or orange-brown oval markings. The maize weevil has the characteristic rostrum (snout or beak) and elbowed antennae of the family Curculionidae (weevil family). The antennae have eight segments and are often carried in an extended position when the insect is walking. The larvae of maize weevils are white, fleshy and legless.

Figure: The maize weevil

Life cycle

Females chew into maize grains where they lay their eggs throughout most of their adult life of up to one year, although 50% of their eggs may be laid in the first 4-5 weeks. Each female may lay up to 150 eggs in her lifetime. Development time ranges from about 35 days under optimal conditions to over 110 days in unfavourable conditions. Eggs, larval and pupal stages are all found within tunnels and chambers bored in the grain and are thus not normally seen. Because larval stages feed on the internal parts of the grain, it is difficult to detect infestations early. Adults emerge from the grain and can be seen walking over the grain surfaces. Adult emergence holes are large with irregular edges. Females release a sex pheromone which attracts males.

Damage symptoms

The pest causes hollowing of whole previously undamaged grains. In severe infestations only, the grain hull is left along with powdery white frass (insect waste). The large emergence holes with irregular edges are characteristic. Grains which float in water often indicate larval damage.

The maize damaged by the maize weevil

Management

Cultural practices

The severity of a maize weevil infestation can be reduced by good store hygiene: cleaning the store between harvests, removing and burning infested residues, fumigating the store to eliminate residual infestations and the selection of only uninfested material for storage. Harvesting the maize as soon as possible after it has reached maturity will reduce the chances of attack by maize weevil and other storage pests. The use of resistant cultivars may also reduce the severity of an infestation.

Physical control

The removal of adult insects from the grain by sieving can reduce populations but this is very labor-intensive. The addition of inert dusts such as ash and clay to the grain can reduce insect numbers by causing the insects to die from desiccation.

Biological pest control

There have been various studies on biological control agents for the maize weevil. Various parasitoids (*Anisopteromalus calandrae*, *Cephalonomia tarsalis*, *Lariophagus distinguendus* and *Theocolax elegans*) could be effective if introduced early in the storage period. The fungus *Beauveria* *bassiana* can be used as a biological insecticide to control maize weevil in stored maize. The bacterium *Bacillus thuringiensis* can be used on adults.

Controlled atmosphere

Use of hermetic silo/ Where suitable infrastructure exists, low oxygen and carbon dioxide-enriched atmospheres can be used to control stored product pests.

Freezing and Heating

Where the infrastructure exists, freezing for several days and heating for 24 hours have proved to be effective control methods for stored product pests.

Chemical control

Maize weevil populations build up the longer the maize is kept in store so it is important to inspect the stock regularly. If the pest is found then some form of treatment will be required. Use only registered insecticides if chemical control is needed. The list of registered insecticides can be obtained from the Crop Protection directorate of the Ministry of Agriculture and Livestock.

Angoumois grain moth (*Sitotroga cereallela*)

The grain moth is found throughout the warmer parts of the world. It is a pest of stored maize and a very broad range of other stored products. The grain moth has a very broad host range. The larvae (caterpillars) feed internally on maize grains

Description

The adult grain moth is small (5-7 mm long with its wings folded) with a wingspan of 10-20 mm. The head,,thorax and thin and thread-like (filiform) antennae are pale brown. The forewings are elongate, pale brown/golden yellow with a few blackish tinges. The hind wings are light greyish-brown with long lashes along the edges. The abdomen is brown. Its eggs which are oval but flattened at one end are white when laid but they quickly change to a reddish colour. The larva completes its development within a single grain so is rarely seen. Its body is yellowish-white and its small head, which is retracted into its body, is yellowish-brown. The pupa is reddish-brown.

Adult Angoumois grain moth

Life cycle

The adult lives for up to 15 days during which the female may lay up to 200 eggs although 40 is a more average number. The eggs are laid singly or in clumps of variable numbers. The newly emerged larvae bore into the grain where they will complete their development. The rate of development is dependent on temperature, humidity and the host. At 25°C and a relative humidity of 70% larvae take about 30 days to develop in maize. The pupal stage lasts about 10 days but can be as quick as 5 days. The newly emerged adult pushes through the window of the seed coat, leaving a small, but characteristic, round hole, usually in the crown end of the grain. Adults are strong fliers and can disperse easily. However, they are not strong and are can only infest the outermost layers of stored grain if it is closely packed.

Damage symptoms

Damage is initially difficult to detect as the larvae complete their development within a single grain. The larva or caterpillar produces a visible ‘window’ just below the surface of the grain when it constructs the chamber in which it pupates. Flour dust from internal feeding can spill from the grain once the grain moth has emerged.

Damage symptoms on maize infested by Angoumois grain moth

Management

The management pointed out for Maize weevil ia applicable for Angoumois grain moth.

Beans

Beans (*Phaseolus vulgaris*) are attacked by a large number of insect pests both in the field and storage. Field insect pests of beans include the stem mining and girdling Bean stem maggots (*Ophiomyia* spp.,Diptera: Agromyzidae) , the defoliators foliage beetles (*Ootheca* sp. , Coleoptera: Chrysomelidae), pod borers (*Helicoverpa armigera* , Lepidoptera: Noctuidae, *Maruca testulalis*, Lepidoptera: Pyralidae), the sup suckers Aphids (*Aphis fabae*, Homoptera: Aphididae) and flower thrips (Thysanoptera: Thripidae). Stored beans suffer heavy losses in terms of both quality and quantity, and these loses are caused mostly by bean bruchids (Coleoptera: Bruchidae). About half a dozen species of bruchids attack beans. Of these *Acanthoscelides obtectus* and *Zabrotes subfasciatus* are the most important. Bean stem maggots in standing beans and bruchids in storage are important insect pests of beans in Ethiopia.

Bean stem maggots (Bean flies)

Bean stem maggots, also called bean flies, are serious pests of all types of beans, especially common beans. A bean fly is tiny, only about half the size of a housefly, and is shiny metallic black. Its larvae feed into and through the leaves. They feed and tunnel down towards the stem and stem base. They attack beans that have 2 to 3 leaves. Leaves of damaged plants become yellow, and drop. There are also swellings and ruptures of the stem near the ground. Because of stem destruction, plants are often stunted, wilt and die which can cause up to 90% loss. Three species of Bean stem maggots are known to occur in Ethiopia and Africa. These are *Ophiomyia phaseeoli*, *Ophiomyia spencerella* , and *Ophiomyia centrosematis.* Of these the first two species are most important but *O. centrosematis* occurs rarely and in small number.

Biology

Bean flies mostly occur during the dry season. They lay eggs on the base of both the upper and underside of young leaves on young plants. They can lay up to 70 eggs in their 1-week lifetime. Eggs are white, white and about 1 mm long. They are laid singly on the different parts of the seedling. Each female can lay approximately 100 eggs in her lifetime. Incubation takes 2-4 days, depending on temperature. On hatching the small white maggots, mine in the leaf and then bore into the stem, which produces cracks near soil level. The larvae pass through three instars over a period of 6-14 days. The mature larvae pupate mostly in the stem and sometimes in petioles or in the soil. The puparia are barrel-shaped and about 3 mm long. The pupal period lasts about 7 days, after which the shiny black adult flies, measuring approximately 2 m, emerge. Mating takes place 2-6 days after emergence, and egg laying begins 2-4 days after mating. Depending on the temperature the life cycle is completed in 20 to 30 days. Thus 4 - 6 generations can develop in one bean growing season. At the end of the season, larvae and pupae remain in the plant stems and roots of beans and other legumes. Some move into the soil and survive until the next bean cropping season.

Damage symptoms

Larvae damage seedlings by feeding on the stem, which results in characteristic swelling and cracking just above ground level. Damaged plants become yellowish, wilted (signs often confused with symptoms of moisture stress or root disease), and stunted and may eventually die unless they form adventitious (secondary) roots. Bean stem maggots feed at the base of stems, which blocks the movement of water and nutrients from the roots to the upper parts of the plant. This can cause wilting and death of plants.

The bean fly (left), Bean stem maggot (center) and pupae (right) in stem base of beans

Loss of plant resulting very low plant population due to seedlings damage by BSM

Management

An IPM approach involving Host plant resistance cultural, biological and Chemical control mainly dressing seeds with registered pesticides are practiced to minimize Bean stem maggot damage on beans.

Cultural control

- Practice post-harvest ploughing, 15 - 20 cm deep, then harrow the soil with a tractor to facilitate the following: to bury the larvae, pupae and adults that are living in the remaining bean plants, bean residues, and re-growing volunteer bean plants after harvest. When buried deeply, they cannot survive; to expose larvae and pupae onto the soil surface to be killed by the sun and eaten by birds
- Remove infested bean residues after harvest and feed to livestock
- Use high plant population (40, 000 plants per ha)

Host plant resistance
Bean varieties susceptibility to BSM damage vary. Resistance sources have been identified at Melkassa. The bean varieties 'Melko' and 'Beshbesh' have been registered in Ethiopia for use in as an integral component of Integrated Pest Management (IPM).

Chemical control
Use only pesticides registered for the control of the pest. List of pesticides registered for the control of this pest can be obtained from the Crop Protection directorate of the Ministry of Agriculture and livestock.

Bruchids
Major insect pests responsible for reduction in both quantity and quality in stored beans are bruchids (the bean weevils).

Biology
The two major species, *Acanthoscelides obtectus* and *Zabrotes subfasciatus* have similar biologies. After hatching from the eggs, the first-instar larvae penetrate the seed coat, form a cell, and proceed to develop inside the seed. They pass through four instars before pupation. Feeding by the last instar produces the characteristic circular 'windows' that become visible externally as insect development progresses. The newly formed adults may remain in the cell for several days before pushing out the window and exiting the seed. Mating occurs immediately, and egg laying follows. The life cycles of *A.obtectus* and *Z. subfasciatus* are completed in about 28 and 24 days, rspectiveley. Adult longevities for *A. obtectus* and *Z. subfasciatus* are 28 and 24 days, respectively. The adult female of *A. obtectus* lays an average of 60 eggs, and a Z. *subfasciatusfemale lay about 35 eggs in her lifetime.* Adult bruchids do not feed; only the larvae cause damage. The behavior and characteristics of the two species differ in the following ways
a. The eggs of Z. *subfasciatus* are glued to the seed coat, whereas those of *A. obtectus* are scattered between the seeds
b. Z. *subfasciatus* infest only harvested seeds, whereas A. *obtectus* infestation may start in the field on growing pods
c. Upon hatching Z. *subfasciatus* larvae bore through the seed directly. Those of *A. obtectus* wander about before they penetrate the seed.
d. Z. *subfasciatus* adults are smaller than those of those of *A. obtectus*
e. The larvae of Z. *subfasciatus* are white, where as those of A. *obtectus* are dirty white or pale yellow.

Damage symptoms

Feeding by the last instar produces the characteristic circular ‘windows’ that become visible externally as insect development progresses. The beans in storage are hollow and unmarketable.

obtectus *Z. subfasciatus*

Bean bruchids on beans

Management

Farmers’ in several countries of Africa practice a variety of methods to lower bruchids infestation. These include solar heating, varietal selection, removal of infested grain at harvest, admixing grain with ash and botanicals, use of different storage methods, and granary hygiene. Bruchids resistant varieties have been developed by the national research program in collaboration with International Research Centers such as CIAT.

The use of insecticides on small scale storage is not advisable since the grains are stored for duration and often used for family consumption. Clean storage facilities and non-toxic chemical control measures are necessary. These measures include drying of seeds to moisture level of 7% or lower before storing, and mixing seeds with nontoxic chemicals such as neem (*Azadirachta indica*) seed extracts. If chemical control is necessary relatively safe insecticides should be applied. Fumigation is practical in large scale storage facilities. Phosphine is effective and convenient fumigant

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