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Oilseed Pests

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1. Introduction

Oilseeds occupy an important position in agriculture and industrial economy. So, management of pest problems and using possible control techniques could increase the quality and quantity of the products.

A large variety of pests damage oilseeds and cause significant losses in the farms or storages. Among which insect pests are a significant factor in the economics of oilseed production. There are also several vertebrate pests such as rats, slugs and birds.

An extensive review of oilseed pest has been conducted by numerous national research programs in Australia, Canada, Germany, India, United Kingdom, United State and etc.

Pests of oilseeds can be classified according to the different factors such as taxonomic grouping, feeding habitat, distribution. Within each groups, the pest status may vary with country, year and season depending on species, variety, cropping system used. Some of the pests may attack a certain type of oilseed; the others are generalists and can feed on a variety of crops. Pests with different feeding habitat could have either chewing or sucking mouthparts. Pests with chewing mouthparts eat parts of the crops such as flowers, foliage, stems, roots or buds. They may only eat portions of leaves, leave holes in the leaves (flea beetles), cause bud abscission, reducing yield of the pods and leaf area, earlier leaf abscission, delayed flowering (weevils) or bore into stems and roots (borers).

Pests with sucking mouthparts such as aphids, bugs, thrips, whiteflies, mites, and jassids usually cause the plant to discolor or twist and curl. The plant may discolor from tiny yellow speckles (spider mites), larger darkened spots (plant bugs), reducing the canopy area of the plant, and therefore its photo-synthetic capacity, coatings of black sooty mold growing on honeydew deposits or transmitting viruses (aphids and whiteflies).

Also, several pests may attack oilseed crops occasionally or their populations don't exceed threshold levels.

Protection of the crops from pest's infestations and keeping the pests under proper control has become in consideration due to the importance of the crops. Pest management is done by different methods such as cultural control, biological control, physical control, host plant resistance and assessing the economic thresholds to determine the need to apply pesticides (chemical control). By doing one of these methods, farmers can protect their farms and agricultural produce. However, integrating two or more control techniques to manage one

or more species of the same group of pests as an IPM (Integrated Pest Management) program prevent pests from causing significant losses, encouraging natural enemies, saving money while producing a high quality product, enhance the agricultural productivity and usually has the highest probability of cost effectiveness (Fig. 1).

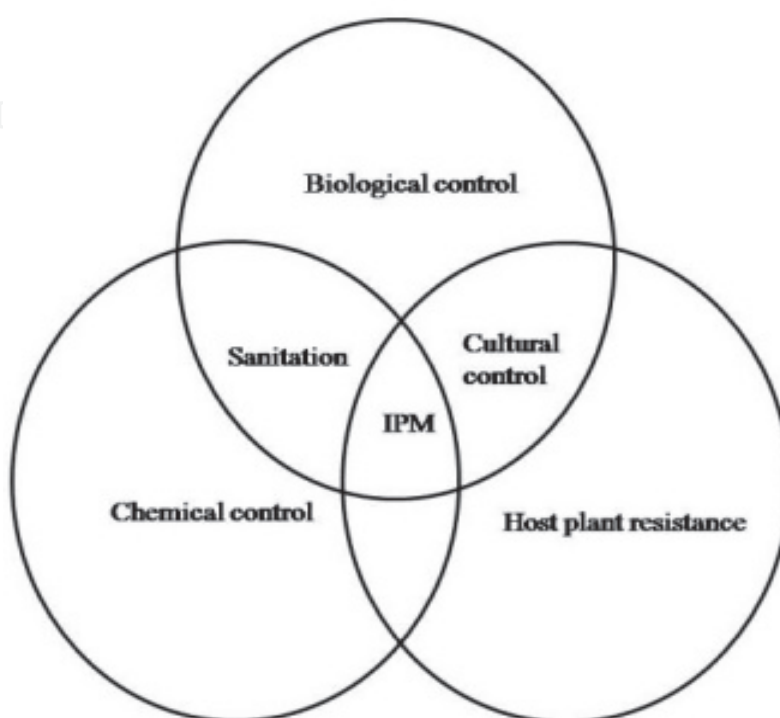


Fig. 1. IPM diagram

In this chapter, the order of presentation is firstly related to the oilseed crops. Although the importance of crops differ from region to region but some most prominent crops are cotton seeds, groundnuts, mustard, rapeseed, safflower, sesame, soybean, sunflower, linseed and castor. Secondly, within each crop, the pests are presented by taxonomic groups; attempt to help you identify the common or special pests. Subsequently, the life cycle, monitoring, economic importance, action thresholds of the pests and methods for keeping pests under control are given. In summary the best management program as IPM will be introduced.

The format for a full entry is:

Oilseed crop: Common and scientific name of oilseed crop.

Pests: arranged by taxonomic order.

Identification: Size of insect and distinctive coloration.

Life cycle: the pest's life cycle, habitat, habits, damage stage and detection of the pests.

Monitoring: monitor and detect significant populations of the species.

Economic importance and action thresholds: number of pests, density, etc. at which a pest becomes an economic threat and control is essential. The action level also depends on costs and the economic benefits of treatment.

Control: different methods can be used to control pests such as cultural control, biological control, physical control, host plant resistance and chemical control.

- Cultural control: Cultural control exploits the factors related to reduce the prevalence of unwanted pests. Crop rotation, intercropping, sanitation, early or late planting, trap

crops, fertilization, and cold and heat treatments are strategies that may be highly effective for controlling some pests.

- Biological control: biological control is the use of one organism to control a particular pest. Biological control agents include predators, parasitoids, and pathogens.
- Physical control: physical control is the use of some physical components of the environment, such as temperature, humidity, light, electromagnetic radiation (microwaves, infrared, and radiofrequencies), mechanical shock, and pneumatic control (blowing or vacuuming tools) to the detriment of pests.
- Host plant resistance: Planting resistant varieties can prevent or decrease pest damages and their injuries to the crop.
- Chemical control: The most common method of pest control is the use of chemicals that either kill pests or inhibit their development. A well chosen insecticide provides the desired level of control, while minimizing negative side effects such as enhancing the development of resistance, hazards effects on non-target species and beneficial organisms, environmental contamination and flaring secondary pests.

IPM program: IPM attempts to find the optimum combination of control tactics including cultural, biological, physical, and chemical control that will reduce pest population below the economic threshold. IPM is a safer, usually less costly and reduced-risk option for effective pest management.

The life cycle of the pests, damage and economic thresholds depend on many factors (crop stage, crop age, socio-economic, climatic conditions and etc.) and cannot be adopted without consideration to local conditions. So, descriptions of each pest are gathered from available literatures and researches depending on the importance of the crop and invasive pests.

Conclusion: at the end of this chapter we could identify the pests and beneficial species community on the oilseed crop, distribution of them on the crop and have information about the infestation. After considering safety, effectiveness, environmental effects and cost of each method; we choose the best method for protecting the crops and minimizing pest's problems.

The oilseed crops listed in this chapter are 1) cottonseed, 2) groundnuts, 3) soybean, 4) mustard, 5) sunflower, and 6) safflower, respectively.

2. Cottonseeds

There are five commercially grown species of cotton:

- *Gossypium hirsutum* L.: known as upland cotton or Mexican cotton, native to Central America and Mexico (90% of world production).
- *Gossypium barbadense* L.: known as Creole, Egyptian, South American, Pima or Sea Island cotton, native to tropical South America (8% of world production).
- *Gossypium arboreum* L.: known as tree cotton, native to India and Pakistan (less than 2%)
- *Gossypium herbaceum* L.: known as Levant cotton, native to semi-arid regions of sub Saharan Africa and the Arabian Peninsula (less than 2%).
- Organic cotton: grown in subtropical countries such as America and India (growing at a rate of more than 50% per year) (Wikipedia, 2011a).

Some of the important pests on cottonseed that require management for realizing better yields are:

2.1 Locusts and grasshoppers

Identification: there are different species of locusts and grasshoppers that attack oilseed crops especially cotton. Australian plague locust, *Chortoicetes terminifera* (Walker), will not generally damage cotton, although some light damage has been observed on field margins as swarms move through and 'test feed'. The spur-throated locust, *Austracris guttulosa* (Walker), if present in large swarms, can cause damage (Bailey, 2007). The variegated grasshopper, *Zonocerus variegatus* (L.) is the only grasshopper pest in the humid forest zone. It causes damage on most crops, mainly cassava, but also cotton (De Groote, 1997).

Life cycle and damage: Grasshoppers can be occasional early season pests. In late summer and fall, females lay eggs in grassy foothills, on ditch banks, along roadsides and fence rows, in pasture areas. The eggs hatch in spring and the young nymphs feed on nearby plants. Higher temperatures result in faster development of the eggs and nymphal growth. Hot and dry weather conditions favor population increase, while cool and moist conditions decrease population growth. When wild grasses and other plants become dry, the grasshoppers migrate to irrigated croplands. Both nymphs and adults can defoliate crops or chew through the stem weakening the plant which often will fall over at the wound site. They overwinter in egg cases which were deposited in the soil (Collins et al., 2010).

Monitoring: when population densities are high, pest managers can use four 180-degree sweeps with a 15-inch sweep net, which is equivalent to the number of adult (or nymph) grasshoppers per square yard (Knodel et al., 2010).

Economic and action thresholds: action threshold is when 8 or more grasshoppers per square yard occur in the field (Knodel et al., 2010).

Control: Control of annual weeds before grasshopper emergence may reduce grasshopper populations by eliminating alternative food sources for young grasshoppers. *Beauveria bassiana* (Bals.) and *Metarhizium anisopliae* (pathogenic fungi) can be applied for controlling grasshopper population. Scelionid egg parasites and blister beetle are effective biocontrol agents. If the threshold is exceeded apply some insecticides such as acephate at 0.33 - 0.66 lbs, beta-cyfluthrin at 2.4-3.2 fl oz, bifenthrin at 1.6-6.4 fl oz, and esfenvalerate at low rate of 3.9-5.8 fl oz (Knodel et al., 2010).

2.2 *Tetranychus urticae* (Koch) (Acari: Tetranychidae)

Identification: the size of the mite is less than 1 mm and varies in the color. The adults have two typical dark spots on the back so they are named two spotted mite. The female is 0.5 mm long; the male is smaller and slender and they have 4 pairs of legs. The females lay small (less than 0.1 mm in diameter) spherical eggs which are translucent after laying. Larva of reduced size has 3 pairs of legs. The common name, red spider mite, is because they spin silk webs to protect the eggs or colony from predators (Bailey, 2007).

Life cycle and damage: the eggs hatch into the nymph named protonymph, and then turns into deutonymph, afterward adult stage form. *T. urticae* has worldwide distribution and infests to a wide range of plants. The mites convene and feed on the under surface of the

leaves causing bronzing, reddening and sometimes desiccation of the leaf. The crop enjoys warm and dry climates which is appropriate for the mites. Yield loss of the mites depends on when mite populations begin to increase and how quickly they increase (Bailey, 2007).

Monitoring: monitor the oldest leaf when plants are very young. As plants grow, choose leaves that are from 3, 4 or 5 nodes below the plant terminal. Begin monitoring at seedling emergence and sample at least weekly. Sample more frequently if the weather conditions are hot and dry. Also, shake the leaves onto a white piece of paper and count the actual number of mites moving around with a hand lens. Eggs and immature stages are difficult to see with the naked eye, so a hand lens should be used (Yvette & Jensen, 2009).

Economic and action thresholds: threshold is when 30% of plants infested through the bulk of the season (squaring to first open boll) (Yvette & Jensen, 2009).

Control: biological control by ladybirds (*Hippodamia convergens* Guerin), big eyed bugs (*Geocoris* spp.), damsel bugs (*Nabis* spp.), lacewings (*Chrysopa* and *Micromus* spp.) and *Phytoseiulus persimilis* (Athias-Henriot) can decrease the population of the mites in early season. Chemical control can be effective by rotation of some acaricides, but only applied when action threshold is observed. Rotation of pesticides is essential because if the same pesticide is used over a prolong period of time they quickly resist to pesticide (Bailey, 2007).

2.3 *Thrips tabaci* (Lind.), *T. palmi* (Karny) and *Scirtothrips dorsalis* (Hood) (Thysanoptera: Thripidae)

Identification: *T. tabaci* adult is about 1 mm long; yellowish-gray to dark-gray and the head has post ocular setae of about the same length as the interocellar setae. The basal segments of the usually seven-segmented antennae are light brown, while the distal segments are dark brown. The prothorax has only two pairs of well developed setae on the posterior margin. The second segment of thoracic has convergent striations on the top surface, and lacks campaniform sensillae. Eggs are microscopic, white or yellow. The nymph ranging from 0.5 to 1.2 mm, white to pale yellow and look like to the adult; just it has short antennae and does not have wings. Pupae are pale yellow to brown, they have short antennae and the wing buds are visible but short and not functional (Rueda, 1995).

T. palmi adults are about 0.8 to 1 mm in length, pale yellow or whitish in color, but with numerous dark setae on the body. A black line, resulting from the juncture of the wings, runs along the back of the body. The slender fringed wings are pale. The hairs or fringe on the anterior edge of the wing are considerably shorter than those on the posterior edge. The egg is colorless to pale white in color and bean-shaped in form. The nymph resembles the adults in general body form though they lack wings and are smaller. The pre pupae and pupae resemble the adults and nymph in form, except that they possess wing pads. The wing pads of the pupae are longer than that of the pre pupae (Capinera, 2010b).

S. dorsalis has small size less than 1 mm in length, yellow coloration, dark antennae with forked sense cones on antennal segments III and IV, antennomeres I-II are pale and III to IX are dark. Also, it has dark striping on the lower abdomen and three distal setae on the lateral margins of abdominal tergites, with pronotal posteromarginal seta II nearly one and a half times the length of I or III, a complete posteromarginal comb on tergite VII; and three ocellar setae with III between posterior ocelli (Wikipedia, 2011d).

Life cycle and damage: *T. tabaci* is known as cotton seedling thrips. Adults prefer to lay their eggs in leaf, cotyledon, or flower tissues. Usually, cotton thrips destroy the cotyledons at first and then other parts of the crop including the bolls. Most damage occurs during early vegetative stage of the crop. Both adult and nymph feed on the under surface of the leaves make them thickened, blistered and bronzed due to continuous feeding. Developing bolls become brown due to development of necrotic patches (Natarajan, 2007; Yvette & Jensen, 2009). *S. dorsalis* can severely damage other oilseed crops such as sunflower.

Monitoring: monitoring should be started from seedling emergence of the crop and number of thrips on 20 - 30 plants counted weekly for every 50 ha (Yvette & Jensen, 2009). Monitor by picking and slapping a leaf on a white index card to see if the tiny specks move around. Open and microscopically examine the plant's growing point for thrips. Plucked growing points can also be dunked in alcohol to dislodge thrips (Bailey, 2007). Also, colored sticky traps can be used for monitoring thrips. Male thrips were most attracted to yellow sticky traps while female thrips were more attracted to pink sticky traps (Yaku et al., 2007).

Economic and action thresholds: The economic threshold from seedling stage until having six true leaves is when 10 adults or nymphs per plant is observed (Yvette & Jensen, 2009).

Control: in moderate infestations, biological control of the thrips by *Anthocoridae*, *Lygaidae* and predator mites will be effective. Seed treatment with Imidacloprid 70 WS and Chlothianidin (Poncho 600 FS) at 9 ml/kg can protect cottonseeds from early season infestation (Udikeri et al., 2007). However, when high population of thrips recorded systemic insecticides (acetamiprid, imidacloprid and acephate) should be applied (Natarajan, 2007). Aslam et al., (2004) reported that Mospilan, Confidor and Tamaron were highly effective against thrips on cotton.

2.4 *Aphis gossypii* (Glover) (Homoptera: Aphididae)

Identification: *A. gossypii* is commonly referred as cotton aphid. Adults are small (apterate 0.9 - 1.8 mm long and alate 1.1 - 1.8 mm long) and variable in color from greenish brown to orange or dirty yellow with soft body. Nymphs are small sizes of adults.

Life cycle and damage: The females reproduce nymphs parthenogenetically and viviparous which become adults in 7 - 9 days. Cotton aphid is the most common aphid pest infests the cotton seedlings. They are phloem feeders, causing direct leaf crumpling and downward curling with severe attack. Adults and nymphs suck sap from the under surface of the leaves, produce honeydew, indirectly decrease cotton fiber quality and may burn the leaves. Black sooty mould develops on the honeydew interfere photosynthesis of the leaves. Also, they are known as a vector of viruses (Vennila, n.d.). Wilson (2011) reported that aphids transmit plant virus Cotton Bunchy Top appearing in fields across the Australia.

Monitoring: monitor adults and nymphs on the underside of main stem leaves, 3 - 4 nodes below the plant terminal. Presence of ants may indicate presence of aphids. Early detection of aphids is important as they can multiply rapidly. If a high proportion of plants have only the winged form of aphids, recheck within a few days to see if they have settled and young are being produced. Yellow traps are useful for monitoring winged aphids. The presence and abundance of natural enemies should also be recorded (Yvette & Jensen, 2009).

Economic and action thresholds: The economic threshold level in the first open boll stage until harvest is the time if 50% of the plants (counted randomly) are affected or 10% trace amounts of honeydew is present (Yvette & Jensen, 2009).

Control: planting resistant or tolerant varieties which are densely hairy and with stiff leaves are reliable control technique. Seed treatment with *Trichoderma viride* or Imidacloprid 70 WS or Chlothianidin at 9 ml/kg can be effective in reducing population buildup. Aphids are biologically controlled by several species of *coccinellids*, *chrysopids*, *syrrhids* and the parasitoid *Aphelinus gossypii* (Timberlake). Application of safe and systemic insecticides like Monochrotophos 36SL, Dimethate 30 EC, Endosulphan should be considered if the threshold is exceeded (Natarajan, 2007; Navarajan, 2007; Udikeri et al., 2007).

2.5 *Amrasca devastans* (Distant) or *Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae)

Identification: adults are usually less than 13 mm long, with slender, tapered bodies of various colors and legs with rows of sharp spines. Eggs are curved and nymphs are flattened, pale yellowish green (Natarajan, 2007).

Life cycle and damage: the common name of the pest is Indian cotton leafhopper or Indian cotton jassid. The female inserts eggs inside leaf veins and after 4 to 11 days the eggs hatch. Nymphs remain confined to the lower surface of leaves during day time. Nymphs' period lasted 7 - 21 days depending on the weather conditions. They have about eleven generations in a year. Both adult and the nymph stages suck the plants sap from under surfaces of the leaves and produce a salivary toxin which impair photosynthesis and cause the edges of the leaves to curl downward. Subsequently, the leaves become yellowish and then redden. Hairy varieties of cotton such as *hirsute* are less susceptible to the jassids. So, yield loss can be reduced by growing hairy varieties (Natarajan, 2007; Navarajan, 2007). *A. biguttula biguttula* also damage severely other oilseed crops such as sunflower.

Monitoring: monitor the presence of leafhoppers by brushing the foliage; watching for adults and nymphs to jump and fly from plant to plant. Leafhoppers are most sampled with a sweep net. Empty captured jassids into a container with 70% alcohol (or methylated spirits), and express counts as leafhoppers per sweep (one sweep per row) (Bailey, 2007).

Economic and action thresholds: The economic threshold is observing 2-3 adults or nymph per leaf; although for glabrous varieties the threshold may be lowered to one jassid per leaf. Threshold should consider when the margins of the leaves become yellow (Natarajan, 2007).

Control: Natural enemies are not considered to have a significant effect on population of jassids although the parasitoid *Anagrus sp.* has been recorded, but it does not play any significant role in reducing the population. Applying systemic insecticides such as acetamiprid, acephate, so on or seed treatment with imidacloprid or Chlothianidin at 9 ml/kg give good control of jassids (Natarajan, 2007; Navarajan, 2007; Udikeri et al., 2007). also Aslam et al., (2004) declared that Confidor and Mospilan are effective against jassids.

2.6 *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae)

Identification: adults are about 1 mm long with two pairs of white wings and light yellow bodies. Their bodies are covered with waxy powdery materials. Eggs are tiny, oval-shaped,

with about 0.25 mm diameter and stand vertically on the leaf surface, eggs at first are white then turn to brown. Nymphs' first instar is 0.3 mm length and the second instar has legs pulled up under its body and other immature stages are sessile. The last nymphal instar develops red eye spots and often is called the pupal stage (Bailey, 2007).

Life cycle and damage: the female lays two types of eggs; one that have not been fertilized and these eggs will result in male offspring. However, fertilized eggs will result in female offspring. Eggs are laid on the under surface of the leaves where the nymphs can suck the plants sap. The incubating time is different due to the season; in the summer eggs hatch after 3-5 days and nymphal period occupy about 9-14 days. However, for winter this period is 5-33 and 17-53 days, respectively. *B. tabaci* has the pupal stage which prolongs approximately 2-8 days and the life cycle ranges from 14-107 days depending on the weather conditions. Whiteflies are found on the under surface of the leaves. They directly feed from the crop, produce honeydew, developing sooty mould and also can transmit viruses (Natarajan, 2007; Navarajan, 2007). *B. tabaci* transmits plant viruses in seven distinct virus groups including: geminiviruses, closteroviruses, carlaviruses, potyviruses, nepoviruses, luteoviruses and a DNA-containing rod-shaped virus. Cotton followed by soybean have been affected by one or more whitefly transmitted viral diseases (Oliveira et al., 2001). They cause contamination of lint through the excretion of honeydew. Their honeydew is considered to be worse than aphid honeydew because it has a lower melting point and during the processing stage, can cause machinery to gum up and overheat (Yvette & Jensen, 2009). Whiteflies can severely damage other oilseed crops such as sunflower.

Monitoring: Monitoring is done by visual counting of nymphs and adults and catching with suction traps or yellow sticky traps. The latter are especially effective in detecting low density populations. Sample the population of larvae per leaf (Ohnesorge & Rapp, 1986).

Economic and action thresholds: the economic threshold is observing 5-10 nymphs or adults per leaf (Navarajan, 2007). Ellsworth & Martinez-Carrillo (2001) declared that based on comparative researches and observations in cotton two adults per leaf in Thailand, 6-8 adults in India, and ca. six adults per leaf in the Sudan were appropriate action thresholds.

Control: *Eretrmoceris mundus* (Mercet) and *Enacarsia* sp. are special parasites of *B. tabaci*. Also, the predators *Amblyseius* sp. (predatory mite), the green lacewing bug (*Chrysoperla* sp.) the coccinellids *Brumus* sp., *Scymnus* sp. and *Menochilus* sp. play important role in reducing whitefly population. Spray application of systemic insecticides can be effective; also neem oil can control whiteflies build up (Natarajan, 2007; Navarajan, 2007). In addition, Aslam et al., (2004) recommended Mospilan and Actara, as a good control agent against this pest.

2.7 *Oxycarenus hyalinipennis* (Costa) (Hemiptera: Lygaeidae)

Identification: Adults' measure 4-4.3 mm long; their thorax, head, antennae, and femora are black and wings folded flat on the back and they are translucent white. Males are slightly smaller than females. Nymph has pink to red abdomens. All stages are characterized by a powerful smell when crushed (USDA, 2010).

Life cycle and damage: the cottonseed bug is a major economic threat to cotton. The eggs are laid in open bolls and nymphs can be found in clusters among the lint. This species has five nymphal instars. Adults and nymphs suck sap from mature seeds and leaves of young

stems to obtain moisture. These pests prefer inside the bolls and they occasionally go through the leaves of cotton plants or in a single cotton boll, resulting in reduction of seed weight and seed viability in late bolls. A generation from egg to adult can be completed in 20 days, and the pest has three to four generations per year (Smith & Brambila, 2008).

Monitoring: monitor by visual observation and count the number of adults and nymphs. Seed bugs usually found in open bolls and boll opening onwards (Brien, 2010). Also, UV-light traps can be placed in areas related to potential pathways for *O. hyalinipennis* (Derksen et al., 2009).

Economic and action thresholds: No action threshold has been set for *O. hyalinipennis*.

Control: Burning old cotton stalks with bolls may limit future damage by the cottonseed bug. Removal of all weeds or alternative malvaceous host plants near cotton fields is recommended. The cottonseed bug does not normally require control as damage tends to be only to seeds in late bolls. However, Chlorpyrifos-ethyl/hexaflumuron, Dimethoate, Biphenthrin, Endosulfan, Malathion, Methomyl/diflubenzuron and Neem are insecticides available for use against the cottonseed bug (Brien, 2010; USDA, 2010).

2.8 *Creontiades dilutus* (Stal) (Hemiptera: Miridae)

Identification: Adults of green mirid are about 7mm long, pale green with long antennae. They have sparse setae on their scutellum and pronotum. Females can be distinguished from males by the presence of a median cleft which runs along the mid ventral line of the last abdominal segment. Eggs are about 1.5 mm long, banana shaped, narrowing to a neck below the operculum. Nymphs are the small size of adults; newly hatched nymphs about 1.5–2 mm long and larger nymphs (4th and 5th stage) can be up to 7mm long. They are characterized by their distinctive red tipped antennae (McColl et al., 2011).

Life cycle and damage: Females lay eggs singly within the plant tissue on cotton plants. This species showed a tendency to lay eggs at the distal end of the petioles on the upper one third of the plant. It has four to six nymphal stages. Adults and nymphs cause early season damage to terminals and buds and mid season damage to squares and small bolls; cause blackening, death of young plants terminals and rapid square loss. Bolls that are damaged during the first 10 days of development will be shed, while bolls damaged later than this will be retained but not continue normal development. Black, shiny spots indicate feeding sites on the outside of bolls. When sliced open, warty growths and discolouration of the immature lint can be seen within the boll. So, they cause both direct damage (destruction of terminals, leaves, bolls and branch primordia), and indirect damage (deformed plants) to cotton plants. From first flower until the time when approximately 60% of bolls are 20 days old, the crop is most susceptible to fruit loss that causes yield losses (McColl et al., 2011).

Monitoring: as mirids are very mobile and easily disturbed during monitoring so sample fruit retention and types of plant damage such as tip damage (early season) and boll damage (mid season). Beat sheet or sweep net techniques have proven to be the best sampling methods to find nymphs and adults, respectively (McColl et al., 2011).

Economic and action thresholds: Threshold for *C. dilutus* ranges from 0.5 to 4 mirids per meter of row, depending on the crop stage, sampling technique (visual or beat sheet) and climatic conditions (McColl et al., 2011).

Control: damsel bugs, big-eyed bugs, predatory shield bugs, as well as lynx, night stalker and jumping spiders are known to feed on mirid adults, nymphs and eggs (Yvette & Jensen, 2009). *C. dilutus* is coincidentally controlled in cotton by applications of insecticides targeted at other pests such as *Heliothis* spp. (McColl et al., 2011).

Some other important sucking insect pests of cottonseeds are:

Occasionally green peach aphid, *Myzus persicae* (Sulzer) and cowpea aphid, *Aphis craccivora* (Koch) (Homoptera: Aphididae), infest young cotton. Green vegetable bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae), pale cotton stainer, *Dysdercus sidae* (Montr.) and red cotton bug, *Dysdercus cingulatus* (F.) (Hemiptera: Pyrrhocoridae) sometimes cause economic damage and heavy crop losses in some regions. Also, brown mirid, *Creontiades pacificus* (Stål) (Hemiptera: Miridae) and cottonseed bug, *Oxycarenus luctuosus* (Montrouzier) (Hemiptera: Lygaeidae) can cause damage to the cotton but the damage of these pests is minor and doesn't require control.

2.9 *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae)

Identification: The cotton leaf worm adult has a wingspan of 35 to 40 mm. Forewings are brownish with bluish overtones and straw yellow along the median vein. The ocellus is marked by 2 or 3 oblique whitish stripes. The front of the wing tip has a blackish marking, more pronounced in the male. Hind wings are whitish, with a brown front edge. Eggs are spherical and about 0.6 mm long. Neonate larva is pale green with a brownish head; when fully developed (fourth instar), it is 35 to 45 mm long. The color of larvae varies from grey to reddish or yellowish, with a median dorsal line bordered on either side by two yellowish-red or grayish stripes, and small yellow dots on each segment. Pupa is about 15 to 20 mm long, brick red color (Vaamonde, 2006).

Life cycle and damage: adults appear in early spring and female lays eggs in clusters and covered with brownish-yellow hairs detached from the abdomen of the female. Most of the clusters are sited on the lower parts of plants. Eggs hatch after 3-4 days and after 2 weeks, pupation takes place in the soil at a depth of 2 to 5 cm. They overwinter as a pupa in the soil. When they are small they feed from the cuticle of the leaves, but if growing they feed from any green part of the plant and also from fruits, resulting in major defoliations. They can also chew the stems, where galleries are drilled. The injuries caused for that pest facilitate the penetration of other pathogens such as fungi, bacteria and etc (Vaamonde, 2006).

Monitoring: detect the presence of adults with monitoring device consisting on insecticide or pheromones traps (3-4 traps per acre). Once the first captures occurs, it is advisable to make a visual estimate by means of a direct sampling on the plants, paying attention to the leaves or other parts of the plant. Count the number of active larvae at the upper and lower surfaces of the leaves and determine the percentage of defoliation (Vaamonde, 2006).

Economic and action thresholds: observation of 35, 45 and 100 egg masses or 0.3, 0.4 and 0.9 larvae per plant is recommended as economic threshold during *S. littoralis* first, second, and third generations, respectively (El-Sherif et al., 1991).

Control: applying azadirachtin and neem oil can control and disrupt growth of insects. Also, sex pheromones can use in the control programs (Martinez & Emden, 2001). Pineda et al., (2007) stated that combination of lethal and sub lethal doses of methoxyfenozide and spinosad might significantly control the population dynamics of *S. littoralis*.

2.10 *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae)

Identification: The moth is small and dark brown with blackish bands on the forewings, and hind wings are silvery grey. Eggs are flattened oval and striate about 0.5 mm long, 0.25 mm wide. The larvae are pinkish with dark brown head and about 15 mm length. Pupae are in a thin silken cocoon among the lint inside a seed, in between bracts or in cracks in the soil.

Life cycle and damage: The pink bollworm female lays the eggs on the bolls or in between bracts or on buds and flowers. After 4-25 days, due to the weather conditions, eggs hatch and larvae crawl to the bolls. Larva full grown in 25-35 days and the pupal period is about 6-20 days. The larvae feed early in the season from the inside of the green bolls. Seeds being destroyed in addition to retardation of lint development, lint weakened and stained both inside the boll and in the gin, causing lint yield losses. In addition, infested bolls open prematurely and are invaded by saprophytic fungi.

Monitoring: monitoring can be done with pheromone baited traps as well as by sampling flowers and bolls to record damage levels in cotton fields (Lykouressisa et al., 2005).

Economic and action thresholds: the economic threshold is 8 moths per trap (glossyplure pheromone traps) per day for 3 consecutive days. The number of traps should be 5 per ha or 10% infested flowers or bolls with live larvae (Sabesh, 2004).

Control: Biological control of larvae with *Chelonus* sp., *Camptothlipsis* sp., and *C. blackburni* (Cam.) is effective against overwintering stage. Parasitoids include *Trichogramma brasiliensis* (Ashm.), *Bracon kirkpatricki* (Wilkinson), *Chelonus blackburni* (Cameron); predatory mites such as *Pyemotes ventricosus* (Newport) and *P. herfsi* (Oudemans) are widely reported on reducing bollworm population. Also, entomopathogenic nematodes (Rhabditida: Steinernematidae) such as *Steinernema riobris* (Cabanillas, Poinar and Raulston) and *Steinernema carpocapsae* (Weiser) may control pests infestations. Applying insecticides is advised if the threshold is exceeded. Application of carbaryl 50 WP, quinalphos 25 EC, profenofos 50 EC, or fumigation of seeds with aluminum phosphide at 18 tablets per 100 cu. m. is recommended (Gouge et al., 1998; Navarajan, 2007; Salama, 1983; Vennila, n.d.).

2.11 *Heliothis armigera* (Hübner) and *Heliothis punctigera* (Wallengren) (Lepidoptera: Noctuidae)

Identification: moth of *H. armigera* is about 35 mm long, with a small pale patch in the dark section of the hind wing; while in *H. punctigera* the dark section is uniform. Eggs of both species are 0.5 mm in diameter, sculptured with longitudinal ribs. *H. armigera* larvae have white hairs around head; medium larvae have saddle of dark pigment on 4th segment from head, and have dark legs. *H. punctigera* larvae have black hairs on the prothorax, dark triangles on the first abdominal segment with light legs. Pupa is smooth surfaced, brown, rounded both anterior and posterior with two tapering parallel spines at posterior tip (Vennila, n.d.).

Life cycle and damage: *H. punctigera* is known as native budworm; and *H. armigera* is the cotton bollworm or corn earworm. *H. armigera* occurs throughout the Africa, Western Europe and Australian pacific region. The adults lay their eggs on young terminal branches of the cotton and after 2 or 3 days the eggs hatch and larvae go through the young leaves and flower buds. So, they burrow fruit and feed from developing seeds and fibers until

larval ultimate period. Bollworms have four or five generations and in the last generation burrow into the soil around the base of plant for overwintering and the pupae emerge from the soil in the next spring. *H. punctigera* is similar to *H. armigera*; just there are a few differences between them, such as *H. armigera* usually prefers grass or cereal crops but *H. punctigera* prefers to feed on broadleaf species (e.g. cotton, sunflower, soybean, canola, safflower, linseed and etc.). The diapause is not common in *H. punctigera* (Vennila, n.d.). *H. armigera* also severely damage other oilseeds such as sunflower.

Monitoring: monitor from seedling emergence to maturity of the cotton for the presence of eggs and larvae. Pheromone traps (5 per ha) will detect the presence and intensity of adults (Yvette & Jensen, 2009).

Economic and action thresholds: the economic threshold in early stages of the crop is 2-3 larvae with about 3 mm length/m or 1 larva > 8 mm and for the time when 15-40% of the bolls opened, 5 larvae with 3 mm length/m or 2 larva > 8 mm/m (Yvette & Jensen, 2009).

Control: mechanical cultivation of the soil at the end of the season destroys the tunnels and shelters made by the larvae and can kill over 90% of the pupae in the soil. *Trichogramma* spp., *Compoletis chloridae* (Uchida) can release against early instar larvae and Tachinids: *Carcelia illota* (Curran), *Goniophthalmus halli* (Mesnil.) and *Paleorixa laxa* (Curran) have been recorded on late larval instars of *H. armigera* (Vennila, n.d.). Spraying insecticides can be applied by consulting the field guide because *H. armigera* indicates resistance to insecticides (Salama, 1983). Recently, planting of transgenic *Bacillus thuringiensis* (Bt) cotton seeds is approved (Menon & Jayaraman, 2002).

2.12 *Earias insulana* (Boisd.) and *Earias vittella* (F.) (Lepidoptera: Noctuidae)

Identification: *E. vittella* moth has green forewings with a white streak on each of them whereas that of *E. insulana* is completely green. The eggs are less than 0.5 mm diameter, crown-shaped, sculptured and blue. The larva of *E. vittella* is brownish with a longitudinal white stripe on the dorsal side and without finger-shaped processes on its body. Larva is cream with orange dots on the prothorax. The boat shaped tough silken cocoon is dirty white brownish (Navarajan, 2007).

Life cycle and damage: They are known as spotted bollworm. Females lay eggs singly on most parts of the cotton such as flower buds, bolls, peduncles, bracts, leaf axils and veins on the under surface of leaf and after 3 days eggs hatch. The larval period is about 10-12 days. In the early vegetative stage of the crop the larvae cause damage to the terminal bud of the shoots and channel downwards or into inter node which redound to drying the shoot. Afterward, in the later stages of the crop growth; the larvae migrate to the buds, flowers, bolls and fresh parts of the plants and damaged them. Tunnel in bolls is often from below, angled to the peduncle. Larvae do not confine their feeding to a complete single boll; hence damage is disproportionate to their numbers. So, heavy shedding of early formed flower buds is observed in cotton fields and the lint from attacked bolls will not be clean. The period of pupae is 7-10 days. The total life cycle ranges from 20 to 22 days (Navarajan, 2007).

Monitoring: monitor the population fluctuation by installation synthetic sex pheromone traps. Also, determine larval infestation in bolls of cotton (Qureshi & Ahmed, 1991)

Economic and action thresholds: the economic threshold is differ from region to region, Navarajan (2007) stated 5% damaged fruiting bodies or one larva per plant from 20

Table **Impact of insecticides and miticides on predators, parasitoids and bees in cotton**
By Lewis Wilson^{1,2}, Simone Heinemann^{1,2}, Robert Mensah^{2,3}, Mouzzen Khan^{1,2}, Martin Dillon⁵, Mark Wade⁴, Brad Scholz³, David Murray^{3,7}, Richard Lloyd³, Richard Sequeira³, Paul DeBarro⁵ Viliami Heimoana⁶ and Jonathan Holloway⁶. ¹CSIRO Plant Industry, ²1&I NSW, ³DEED, ⁴CSIRO Entomology, ⁵Formerly CSIRO Entomology, ⁶Formerly 1&I NSW, ⁷Cotton CRC.

Insecticides (in increasing rank order of impact on beneficials)	Rate (g a.i./ha)	Target pest(s)						Beneficials														Pest resurgence ¹²																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
		Helicoverpa	Mites	Mirids	Aphids	Thrips	Silverleaf whitefly	Persistence ⁸	Overall Ranking ⁹	Predatory beetles				Predatory bugs				Lacewing adults	Spiders	Hymenoptera					Thrips																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
										Total ¹ Predatory beetles	Red and blue beetle	Minute 2-spotted lady beetle	Other lady beetles	Total ² Predatory bugs	Damsel bugs	Big-eyed bugs	Other predatory bugs			Apple dimpling bug	Total wasps	Eretmocerus 19	Trichogramma	Ants																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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Dimethoate (low)	80			✓ ¹⁸	✓	✓ ¹⁸	✓		short	moderate	M	L	H	H	M	L	M	—	M	H	M	+	+	+	H
Dimethoate (low + salt)	80			✓ ¹⁸	✓	✓ ¹⁸	✓		short	moderate	M	L	H	H	M	L	M	—	M	H	M	+	+	+	H
Endosulfan (low)	367.5	✓			✓		✓		medium	moderate	M	VL	VH	M	M	M	L	M	—	VH	H	—	—	—	M ¹⁵
Propargite	1500								medium	moderate	M	H	H	M	M	M	VL	M	L	H	M	—	+	+	L
Acetamiprid	22.5				✓			✓	medium	moderate	M	M	VH	H	M	M	VL	L	VH	H	VH	—	—	—	M ¹⁵
Clothianidin (low)	25				✓			✓	medium	moderate	M	VL	—	H	L	M	M	H	M	VH	VL	—	—	+	H
Amitraz	400	✓		✓ ⁹				✓ ⁹	medium	moderate	H	M	VH	H	—	—	VL	M	H	L	M	—	—	—	L
Fipronil (low)	12.5				✓			✓	medium	moderate	L	L	L	H	L	L	VL	M	—	VH	VH	+	+	+	VH
Chlorfenapyr (low)	200	✓		✓					medium	moderate	M	L	VH	VL	M	M	VL	L	—	VH	H	—	—	—	H
Thiamethoxam	100					✓		✓	medium	moderate	H	H	H	H	M	M	VL	M	—	H	VH	+	+	+	H
Endosulfan (high)	735	✓		✓	✓	✓		✓	medium	moderate	M	VL	VH	M	M	M	M	L	H	VH	H	—	—	—	M ¹⁵
Fipronil (high)	25			✓		✓		✓	medium	moderate	L	VL	H	L	M	M	M	—	M	VH	VH	+	+	+	VH
Imidacloprid	49					✓		✓	medium	moderate	H	L	VH	H	H	M	L	L	VH	M	H	+	+	+	M
Clothianidin (high)	50			✓		✓		✓	medium	moderate	H	VL	—	VH	M	M	L	VL	H	VH	H	+	+	+	H
Methomyl	169	✓							very short	high	H	L	VH	VH	M	L	VL	H	VH	H	H	+	+	+	H
Thiodicarb	750	✓							long	high	VH	M	VH	VH	M	M	VL	M	—	M	H	+	+	+	M ¹⁵
Dimethoate (high)	200			✓ ¹⁸	✓	✓ ¹⁸	✓		short	high	M	M	H	H	M	M	M	H	H	VH	M	+	+	+	H
Chlorfenapyr (high)	400	✓		✓		✓			medium	high	H	M	VH	L	H	H	M	—	VH	VH	M	—	+	+	H
OP ⁵		✓		✓	✓	✓		✓	short–medium	high	H	M	H	H	M	M	L	H	VH	H	VH	+	+	+	H
Carbaryl ³									short	high	H	—	—	—	—	—	—	—	—	—	—	—	—	—	H
Pyrethroids ⁴		✓	✓ ⁷	✓ ⁷	✓ ⁷	✓ ⁷	✓ ⁷	✓ ⁷	long	very high	VH	—	—	—	VH	—	VH	—	VH	VH	VH	+	+	+	H

1. Total predatory beetles – ladybeetles, red and blue beetles, other predatory beetles.

2. Total predatory bugs – big-eyed bugs, minute pirate bugs, brown smudge bugs, glossy shield bug, predatory shield bug, damsel bug, assassin bug, apple dimpling bug

3. Information: Citrus pests and their natural enemies, edited by Dan Smith; University of California Statewide IPM project; Cotton. Selectivity and persistence of key cotton insecticides and miticides.

4. Pyrethroids; alpha-cypermethrin, cypermethrin, beta-cyfluthrin, cyfluthrin, bifenthrin, fenvalerate, esfenvalerate, deltamethrin, lambda cyhalothrin

5. Organophosphates; omethoate, monocrotophos, profenofos, chlorpyrifos, chlorpyrifos-methyl, azinphos ethyl, methidathion, parathion-methyl, thiometon

6. *Nidicoerpa punctigera* only.

7. Bifenthrin is registered for mite and silverleaf whitefly control; alpha-cypermethrin, beta-cyfluthrin, bifenthrin, deltamethrin and lambda-cyhalothrin are registered for control of mites

8. Persistence of pest control; short, less than 3 days; medium, 3–7 days; long, greater than 10 days.

9. Suppression of mites and aphids only.

10. Impact rating (% reduction in beneficials following application, based on scores for the major beneficial groups); VL (very low), less than 10%; L (low), 10–20%; M (moderate), 20–40%; H (high), 40–60%; VH (very high), > 60%. A “–” indicates no data available for specific local species.

DISCLAIMER: Information provided is based on the current best information available from research data. Users of these products should check the label for further details of site, pest, spectrum, safe handling and application. Further information on the products can be obtained from the manufacturer.

Fig. 2. Some effective pesticides against cotton pests and their efficiency on parasitoids, predators and bees (Yvette & Jensen, 2009).

randomly counted plants. However in the other study, Qureshi & Ahmed (1991) declared that a mean trap catches of 9-12 moths per night was associated with economic injury level and the economic threshold is 10% larval damage.

Control: application of insecticides such as phosalone 35 EC, carbaryl 50 WP, endosulfan 35 EC, monocrotophos 40 SC, thiodicarb 75 WP, or profenofos 50 EC are advised. Also, the synthetic pyrethroids, fenvalerate, deltamethrin and permethrin has been reported to be effective against bollworms (Navarajan, 2007).

3. Groundnuts

Groundnuts contain seeds of:

Arachis villosulicarpa Hoehne: known as groundnut; cultivated in some states of Brazil.

Vigna subterranea L.: known as Bambara groundnut; originated in West Africa and a traditional food plant in Africa.

Macrotyloma geocarpum Harms: known as geocarpa groundnut, Hausa groundnut, or Kersting's groundnut, in Sub-Saharan Africa.

Arachis hypogaea L.: known as peanut, earthnuts, ground nuts, goober peas, monkey nuts, pygmy nuts and pig nuts. About 41.5% of world production is in China, 18.2% in India and 6.8% in the United States of America.

Also, roots and: *Apios americana* Medik.: known as potato bean, hopniss, Indian potato or groundnut, native to eastern North America.

Conopodium majus Gouan: known as kippernut, cipernut, arnut, jarnut, hawknut, earth chestnut, groundnut, and earthnut, native to Europe and parts of North Africa.

Panax spp.: is in parts of north America and eastern Asia (Wikipedia, 2010).

A few of the insect pests that cause economic losses to groundnut are introduced here:

3.1 *Tetranychus cinnabarinus* (Bois.) (Acari: Tetranychidae)

Identification: females are reddish, and more or less elliptical. The males are slightly smaller and wedge shaped. They have a black spot on either side of their relatively colorless bodies. Eggs are spherical, shiny, straw colored. Larvae are slightly larger than the egg, pinkish, and have three pairs of legs. They have two nymphal stages, the protonymph and deutonymph. The nymphal stage differs from the larval stage by being slightly larger, reddish or greenish, and having 4 pairs of legs (Mau & Kessing, 2007a).

Life cycle and damage: the females lay eggs singly on the underside of the leaf or attached to the silken webs spun which hatch in 3 days. The larval stage lasts a short time, perhaps a day and afterward formed the nymphs. Nymphal stage lasts about 4 days. Spider mites feed on the underside of the uppermost leaves. They can be very serious pests during extended dry periods (Mau & Kessing, 2007a). Resistance of peanut, and wild species of *Arachis* has been declared to the two spotted spider mite in the USA (Lynch, 1990).

Monitoring: monitor for areas of light colored (chlorotic) plants, especially along field edges. Look under the top leaves to see if mites are present (Linker et al., n.d.).

Economic and action thresholds: No threshold has been set for mites (Linker et al., n.d.).

Control: mites quickly resist to pesticide so consult with county Cooperative Service Extension agent which pesticides are associated with mite problems.

3.2 *Balclutha hortensis* (Lindberg) and *Empoasca kerri* (Pruthi) (Homoptera Cicadellidae)

Identification: *B. hortensis* adults are small and have a well developed appendix on the tegmen. Most species of *Balclutha* genus are green coloured although some of them are pink or red (NSW, 2001). *E. kerri* adults are yellowish green in color, wedge shaped and walked diagonally in a characteristic manner (Khanpara, 2011).

Life cycle and damage: the females insert eggs into the leaf tissue close to the midrib or into the petiole. The eggs hatch in a week and in 10 days nymphs change to the adult form. The nymphal stage passed through five instars. Both nymphs and adults suck sap from central surface of leaves; inject toxins resulting in whitening of veins and chlorotic patches especially at the tips of leaflets. This type of feeding cause 'V' shaped yellowing. Heavily attacked crops look yellow and give a scorched appearance known as 'hopper burn'. Also, stunting of crop growth is observed where they are endemic. life cycle is about 18-30 days in the case of male, while it is 20-34 days for female at an average temperature of $31.30 \pm 1.96^\circ\text{C}$ and $73.96 \pm 3.02\%$ r.h. (Ghewande & Nandagop, 1997; Khanpara, 2011). In the USA plant resistance has been confirmed to the leafhoppers (Lynch, 1990; Nandagopal & Reddy, 1987).

Monitoring: monitoring should be done weekly from 3 weeks after emergence (R1) up to maturity (R9) when the plants had no leafhoppers left on them. D-vac suction sampler can use for determining the number of adults and nymphs (select 10 sites in the field and five plants randomly per sample site). Also, determine the percentage of leaves affected by hopper burn (Linker et al., n.d.).

Economic and action thresholds: the economic threshold level is when 25% of the leaves are damaged or the presence of 5-10 nymphs or adults per plant. If the field is to be sprayed with fungicide, 15% threshold can be used (Linker et al., n.d.).

Control: planting tolerant varieties; crop rotation with non host crop; intercropping with pearl millet; avoidance of groundnut-castor inter crop; and once irrigation to avoid prolonged mid season drought are cultural techniques for preventing pests infestations. Applying safe insecticides such as Dimethoate 30 EC, or Monochrotophos 36SL can be effective against jassids (TIFP, n.d.-a).

3.3 *Caliothrips indicus* (Bagn.); *Thrips palmi* (Karny); *Scrithrips dorsalis* (Hood); *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae)

Identification: in the case of *C. indicus* both adults and nymphs are dark colored with fringed wings. For *F. schultzei*, dults are dark colored with fringed wings but nymphs are yellowish. For identification *T. palmi* and *S. dorsalis* refer to the cotton (Krishworld, n.d.).

Life cycle and damage: symptoms of damage is different as tender leaves show yellowish green patches on the upper surface; brown necrotic areas and silvery sheen on the lower surface. Severe infestations cause stunted plants. For *C. indicus*, lower leaves showing white spots or streaks intermingled with black excreta on the surface. In *F. schultzei* damage, young and terminal leaves showing white scars. They also transmit peanut bud necrosis. Peanut and its wild species show resistance to thrips species in the USA (TNAU, n.d.-c).

Monitoring: Colored sticky traps or water traps are useful for monitoring thrips. The color spectrum of sticky traps influenced their efficacy. Blue, yellow or white colors are used especially and it seems bright colors attract more thrips than darker ones.

Economic and action thresholds: economic threshold level is when 25% of the leaves are damaged and live thrips are found in the field or 5 thrips per terminal shoot (Bhubaneswar, 2008; Linker et al., n.d.).

Control: Spraying Monochrotophos 36 WSC, Dimethoate 30 EC, Methyldemeton 25 EC, or Monocrotophos 320 ml mixed with neem oil, 1 lit and 1 kg soap powder mixed in 200 lit of water twice at 10 days interval can be effective against thrips infestations (TNAU, n.d.-c).

3.4 *Aphis craccivora* (Koch) (Homoptera: Aphididae)

Identification: *A. craccivora* is known as groundnut aphid or cowpea aphid. The adult is about 2 mm long, pear shaped, green greenish brown or greenish black in color. The nymphs are dark brown and turns to shiny dark. Adults are mostly wingless but few winged forms also seen (TIFP, n.d.-a).

Life cycle and damage: Both nymphs and adults feed on the growing tips, tender foliage, flowers and growing pegs causing stunting and distortion of the foliage and stems. They excrete honeydew on which sooty molds develop. Aphids are also known to transmit peanut stripe virus and groundnut rosette virus complex. They have 12-14 generations per year (TIFP, n.d.-a). In the USA Peanut and its wild species show resistance to the groundnut aphid (Lynch, 1990). Bottenberg & Subrahmanyam (1997) stated that aphids in central Malawi were first recorded when the crop was at the flowering stage, but after 2 weeks the population of aphids decreased and the infestation ranged from 6 to 32%.

Monitoring: monitoring should be done during seedling, flowering and pegging stages of the crop. Monitor undersides of the leaves and yellow traps can use for monitoring aphids.

Economic and action thresholds: on average recorded in 1986, *A. craccivora* was of economic importance with economic threshold of 22.3 aphids per plant. However, the economic damage of aphids varies with the stage of plant, with most damage caused if aphids infest the growing points of groundnut early in the plant's development (CABI, 2011).

Control: releasing *Cheilomenes sexmaculata* (F.) or other biological control agents such as flower bugs (Anthocorids), and etc. would be effective in controlling aphids (Jasani, 2009).

3.5 *Anisolabis stali* (Dohrn) (Dermaptera: Forficulidae)

Identification: Pod borer adults are dark brown to black with forceps like caudal cerci and white leg joints. Nymphs are white in early stages and later turns brown (TNAU, n.d.-c).

Life cycle and damage: young pods showing bore holes plugged with excreta. Sand particles or discolored pulps is also observed and the pods lose their kernel (TNAU, n.d.-c).

Monitoring: monitoring can be accomplished with wheat bran or oat meal baits or traps. Likewise, traps take advantage of the natural tendency of earwigs to hide in crevices and can be used to detect presence of earwigs, and to estimate abundance (Capinera, 2009).

Economic and action thresholds: No action threshold has been set for pod borers.

Control: Application of Malathion 5D 25 kg/ha or Endosulfan 4D 25 kg/ha to the soil prior to sowing in endemic areas. Forty days after sowing, the application of insecticides should be repeated (TNAU, n.d.-c).

3.6 *Odontotermes obesus* (Rambur) (Isoptera: Termitidae)

Identification: termites are social insects, live in territorial, in distinct castes, workers, kings and queen. Workers are smaller; have a soft, white body and a brown head (Jasani, 2009).

Life cycle and damage: termites are one of the major soil pests of groundnut. However, in the USA peanut and its wild species show resistance to the genus *Odontotermes* (Lynch, 1990). Termites favor red and sandy soils and lay eggs on plants or in the soil. They penetrate, hollow out the tap root and feed on the roots of the groundnut. The attack continues with boring holes into pods and damages the seed. It removes the soft corky tissue from between the veins of pods causing scarification, weaken the shells, and make them liable to entry and growth of *Aspergillus flavus* that produces aflotoxins (Jasani, 2009; Umeh et al., 2001).

Monitoring: for determining the presence of termites in the field insert two pieces of wood into a hole in the ground as monitoring devices at fixed intervals (typically 10 to 20 feet apart). If termites are found in the monitoring station, woods are replaced with a perforated plastic tube containing baits. After termites are no longer found in installed bait tubes, the baits are once again replaced with untreated wood pieces and monitoring continues.

Economic and action thresholds: No action threshold has been set for termites.

Control: cultural control techniques for termites are: digging the territorial and destruction of the queen and harvesting the groundnuts as soon as they are matured. Termites can be controlled mechanically by avoiding physical loss of the crop during harvesting, destruction of debris, nests and queen. Applying insecticides like Chlorpyrifos 20 EC, Lindane 1.3% or Chlorpyrifos dust in soil before sowing may reduce termite damage (Jasani, 2009).

3.7 *Holotrichia consanguinea* (Blanchard), *Holotrichia serrata* (F.) and *Sphenoptera indica* (Laporte & Gory) (Coleoptera: Scarabaeidae)

Identification: The adult of *S. indica* is shiny beetle, about 10 mm long and 3 mm wide. The larvae are C shaped, slow movers having globular head and elongated, dorso-ventrally flattened body. Population takes place in the larval tunnel. Adults of *Holotrichia* spp. are about 18-20 mm long and 7-9 mm wide. The eggs are white, almost round. The young grubs are translucent, white and 5 mm long (Jasani, 2009).

Life cycle and damage: grubs are one of the major soil pests of groundnut. They are polyphagous and both adults and larvae are damaging stages. The females lay eggs singly on the main stem. The grubs live in soil and remain active, feed on the functional roots of the plant, leaving behind only tap root. They also burrow into the stem, close to the soil surface and kill the plant. Grub infested plants turn pale, leaves and branches drop down, the plant withers and can be easily uprooted. It ultimately dies off resulting in patchy crop growth (Jasani, 2009; Umeh et al., 2001).

Monitoring: install light traps in the field; with the onset of rains the beetles come out of the soil and attract to the light so count the number of beetles per day. Also, dig 10 pits per ha in 100 × 100 × 20 cm and count the number of beetles per pit every day (Jasani, 2009).

Economic and action thresholds: the economic threshold in south-central India for white grubs is observation of 0.14 larvae m⁻² (Anitha et al., 2005).

Control: planting tolerant varieties; deep ploughing in the summer; manual destruction of infested plant stems; treatment of the seeds before sowing with Chloropyrifos can control grubs population and their damage. The seeds can further be treated with fungicides like Thiram. Applying carbofuran granules in the planting row can be effective (Jasani, 2009).

3.8 *Diabrotica undecimpunctata howardi* (Barber) (Coleoptera: Chrysomelidae)

Identification: adults are greenish-yellow beetles and have 12 irregular black spots on their backs. Eggs are about 0.5 mm long, oval and yellow. The damage to peanuts, however, is caused by the whitish-clear tender looking larvae. The larvae are 12-19 mm long and have a dark head, and a small dark spot at the rear (Mossler & Aerts, 2009).

Life cycle and damage: The southern corn rootworm female lays 200-1200 eggs in the soil near host plants. They usually hatch in 1-2 weeks, depending on the temperature. Larvae damage peanuts by feeding on the pods and pegs in the soil. These pests tend to be a problem more often in damp weather and on heavier type soils; however, it can occur in sandy soils. Larvae develop over about 2-4 weeks. They then pupate in the soil and adults emerge about 1-2 weeks later. Adults may also be vectors of plant pathogenic bacteria and viruses, e.g. *Pantoea stewartii* subsp. *stewartii* (synonym: *Erwinia stewartii*) (Linker et al., n.d.).

Monitoring: monitor after pegging with a hand trowel or small spade to unearth the nuts under 2-3 row feet of plants (without digging up the plants). Monitor randomly, but check low, moist spots or areas of heavier soil where plants are most likely to show signs of damage. Examine the pegs and pods for small holes and signs of boring (Linker et al., n.d.).

Economic and action thresholds: no threshold has been set for rootworm. However, if 10% of samples showed live larvae or fresh damage, treatment is advised (Linker et al., n.d.).

Control: management of this pest can be quite frustrating because it feeds underground. Early-planted fields or crop rotated ones are at less risk from damage. Apply insecticides such as Chlorpyrifos if the threshold is exceeded (Mossler & Aerts, 2009).

3.9 *Stomopteryx submissella* (Frey) and *Aproaerema modicella* (Deventer) (Lepidoptera: Gelechiidae)

Identification: The moth of *S. submissella* is brownish gray, 6 mm long with 10 mm wing span. The eggs are shiny white. The larvae are about 1 mm long at first and enlarge as the larvae grow. Pupation takes place in the webbing (Jasani, 2009). *A. modicella* moths are brownish grey, 6 mm long with 10 mm wing span. Forewings have white spot on the costal margin. The larvae are green in color with dark head and prothorax (TNAU, n.d.-c).

Life cycle and damage: leaf miner is one of the most important pests of groundnut. The females lay eggs singly underside of the leaflets. Young larvae initially mine into the leaflets, feed on the mesophyll and form small brown blotches on the leaf. Afterward larvae web the leaflets together and feed on them, remaining within the folds (Jasani, 2009). In the USA plant resistance has been confirmed to the *A. modicella* (Lynch, 1990).

Monitoring: monitor moths by pheromone trap, 1/ha or light trap 12/ha. Also, count the number of larvae on randomly selected plants in the field (Jasani, 2009).

Economic and action thresholds: Economic threshold is 2-3 larvae per plant or 10% leaflets damaged in central whorl (Bhubaneswar, 2008; Jasani, 2009).

Control: planting of cowpea or soybean as trap crop; crop rotation with non leguminous crop is advised and rotation with leguminous crops should be avoided. There are some resistant or tolerant varieties that can be planted. Egg masses and early instars larvae can be collected and destroyed manually. Also, installation of pheromone traps for mass trapping is one of the mechanical control techniques of leaf minor. *Trichogramma Chilonis* (Ishii) is special biological control agent of the minor in groundnut. *Pennisetum glaucum* (L.) enhanced the parasitoid *Goniozus* spp. on leaf miner. Applying insecticides is recommended if the insect population crosses the ETL. Carbaryl 50WP, Quinalphos 25 EC, Methyldemeton 25 EC or Dimethoate 30 EC are effective against leaf minor (Jasani, 2009; TNAU, n.d.-c).

3.10 *Spilosoma (Diacrisia) obliqua* (Walker) (Lepidoptera: Arctiidae)

Identification: Bihar hairy caterpillar moth is brown with a 40-50 mm wing span and a red abdomen. Eggs are light green spherical in clusters on the underside of leaves. The larvae are covered with long yellowish to black hairs and are up to 5 cm long. The pupa forms a thin silken cocoon by interwoven shed hairs of the larvae (Jasani, 2009; TNAU, n.d.-c).

Life cycle and damage: each female lays 533-1287 eggs and the eggs hatch after about 6-9 days. Larval and pupal stages lasted 34-45 and 16-22 days, respectively, giving a total life cycle of 59-76 days. Young larvae feed gregariously on the under surface of the leaves and cause loss by way of defoliation. Sometimes, after defoliated the crop larvae feed on the capsules. In severe cases only stems are left behind. Pupation takes place in the soil under dry foliage and debris where the pupae overwintering (Jasani, 2009; TNAU, n.d.-c). They also severely damage other oilseeds such as sunflower.

Monitoring: monitor the flight intensity of the male moth by using pheromone traps 5/ha and determine the percentage of crop defoliation (TNAU, n.d.-c).

Economic and action thresholds: economic threshold is when 20-25% defoliation is observed (Bhubaneswar, 2008).

Control: deep ploughing in the pre-monsoon (two/three times) will expose the hibernating pupae to sunlight and predatory birds. Removal and destruction of alternate wild hosts which is the harbor of caterpillars can be effective method of controlling *S. obliqua*. Also, planting trap crops like cowpea, castor and Jatropha on field bunds to attract the caterpillars may be efficient. Setting up bonfires on field bunds during night, mass collection and destruction of eggs and emerged larvae are mechanical ways of controlling hairy caterpillars. Spraying B.t is also advocated at 1 kg/ha where mulberry is not grown. Application of insecticides should be considered if the threshold is exceeded. Dust Lindan 1.3% and Fenvalerate 0.4% can use in the early stage of larvae. In addition, spraying Quinalphos 25 EC, Chlorpyrifos 20 EC or Endosulfan 35 EC recommended when the caterpillars are younger (Jasani, 2009; TNAU, n.d.-c).

3.11 *Amsacta albistriga* (Walker) (Lepidoptera: Arctiidae)

Identification: the moths emerge from the soil at the onset of the south-west monsoon. They are brownish-white moths with a 40-50 mm wing span. The larvae are light brown and turn reddish as they grow. They are haired and are up to 5 cm long (Jasani, 2009).

Life cycle and damage: Females lay around 800-1000 eggs in clusters of 50-100 on the host plants. The eggs hatch in 2-3 days and tiny first instar caterpillars remain under the cover of natural vegetation for about 8-10 days. A week to 10 days old caterpillars spreads to the fields and start feeding. Red hairy caterpillars cause defoliation of the crop as they are voracious feeders and often migrate from one field to another devastating whatever crops come their way. After about 30-40 days of feeding the larvae burrow into soil, usually in the undisturbed soil of field or non-cropped areas and pupate for diapauses. They have one generation in a year (Jasani, 2009; TNAU, n.d.-c).

Monitoring: monitor by erection of 12 light traps per ha for 20-45 days (Jasani, 2009).

Economic and action thresholds: Economic threshold is when 15-20% of plants are affected.

Control: there are different methods for managing this pest. The cultural techniques are: deep ploughing in summer to expose the pupae to predatory birds; early sowing to escape crop from pest infestations; mechanical weeding at 15-20 days after sowing; and intercropping one row of castor for every 5 or 6 rows of groundnut. Crop rotation with sorghum, pearl millet or maize should be followed. Vegetative traps utilizing jatropa (wild castor) or ipomoea prevent the migration of the grown up larvae. Irrigate once to avoid prolonged mid season drought to prevent pre-harvest infestation. Install light traps in endemic areas, collect then kill the moths. Collect and destruct egg masses in the fields around light trap areas. Red hairy caterpillar can be controlled biologically by releasing *Coccinella* sp., and parasitoids like *Bracon hebetor* (Say), *Chelonus* spp. Also, spraying A-NPV and B.t can reduce the *A. albistriga* population and if the threshold is exceeded applying insecticides is recommended. Methyl parathion 2%, Fenvalerate 0.4%, Endosulfan 35 EC, Quinalphos 25 EC, Nuvan (76%) can control full grown insect pests (TNAU, n.d.-c).

3.12 *Spodoptera litura* (F.) (Lepidoptera: Noctuidae)

Identification: Tobacco bud worm moths are light brown with a wing span of about 30 mm and mottled forewings. The eggs are laid in the masses about 4 × 7 mm and appear golden brown on the upper surface of leaves. Young larvae are light green in color. Full grown larvae are stout, cylindrical and pale greenish brown with dark markings. The pupae are reddish brown and are found in the soil close to the plant (Jasani, 2009).

Life cycle and damage: females lay around 2000 eggs on the abaxial surface of groundnut leaves, in batches of 200-300 each. The larval and pupal periods take about 20 and 7-10 days, respectively. Freshly hatched larvae feed gregariously, scraping the chlorophyll, and they disperse very soon. Larvae feed mostly during night time. Later stages feed voraciously on the foliage at night, hiding usually in the soil around the base of the plants during the day. Sometimes the feeding is so heavy that only petioles and branches are left behind. In light soil, caterpillar bores into the pods. The total life cycle is completed in 30 days and there may be as many as 12 generations annually in southern India (Jasani, 2009; Mallikarjuna et al., 2004). Peanut and its wild species have three flavonoids chlorogenic acid, quercetin and

rutin which are involved in the components of resistance to *Spodoptera* species (Mallikarjuna et al., 2004). They also severely damage other oilseeds such as sunflower.

Monitoring: pheromone trap can use for monitoring *S. littoralis* (5 per ha).

Economic and action thresholds: economic threshold for this pest is 20-25% defoliation of the crop (Bhubaneswar, 2008).

Control: some cultural techniques for controlling *S. litura* are: deep summer ploughing; early sowing to escape from insect pest damage; once irrigation to avoid prolonged mid-season drought; planting castor or sunflower plants as trap crop for egg laying and destroying eggs or first stage larvae. Also, mechanical techniques are: installation of light traps; mechanical weeding at 15-20 days after sowing; collection of egg masses or early instars larvae from trap crops. *S. litura* can be controlled biologically by *Telenomus remus* (Nixon), *Apanteles africanus* (Cameron), *T. chilonis* and *B. hebetor* or by spraying SNPV, B.t., insect pathogenic fungus *Nomuraea rileyi* (Farlow). B.t is occasionally used to manage early instar lepidopteran larvae pests. If the insect population crosses ETL applying insecticides are advised. Methyl parathion 2% dust, Monocrotophos 36 SL, Quinolphos 25 EC, Endosulfan 35 EC, and Trizophos 40EC are effective against tobacco bud worm. Poison baits with Monocrotophos 36 SL or Carbaryl, rice bran, jaggery and water can use to control the grown up larvae (Jasani, 2009; Mossler & Aerts, 2009). Also, Sahayaraj & Martin (2003) stated that *Rhynocoris marginatus* (F.) significantly reduced *S.litura* population (85.89%).

3.13 *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidea)

Identification: refer to the section on identification of *H. armigera* for cotton.

Life cycle and damage: it is known as gram pod borer. Female lays the eggs singly on young leaves and flower buds. Larvae feed on the foliage, prefers flowers and buds. When tender leaf buds are eaten symmetrical holes or cuttings can be seen upon unfolding of leaflets. Pupate is formed in the soil (Jasani, 2009).

Monitoring: sex pheromone traps can use for monitoring adult male population (Jasani, 2009).

Economic and action thresholds: economic threshold is the presence of two eggs or one larva per plant (Chaturvedi, 2007).

Control: ploughing deeply in summer; releasing *T. chilonis*, *Chrysoperla carnea* (Stephens), and the reduviid predator *R. marginatus* are effective for protecting groundnut from pest infestations. Application of safe chemical insecticides is recommended only if the insect population crosses the ETL. Endosulfan, Monocrotophos, Quinolphos, or Chloropyriphos is found effective (Jasani, 2009; Sahayaraj & Martin, 2003).

3.14 *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae)

Identification: The lesser cornstalk borer is small and slender with alternating green and brown bands on its body. The eggs are oval about 0.6 mm long and 0.4 mm wide. When first deposited, they are greenish, soon turning pinkish, and eventually reddish. The larvae have brown and blue (or tan) alternating rings down the body. The pupae are yellowish initially turning brown and then almost black just before adults emerge. Pupae are about 8 mm long

and 2 mm wide and the cocoons measure about 16 mm in length and 6 mm in width (Gill et al., 2008; Mossler & Aerts, 2009).

Life cycle and damage: The female deposits nearly all her eggs below the soil surface adjacent to plants. The eggs hatch in two to three days. The larvae live in the soil, constructing tunnels from soil and excrement tightly woven together with silk. Lesser cornstalk borers frequently attack seedlings emerging from the ground or shortly thereafter. It is an erratic pest with outbreaks and plant damage usually occurring during dry periods on sandy soils. The larvae also can be a severe problem from pegging time until harvest. They construct a cocoon of sand attached to the pod or stem at the point of penetration. Normally there are six instars, but the number of instars can range from five to nine depending on environmental conditions. At larval maturity, caterpillars construct pupal cells of sand and silk at the end of the tunnels. Pupa develops about 9 to 10 days, with a range of 7 to 13 days. *E. lignosellus* overwinter as larvae or pupae in the soil. This species has three or four generations annually (Gill et al., 2008; Mossler & Aerts, 2009).

Monitoring: monitor stems and lateral limbs for webbing and live larvae. For scouting the pest, monitor higher, drier parts of the field, plants on the end of rows, and those without adjacent plants. Also, determine the percentage of damage to the crop (Linker et al., n.d.).

Economic and action thresholds: economic threshold is when 10% of the monitored samples are affected (Linker et al., n.d.).

Control: Outbreaks occur during periods of hot and dry weather. Rainfall or irrigation will greatly reduce the threat of damage. Keeping the land free of weeds and grass for several weeks before planting; and earlier planting may prevent late season losses. Liquid insecticides directed at the base of host plants or granules applied to the soil can be effective but hot, dry conditions often reduce the longevity of registered insecticides (Gill et al., 2008).

Groundnuts are stored both as unshelled pods and as kernels for different uses. Some of the groundnut pests may infest kernels in storages. The ones which attack whole kernels in storages usually develop and feed inside the kernels of grain. These pests are not usually capable of existence outside the grain kernel as immature insects. Examples of whole grain pests are the rice weevil, *Sitophilus oryzae* (L.); the granary weevil, *Sitophilus granarius* (L.); and the lesser grain borer, *Rhyzopertha dominica* (F.). Other insect pests which attack stored groundnut are usually unable to penetrate whole grain. These insect pests however, can attack grain after it has been either mechanically broken or attacked by whole grain insects. Examples of these secondary pests are the confused flour beetle, *Tribolium confusum* (Jacquelin du Val.); red flour beetles, *Tribolium castaneum* (Herbst); Indian meal moth, *Plodia interpunctella* (Hubner); almond moth, *Ephestia cautella* (Walker); and the sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.) (Fig. 3) (Koehler, n.d.). *Caryedon serratus* (Olivier) is the only major pest of groundnut that infests unshelled nuts (Ranga Rao et al., 2010).

Monitoring: monitoring pests in silos and storages should be done once in fortnight; so remedial measures can be taken as soon as infestation is noticed. Insect traps (sticky traps, light traps, pitfall traps, and pheromones) are effective in detecting insects which are placed either indoors or outdoors. However, estimating insect's population is difficult from a trap because some of the insects are inside the kernels and cannot be trapped. So, the symptoms of damage should be considered too (Koehler, n.d.; Ranga Rao et al., 2010).

Table : Economically important insect pests of groundnut in storage.	
Latin name	Common name
<i>Abasverus advena</i> (Waltl.)	Foreign grain beetle
<i>Alphitobius diaperinus</i> (Panzer)	Lesser mealworm
<i>Araecerus fasciculatus</i> (De Geer)	Coffee bean beetle
<i>Attagenus megatoma</i> (L.)	Black carpet beetle
<i>Carpophilus dimidiatus</i> (F.)	Corn sap beetle
<i>Caryedon serratus</i> (Olivier)	Groundnut bruchid
<i>Corcyra cephalonica</i> (Stainton)	Rice moth
<i>Cryptolestes pusillus</i> (Schoenherr)	Flat grain beetle
<i>Dermestes lardarius</i> (Linnaeus)	Carpet beetle
<i>Elasmolomus sordidus</i> (F.)	Pod sucking bug
<i>Ephestia cautella</i> (Walker)	Almond moth
<i>Lasioderma serricorne</i> (F.)	Cigarette beetle
<i>Latheticus oryzae</i> Waterhouse	Longheaded flour beetle
<i>Liposcelis</i> sp.	Booklouse – several species
<i>Necrobia rufipes</i> (De Geer)	Checkered beetle
<i>Oryzaephilus mercator</i> (Fauvel)	Merchant grain beetle
<i>Oryzaephilus surinamensis</i> (L.)	Saw-toothed grain beetle
<i>Plodia interpunctella</i> (Hubner)	Indian meal moth
<i>Sitophilus oryzae</i> (L.)	Rice weevil
<i>Stegobium paniceum</i> (L.)	Drugstore beetle
<i>Tenebrio molitor</i> L.	Yellow mealworm
<i>Tenebroides mauritanicus</i> (L.)	Cadelle
<i>Tribolium castaneum</i> (Herbst)	Red flour beetle
<i>Tribolium confusum</i> Jacquelin du Val	Confused flour beetle
<i>Trogoderma</i> sp.	Khapra beetle
<i>Trogoderma granarium</i> Everts	Khapra beetle
<i>Trogoderma inclusum</i> LeConte	Larger cabinet beetle
<i>Typhea stercorea</i> (L.)	Hairy fungus beetle

Fig. 3. Stored product insect pests of ground nut (Ranga Rao et al., 2010).

Control: sanitize and clean up the empty storage bins by spraying Malathion, or Cyfluthrin thoroughly of waste materials such as old grain, trash, or feed sacks that may furnish living quarters for insects. Clean dry grain may be protected with Pirimiphos-methyl or (S)-Methoprene (DIACON II). Grain treated with protectants should be inspected at monthly intervals to guard against the possibility of infestation. Also, after storing the grain the surface would be treated with Diatomaceous Earth, Diacon II, Pirimiphos-methyl, or Dipel Dust. Fumigation of stored grain with different insecticides such as Detia, Fumitoxin, Gastion, Gastoxin, Phostek, Phostoxin, Quick Phos, carbon dioxide, chloropicrin, or

magnesium phosphide is recommended if the entire mass of the product is infested (Koehler, n.d.; Ranga Rao et al., 2010).

Caryedon serratus is probably the major pests of stored groundnuts introduced here:

3.15 *Caryedon serratus* (Oliver) (Coleoptera: Bruchidae)

Identification: Groundnut borer adult is 4 to 7 mm long, with small black markings on the elytra. It is readily distinguished from other pests of groundnuts by its very broad hind femur, serrate antennae and elytra that do not completely cover the abdomen (Ranga Rao et al., 2010).

Life cycle and damage: It is the only species that can penetrate intact pods to infest the kernels. Infestation of the harvested groundnuts can occur while the crop is being dried in the field, stored near infested stocks or crop residues. Females attach their eggs to the outside of pods or kernels and incubation period is about 4 to 6 days. The first instar larva hatches and burrows directly through the pod wall to reach the kernel, where the larva feeds and develops. Each larva feeds solely within a single kernel. A single larva can make a large excavation in the cotyledons, but no sign of damage is visible externally at this stage. Mature larvae emerge partially or completely from the pod and construct an oval papery cocoon. The life cycle of *C. serratus* is about 60 days under optimum conditions of 30°C and 70% r.h.

3.16 *Bandicota bengalensis* (Kok.); *Rattus meltada pallidior* (gray); *Tatera indica* (Hardwicke)

Among the oil seed crops groundnut often suffers severe attack by rodents. Rodents damage both the standing crop and stored products. They damage the whole or the branches of the plant during burrowing and remove the pods at the mature and harvesting stages and take them into their burrows. *B. bengalensis* is the most predominant and widespread pest of agriculture in wet and irrigated soils. In dry land *T. indica* and then *R. meltada* are the predominant rodent pests. The chronic damage ranging from 2% to 15% persists throughout the country and severe damage, sometimes even up to 100% loss of the field crop (Ghewande & Nandagop, 1997).

Control: clean cultivation; proper soil tillage; crop scheduling; barriers; repellents and proofing are cultural techniques which may reduce rodent damages. Control weeds, which are an important component of the rodents diet. Apply rodenticides like poison baiting of rodents with zinc phosphide; and fumigation with aluminium phosphide are common in agricultural fields (Parshad, 1999).

3.17 Crows (*Corvus splendens* Vieillot), Pigeons (*Columba livia* Gmelin) and Black ibis (*Psaubis papillasa* Temminck)

Birds are relatively less important as pests of groundnut except pigeons and crows, which eat the freshly sown seeds leading to large gaps in the field (Ghewande & Nandagop, 1997). Brooks et al., (1988) assess 164 fields selected along road transects in Pakistan for vertebrate pests loss of groundnut. Lesser bandicoot rat (*Bandicota bengalensis* Gray) and the short-tailed mole rat (*Nesokia indica* Gray) were the most important. They often remove groundnut pods below ground without killing or otherwise damaging the plants. Also, the wild boar (*Sus scrofa* L.), desert hares (*Lepus nigricollis* Blanford); crested porcupines (*Hystrix indica* Kerr) and house crows (*Corvus splendens* Vieillot) cause damage and loss to the crop.

4. Soybean

Glycine max (L.) Merrill: known as Soya bean or soybean; about 35% of the world's production is in the United States, 27% Brazil, 19% Argentina, 6% China and 4% in India (Wikipedia, 2011e).

4.1 *Tetranychus urticae* (Koch) (Acari: Tetranychidae)

Identification: refer to the identification section of *T. urticae* in cottonseed.

Life cycle and damage: The mites generally over-winter as adult females in sheltered areas, such as plant debris and field margins. As the weather turns warm, mites become active in search of food and egg laying sites. Spider mites disperse by crawling, so infestations tend to spread slowly from field edges. *T. urticae* can complete up to seven generations in soybean per year (with generation development overlapping). Mites feed on individual plant cell contents on the underside of leaves. Each feeding site causes a stipple and severe stippling causes yellowing, curling and bronzing of the leaves. Eventually, the leaf will dry up and fall off (OMAFRA, 2011).

Monitoring: monitoring should be done weekly with shaking leaves onto a white piece of paper to see the actual mites moving around (OMAFRA, 2011).

Economic and action thresholds: action threshold is when four or more mites is observed per leaflet or one severely damaged leaf per plant prior to pod fill (OMAFRA, 2011).

Control: drought-tolerant varieties will minimize the effect of *T. urticae*. If number of mites exceed the action threshold, application of an acaricide may be necessary (OMAFRA, 2011).

4.2 *Thrips palmi* (Karny) and *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae)

Identification: for identification *T. palmi* refer to the cotton. *F. schultzei* adults are brown, although some specimens are yellow with eight antennal segments; ocellar setae III located between the posterior hind ocella; ostocular seta I present; pronotum with posteroangular setae are slightly longer than posteromarginal setae; campaniform sensilla absent; tergite VIII with posteromarginal comb of microtrichia weakly developed (Viteri et al., 2010).

Life cycle and damage: Females of *F. schultzei* insert their eggs in flower tissue so they are known as flower thrips. Nymphs and adults feed in growing points and inside flowers. Thrips damage can result in flower abortion and pod distortion. It has two larval instars and two inactive and non-feeding stages (Bailey, 2007). In drier conditions *F. schultzei* species were collected in higher proportion on leaves and flowers. *T. palmi* can transmit tospovirus and *F. schultzei* transmit tobacco streak virus (TSV) and tobacco ringspot virus (TRSV) to soybean.

Monitoring: monitoring should be done from emergence until plants have six to eight true leaves. Shake plants on the soil or cloth and count the number of adults and larvae. At least 20–30 plants should be sampled randomly from across the field (Bailey, 2007).

Economic and action thresholds: action threshold is observation of more than four to six thrips per flower (Bailey, 2007).

Control: thrips can be controlled biologically by pirate bugs, lacewing larvae, ladybirds, *Amblyseius cucumeris* (Oudemans) and *Amblyseius swirskii* (Athias-Henriot). If the threshold is exceeded application of systemic pesticides such as Dimethoate can reduce thrips population (Bailey, 2007).

4.3 *Aphis glycines* (Matsumura) (Homoptera: Aphididae)

Identification: The soybean aphids are small, pale yellow with black cornicles and a pale yellow tail. Adults may be winged or wingless. Nymphs are smaller than adults and wingless. Eggs are small, spherical and yellow when first laid but turn a dark brown.

Life cycle and damage: females usually lay eggs along the seams of the buckthorn bud. In the spring, nymphs hatch and aphids undergo two generations as wingless females on the buckthorn. The third generation develops into winged adults that migrate to soybean plants. The aphids then continue to produce wingless generations until the soybean plants become crowded with aphids and the plants experience a reduction in quality. Then, winged forms are produced to disperse to less-crowded soybean plants. There can be as many as 18 generations of aphids per year on soybeans. Males are only born in the fall so that the females and males can mate to produce the egg on buckthorn. Aphids suck the sap from leaves and stems of the crop. At high populations, aphids can cause the plants to abort flowers, become stunted, reducing pod and seed production and quality. Aphids also excrete honeydew, which can act as a substrate for grey sooty mould development. The soybean aphid may also be a vector of soybean mosaic virus (OMAFRA, 2011).

Monitoring: Monitoring should be done until the soybean is well into the R6 stage. Scout weekly; or as if the populations approach the threshold monitor more frequently (every 3-4 days). Monitor 20-30 random plants across the field and estimate the number of aphids per plant in that field (OMAFRA, 2011).

Economic and action thresholds: The threshold is 250 aphids per plant and actively increasing on 80% of the plants from R1 up to the R5 stage of soybeans (OMAFRA, 2011).

Control: some of the soybean cultivars such as 'Dowling', 'Jackson', and 'Palmetto', showed resistance to aphids. Insidious flower bug, (*Orius insidiosus* (Say)), twospotted lady beetle (*Adalia bipunctata* L.), sevenspotted lady beetle (*Coccinella septempunctata* L.), the spotted lady beetle (*Coleomegilla maculata* De Geer), the polished lady beetle (*Cycloneda munda* (Say)), the multicolored Asian lady beetle (*Harmonia axyridis* (Pallas)), the convergent lady beetle (*Hippodamia convergens* Guérin-Méneville), and the thirteen spotted lady beetle (*Hippodamia tredecimpunctata* L.) can biologically control the aphids. Also, pathogenic fungi including *Pandora neoaphidis* (Remaud. et Henn.) Humber, *Conidiobolus thromboides* Drechsler, *Entomophthora chromaphidis* Burger et Swain, *Pandora* sp., *Zoophthora occidentalis* (Thaxter) Batko, *Neozygites fresenii* (Now.) Remaud. et Keller, and *Lecanicillium lecanii*, (Zimm.) Gams et Zare cause infection in an outbreak aphid population (Nielsen & Hajek, 2005).

4.4 *Bemisia tabaci* biotype B (Genn.) (Hemiptera: Aleyrodidae)

Identification: refer to the identification of *B. tabaci* in cotton section.

Life cycle and damage: The B-biotype is a pesticide-resistant strain of *B. tabaci*. The female lays eggs on younger leaves. Nymphal activity is further down the plant about 5-7 nodes below the plant top. All stages (unlike eggs) secrete large amounts of sticky honeydew and sooty mould develops on honeydew reduces photosynthesis of the leaves. Severe infestations in young plants can stunt plant growth and greatly reduce a crop's yield potential. Later infestations can reduce the number of pods set, seed size, and seed size uniformity, thus reducing yield and quality. However, pod and seed discolouration are a major marketing problem where pods are picked green (Brier, 2011).

Monitoring: monitor eggs and young nymphs from uppermost and youngest leaves; and older nymphs and pupae from older leaves. Yellow sticky traps can use for sampling adults. The presence of honeydew and sooty mould may also indicate *B. tabaci* attack.

Economic and action thresholds: No action threshold has been set for *B. tabaci* on soybean.

Control: avoid successive plantings of summer pulses to prevent movement from early to late crops. Control weed hosts such as rattlegod and milk thistle; and irrigate crops to reduce moisture stress. Also, overhead irrigation washes honeydew off leaves, lessening the risk of sooty mould. Nymphs are biologically controlled by *Encarsia* sp. and *E. mundus*. No pesticides are specifically registered for controlling *B. tabaci* (Brier, 2011).

4.5 *Nezara viridula* (Linnaeus), *Euschistus servus* (Say) and *Acrosternum hilare* (Say) (Hemiptera: Pentatomidae)

Identification: they are known as Southern green stink bug (SGSB), brown stink bug (BSB) and green stink bug (GSB), respectively. All stink bug adults are shield-shaped. Green and southern green stink bugs are bright green and measure 14-19 mm long. The major body regions of the GSB are bordered by a narrow, orange-yellow line. BSB is dull brownish-yellow in color and 12-15 mm long. At first eggs are barrel-shaped and for the SGSB; they are creamy, cylindrical eggs of the measure 1 by 0.75 mm and develop a pinkish hue before hatching. The eggs of BSB are white, kettle-shaped, and slightly smaller than those of the green stink bug. Eggs of the green stink bug are yellow to green, later turning pink to gray and about 1.4 x 1.2 mm. The nymphs of all three species are smaller than adults, but similar in shape. Nymphs of the BSB and SGSB are light green. For SGSB, however, nymphs have two series of white spots along their backs. GSB nymphs are black when small, but as they mature, they become green with orange and black markings. The nymphs remain clustered near the remains of the eggs (Bijlmakers, 2008; Gomez & Mizell, 2008). *A. hilare* can be differentiated from the *Nezara* spp. by its elongated ventral ostiolar canal (external outflow pathway of metathoracic scent gland), which extends well beyond the middle of its supporting plate, while that of *N. viridula* is shorter and does not reach the middle of supporting plate. *A. hilare* has black outermost three antennal segments (Wikipedia, 2011c).

Life cycle and damage: stink bugs overwinter as adults and they become active during the first warm days of spring when temperature rises above 21°C. Adults are strong fliers and will readily move between weeds and other alternate hosts where they complete their first generation. They are attracted most often to plants with growing shoots and developing seeds or fruits. Stink bugs tend to move from host to host as peak reproduction of earlier hosts passes and that of their plants approaches. Both nymphs and adults attack primarily the seeds and pods of soybean. The degree of damage depends to some extent on the

developmental stage of the crop. They also will feed on soybean stems (Olson et al., 2011). Female of the *N. viridula* lays about 300 eggs on the underside of the leaves and stuck them together in batches of 50-60. After the eggs hatch, nymphs disperse and start feeding. However, the first instar nymphs don't feed. SGSB is the major pod-sucking bug in soybeans due to its abundance, widespread distribution, rate of damage and rate of reproduction. Adults prefer pods with well-developed seeds and nymphs are unable to complete their development prior to pod-fill. They can damage soybeans until pods are too hard (i.e. very close to harvest). Damage to young pods cause deformed and shrivelled seeds and reduce yield. Damaged seeds in older pods are blemished and difficult to grade out, which reduce harvested seed quality. *N. viridula* also damages buds and flowers (Bijlmakers, 2008; Brier, 2011). In *E. servus* reproductive diapauses, they color change from green to reddish-brown. Reddish-brown insects lived longer than green ones and laid no eggs. However, green females lay about 18 egg masses; after approximately four to five weeks eggs hatch and form the nymphs. The nymphs have five instars and after about 29 days they develop to the adult. Pod is pierced or kinked and seed is dimpled or blemished. *E. servus* has as many as four to five or more generations per year in Florida but only two generations a year in southeastern USA. However, *N. viridula* can stay in peanut for their third generation, or leave maize for full-season soybean or cotton where they produce their third or even fourth generation. Both SGSB and BSB preferred soybean significantly more often than B.t. cotton, non-B.t. cotton, and peanut (Gomez & Mizell, 2008; Olson et al., 2011).

Monitoring: monitor twice weekly from flowering until close to harvest. Beat sheet sampling is the most efficient monitoring method with at least six sites for adults or 10 sites for nymphs. The standard sample unit consists of five one-metre non consecutive lengths of row within a 20 m radius (Brier, 2011). Sweep net and ground cloth procedures are common sampling methods. Place one four-foot cloth per location and record the number per four-foot sample. In the case of sweep net; use a 15 sweep net and take a series of twenty five sweeps at each location (Johnson et al., 2009). Stink bug trap with the aggregation pheromone is also way of monitoring and capturing the bugs (Gomez & Mizell, 2008).

Economic and action thresholds: economic thresholds depends on the crop size (seeds per m²) and when bugs first infest a crop. The maximum bug damage permitted being only 2% or for *N. viridula* when the adults number ranges from 0.3-0.8/m² (Brier, 2011).

Control: control during early pod-fill before nymphs reach a damaging size. Avoid sequential plantings of summer legumes as bugs population will move from earlier to later plantings. Avoid cultivar and planting time combinations that are more likely to lengthen the duration of flowering and podding. *Trissolcus basalis* (Wollaston), and *Trichopoda giacomellii* (Blanchard) may control stink bugs (Brier, 2011). *A. hilare* is parasitized by the tachinid fly, *Trichopoda pennipes* (F.). The pheromone methyl (E,Z,Z)-2,4,6-decatrienoate may be used to attract the bugs away from fields (Wikipedia, 2011c). Also, trap crops baited with pheromone to catch females for destruction, or even a pheromone-based disruption of orientation behavior to decrease the mating success, are possible semiochemical techniques to suppress populations of *E. servus* second generation (Borges et al., 2001).

4.6 *Piezodorus oceanicus* (Montrouzier) (Hemiptera: Pentatomidae)

Identification: The red banded shield bugs are similar in shape to *N. viridula* but smaller, paler and with pink, white or yellow bands. Eggs ringed by small spines and have a central

pale band. Newly hatched nymphs are orange with black markings. Larger nymphs are pale green with dark red and brown in the centre of their back and late nymphs may turn to the pale pinkish brown. It was previously classified as *Piezodorus hybneri* (Gmelin), and recently as *P. grossi* (Ahmad) or *P. grossi* (Staddon) (Bailey, 2007; Brier, 2011).

Life cycle and damage: Egg rafts contain 15-40 eggs and after 4-5 days hatch. *P. oceanicus* has five nymphal stages. Nymphs usually reach a damaging size during mid to late pod-fill. Their damage is similar to *N. viridula*, with early damage reducing yields, and later damage reducing the quality of harvested seeds. *P. oceanicus* generally has four generations per year (Bailey, 2007; Brier, 2011).

Monitoring: Look for the distinctive twin-row egg rafts which indicate the presence of *P. oceanicus*. Beat sheet sampling is the efficient method for monitoring bugs (Brier, 2011).

Economic and action thresholds: no thresholds have been set for red banded shield bug.

Control: Eggs may be parasitised by *T. basalis*. No insecticides are specifically registered against *P. oceanicus* (Brier, 2011). Brier & McLennan (2006) stated that the addition of 0.5% salt (NaCl) to Decis (deltamethrin) will have a greater impact on *P. oceanicus* population. Also, high yield of the crops contributed to the lower percentage of damaged seeds.

4.7 *Oberea brevis* (Swederus) (Coleoptera: Lamiidae)

Identification: girdle beetles are yellow at first then change to red and brown on the head, thorax and bases of elytra. Larvae are white, soft-bodied with a dark head (TNAU, n.d.-c).

Life cycle and damage: The female deposits a single egg in the petiole of a leaf near the top of the plant. The larva feeds into the petiole and on down into the stem, bore the inside of the stem so it is a stem borer pest. Only one larva is present in each infested plant. The full-grown larva prepares a fibrous cocoon and pupates within the girdled portion of the stem. The adult emerges from the girdled section in 8-11 days. However, most larvae enter diapauses within the cocoon (Kapoor et al., 1972). The leaves of infected plant are unable to get the nutrient and thus are dried up. In later stages the plant is cut at about 15-25 cm above the ground (TNAU, n.d.-c). The weight of the grain from the top-cut portions of infested plants was significantly reduced in relation to that of healthy plants and their germination capacity was also seriously affected (Gangrade & Singh, 1975).

Monitoring: beetles may be collected in sweep net samples. Thereafter, look for lodged plants, which may indicate the presence of stem borer infestations. Cut, open the stem and look for the presence of the larva and its feeding damage. Also, count number of larvae and lodged plants (Boyd & Bailey, 2005).

Economic and action thresholds: Out of thirty-five genotypes studied, Awasthi et al., (2003) recorded stem tunneling (%) from 6.46 to 32.16% and the economic injury level to be 26%. In another study, Rao et al., (2007) declared 5% incidence of *O. brevis* for economic threshold.

Control: summer ploughing; avoid intercropping with maize or sorghum; crop rotation; avoid excess nitrogenous fertilizers; collecting and destroying infested plant parts and egg masses can decrease population of beetles. If the threshold is exceeded application of insecticide is recommended. Apply phorate 10 kg/ha or carbofuran 30 kg/ha at the time of sowing. Spray Endosulfan 35 EC, Dimethoate 30 EC, Quinalphos 25 EC, methyl demeton 25

EC, Monocrotophos 36 SC, Monocrolophos 36 WSC, Quinalphos 25 EC or Triazophos 40 EC at the crop age of 30-35 days and repeat after 15-20 days. Also, acephate 0.10% is effective for controlling girdle beetles from infestations (Pande et al., 2000; TNAU, n.d.-c).

4.8 *Cerotoma trifurcata* (Forster) (Coleoptera: Chrysomelidae)

Identification: The bean leaf beetle adult is 5 mm long, with or without four black spots (parallelogram shaped) on the wing covers. Adults can vary in color but are most often yellow-green, tan or red. A small, black triangle is visible at the base of the wing covers the prothorax - behind the head. The margins of the wing covers have a black border. Eggs are orange colored and lemon shaped (OMAFRA, 2011).

Life cycle and damage: Females lay eggs in small clusters in the soil at the base of the soybean plants. Newly hatched larvae feed on roots and other underground plant parts for about 30 days before pupating. Adults second generation emerges, feeds on the pods until the plants senesce. They then migrate to alfalfa fields if available or move to their overwintering sites. *C. trifurcata* overwinters in the adult stage in woodlots, leaf litter and soil debris. Defoliation injury by this pest is generally not serious and the exception is damage caused by overwintering adults to young soybean plants. Adult feeding appears as small round holes between the major leaflet veins. Cotyledons and seedling plants can be clipped off by heavier populations. They also feed on the surface of the pod, leaving only a thin film of tissue to protect the seeds within the pod. These pod lesions increase the pod's susceptibility to secondary pod diseases such as alternaria. The bean leaf beetle is a vector of bean pod mottle virus (BPMV) which causes the plant and seed to become wrinkled and mottled, reducing the quality of the seed (OMAFRA, 2011).

Monitoring: monitor from seedling stage to dry edible bean pod-fill stages. Fumigation cage, sweep net, pitfall trap and shaking over the ground cloth are the methods used for sampling. For sweep net sampling take 20-sweep samples at each sample location. Sweep as you walk down the row and calculate an average number of beetles per sweep. In the case of shaking over the ground cloth; place a two foot wide strip of cloth on the ground between the rows and shake the plants over them. Then quickly count the number of beetles. In the "seedling stage" see underside of the leaves and calculate the average number of beetles per meter of row; in the soybean "R5-R6 Stage", assess the number of pods with feeding injury or clipping; in the "prior to the dry edible bean pod-fill Stages" determine the percent defoliation that has occurred; and in the case of "dry edible bean pod-fill Stages" determine the percent of pods with feeding damage. For pod sampling collect five plant samples from each sampling location and calculate an average number of pods with holes in the pod wall per five plants (OMAFRA, 2011).

Economic and action thresholds: Thresholds for bean leaf beetle are 16 adult beetles per foot of row in early seedling stages. In V3-R4 stage of soybean; the economic threshold is when defoliation exceeds 30% and for R5-R6 stage if 10% of the pods on the plants have feeding injury and the beetles are still active in the field (OMAFRA, 2011).

Control: Seed treatment using thimethoxam and late planting date, may result in low initial population of beetles. Tachinid species, *Calatoria diabroticae* (Shimer) and *Medina* sp. can control *C. trifurcata*. Application of foliar insecticide between emergence and first trifoliate using pyrethroid has been shown to reduce beetles incidence, by protecting soybean from

overwintering beetles. Additional application of foliar insecticide (around blooming) was shown to further suppress of population. A mid-season foliar insecticide application is aimed at controlling the first generation of bean leaf beetle (Bennett et al.).

4.9 *Epilachna varivestis* (Mulsant) (Coleoptera: Coccinellidae)

Identification: Mexican bean beetles are copper to yellow, rounded with 16 black spots on their backs. Males can be distinguished from females by having a small notch on the ventral side of the last abdominal segment. The eggs are yellow about 1.3 mm long and elliptical. Larvae are yellow, oval, soft-bodied, grub like with darker, branched spines. The pupae are yellow and about 6 mm long. It moves very little, has fewer spines than the larva, and is most commonly found on the lower half of the soybean plant (Sanchez-Arroyo, 2009).

Life cycle and damage: females lay eggs in clusters of 40-75 on the undersides of bean leaves. They hatch in a week during warm weather or after at least two weeks under unfavorable conditions. The larvae are gregarious and feed voraciously for two to five weeks. The larva has five instars and attaches itself by the posterior end of the body to the underside of leaves, stems, or pods of the bean plants and often to parts of nearby plants and pupates. The pupal stage lasts 5-10 days. Adults and larvae feed on the underside of leaves and eat the softer leaf tissues. Damaged leaves appear netlike (Sanchez-Arroyo, 2009).

Monitoring: monitoring should be done weekly with directly observing the plant during early stages of growth. As the plant growth use sweep net or shaking the plants over the ground cloth for sampling *E. varivestis*. After shaking the plants quickly count number of the present adults and larvae (Sanchez-Arroyo, 2009).

Economic and action thresholds: economic threshold level ranges from 1 to 1.5 larvae per plant on beans or when 30–35% defoliation is observed prior to full bloom and 15% during pod-set and podfill (Sanchez-Arroyo, 2009).

Control: destruction of overwintering locations; late planting of the soybean crop; planting trap crops and resistant varieties are techniques that may reduce population build up. Releasing biological control agents such as tachinid fly, *Paradexodes epilachnae* (Aldrich) and the eulophid wasp, *Pediobius foveolatus* (Crawford) can control the number of *E. varivestis* beetles. If the threshold is exceeded application of systemic insecticides at planting has become a standard practice (Sanchez-Arroyo, 2009).

4.10 *Melanagromyza sojae* (Zehntner) (Diptera: Agromyzidae)

Identification: adults of stem fly are shining black and about 2 mm long. The larva which is named maggot is white in color and remains inside the stem. The egg measures about 0.34 mm in length and 0.15 mm in width. It is whitish, partly transparent and the yolk occupies one third of the central part of the egg (TNAU, n.d.-c).

Life cycle and damage: The females lay eggs on or in the leaves. Maggots bore the nearest vein of the leaf and subsequently reach the stem through petiole and bore down the stem. If the infected stem is opened by splitting, zigzag reddish tunnel can be seen with maggot or pupae inside it. The maggots feed on stem cortical, may extend to tap root, killing of the plant. The third larval instar, mine a hole to the epidermis to assist in the emergence of the adult and pupates in the stem. The pupal period lasted 6-12 days (TNAU, n.d.-c). *M. sojae*

has four or five generations per year and pupae overwinter in the stem. The infestation significantly reduced the plant height, number of branches per plant, number of trifoliate leaves, leaf area per plant and dry matter accumulation. The infestation rate ranges from 85 to 100% due to the planting dates and being higher on the late sown crop (Savajji, 2006).

Monitoring: Stem flies reached their peak in the 5th–8th weeks after planting and declined towards the end of the season. Observe percent seedling mortality, percent stem tunneling and areas of poor stand. Also, dig up some seed and examine for the presence of insects and or damage (Savajji, 2006).

Economic and action thresholds: economic threshold level is 5% plant infestation (Rao et al., 2007). However, according to (Johnson et al., 2009) there is no rescue treatment for this pest. Estimate area and amount of stand reduction for reporting in Comments. This information will be useful when making a decision on replanting.

Control: deep summer ploughing; proper crop rotation with dissimilar crops; removing and destroying the damaged plant parts can reduce the population. However, if the threshold is exceeded application of insecticides is essential. Spray monocrotophos 36 WSC twice, at the crop age of one and three weeks. In case of severe infestation, apply phorate or lindane in the soil 10 kg/ha before sowing. Soil application of phorate 10 G, 10 kg/ha or carbofuran 3 G, 30 kg/ha at the time of sowing will prevent early infestation by stem fly. One or two sprays of endosulfan 35 EC or dimethoate 30 EC or quinalphos 25 EC can stop the damage (Pande et al., 2000; TNAU, n.d.-c).

4.11 *Asphondylia yushimai* sp. n. (Diptera: Cecidomyiidae)

Identification: Soybean pod gall midge is described from Japan and at least five named and 13 undetermined species of *Asphondylia* are found in Japan. Most of the undescribed species are morphologically very similar to one another. Yukawa et al., (2003) studied the morphological characteristics of soybean pod gall midge and DNA sequencing of several *Asphondylia* gall midges. They prove that *A. yushimai* is a distinct species of the genus *Asphondylia*, identify its winter host, and outline host alternation by this gall midge.

Life cycle and damage: females lay eggs inside young pods of soybean and cause yield losses with malformation of pods by larval infestations. Soybean pod gall midge is one of the major pests of soybean in Japan, Indonesia and China. In summer and autumn, the soybean pod gall midge has two or more generations in the pods of soybean, *G. max* or wild fabaceous and caesalpiniaceous plants (Yukawa et al., 2003). *Asphondylia* sp. cannot overwinter on soybean because the host dies back in winter; whether the soybean species overwinters on another legume or host (Gagne & Woods, 1988).

Monitoring: collect the galls and count number of larvae. Color traps present a potential tactic for monitoring soybean pod gall midge or mating disruption (RADA, 2010).

Economic and action thresholds: No action threshold has been set for *A. yushimai*.

Control: Controlling weeds beneath or around the plants and removing fallen fruit from fields (bury at least 15 cm deep or burn them) may reduce the infestation of gall midge. If a field is of no further economic use, destroy completely or remove all reproductive structures at least twice weekly (RADA, 2010). Contact county Cooperative Service Extension agent or office for latest applicable insecticides.

4.12 *Spodoptera litura* (F.) (Lepidoptera: Noctuidae)

Identification: refer to the identification of *S. litura* in groundnut. *S. litura* and *S. littoralis* are morphologically similar and distinguish with close examination of the genitalia.

Life cycle and damage: females of common cut worm lay their eggs in hair-covered clusters. Newly hatched larvae are very susceptible to dry heat, usually staying on leaves lower surfaces during the day and feeding at night. The larvae damage soybean extensively by skeletalization of leaves in early stage, severe defoliation in later stage and thus reducing the photosynthetic capacity of plants. After damaging the leaves, they also start feeding on young parts, consequently damaging 30 to 50% of the pods. It has six larvae instars. Mature caterpillars pupate in earthen cells in the soil. Occasionally this insect also cuts plant stems at the soil line and feeds directly on the pods. In severe infestations, leaves are completely gone causing the plant to die (Parker et al., 2001; Santhosh, 2008).

Monitoring: monitor *S. littora* males peak with installation of pheromone traps. Look carefully at the upper and lower surfaces of the leaves to detect the presence of larvae.

Economic and action thresholds: the economic threshold is when defoliation is at or will reach 40% before R1 stage of the crop.

Control: using pheromones to mass trapping of the males by the lure and kill technique may be applied for controlling *S. littora*. Biological control of larvae by fungal pathogen, *Nomuraea rileyi* (Samson) and B.t. can suppress population builds up (Patil & Hegde, 2010). The nematodes *S. carpocapsae*, *Neoaplectana carpocapsae*, and the fly *Exorista japonica* (Townsend) are also effective against *S. litura*. If the threshold is exceeded application of insecticides, and insect growth regulators such as neem is recommended (Santhosh, 2008).

4.13 *Heliothis armigera* (Hübner) and *Heliothis punctigera* (Wallengren) (Lepidoptera: Noctuidea)

Identification: *H. armigera* is known as America bollworm and *H. punctigera* known as Australian bollworm. For identification refer to *H. armigera* and *H. punctigera* on cotton.

Life cycle and damage: *Heliothis* spp. is one of the major pests of soybean. They attack auxiliary buds and terminals in vegetative stage and defoliate the crops. Once crops reach flowering, larvae focus on buds, flowers and pods. Young larvae are more likely to feed on vegetative terminals, young leaves and flowers before attacking pods. Crops are better able to compensate for early rather than late pod damage, however in dry land crops, significant early damage may delay podding with subsequent yield and quality losses (Brier, 2011).

Monitoring: monitor eggs and moths to determine the start of infestations and increase the chance of successful control. Monitor small larvae by opening vegetative terminals and flowers. Monitoring should be done twice weekly from early budding until late podding and sample six widely spaced locations per field. Beat sheet sampling is the preferred sampling method for medium to large size larvae (Brier, 2011).

Economic and action thresholds: Before flowering and in vegetative stage, economic threshold is when 33% leaf loss is determined or approximately 7.5 larvae/m² is observed. For podding soybeans currently ETL ranges from 1-2 larvae/m² (Brier, 2011).

Control: avoiding successive plantings of summer legumes and growing vigorous plants with adequate available moisture are cultural control techniques (Brier, 2011).

4.14 *Spilosoma obliqua* (Walker) (Lepidoptera: Arctiidae)

Identification: refer to the identification of *S. obliqua* in groundnut.

Life cycle and damage: Bihar hairy caterpillar females lay their eggs in cluster on the underside of leaves. The larva is a voracious feeder which feeds gregariously on soybean leaves, on chlorophyll mostly in early instars. In later stages the larvae eat the leaves from the margin. The leaves of the plant give an appearance of net or web and in case of severe infestation, the entire crop is damaged badly thus causing 40% defoliation of leaf area (Harish, 2008; TNAU, n.d.-c). They can severely damage mustard crops too.

Monitoring: install one light trap per hectare to catch the adults of hairy caterpillar. Also, count number of larvae in the meter rows that were selected randomly (TNAU, n.d.-c).

Economic and action thresholds: ETL is observing 5 larvae per meter row (Rao et al., 2007).

Control: summer ploughing, intercropping soybean either with pigeon pea, maize or sorghum; collect and destroying infested plant parts, egg masses and young larvae are techniques that can control *S. obliqua*. If action threshold is observed application of endosulfan 35 EC, chlorpyrifos 20 EC, and trizophos 40 EC, is advised (TNAU, n.d.-c).

4.15 *Plathypena scabra* (F.) (Lepidoptera: Noctuidae)

Identification: moths are triangular when at rest and the wingspan is about 25 mm long. The female moths have charcoal-colored wings with brown and silver patches, while wings of male moths are more uniformly charcoal in color. The male moths have larger body and eyes size than the female moths. The caterpillars of green clover worm are greenish with faint white strips along the body. Sometimes the stripes are not obvious. They have four pairs of pro legs and move with a looping motion similar to the soybean looper. When disturbed, these larvae become very active and fall to the ground (Baldwin et al., 2011).

Life cycle and damage: females lay eggs singly on the underside of soybean leaves. After 3-4 days, the eggs hatch and the larvae start to feed on the leaves. The larva has 6 instars and develops in about 14 days. Green clover worms only infest foliage. They make holes in the leaves and are damaging only under very high populations or in combination with other defoliators. Last instar larvae burrow into the soil or plant debris to pupate and emerge as adults in 7-10 days to repeat the cycle (Hadi et al., 2011).

Monitoring: use ground cloth procedure, roll the cloth beneath the canopy from one row over to the next row and shake the plants on cloths. Make one four-foot shake-cloth sample per location and record the number of larvae (Johnson et al., 2009).

Economic and action thresholds: ETL is when 5.2 larvae is observed per row-foot (17 larvae per row-meter) between bloom and pod-fill. Also, if defoliation reaches 40% pre-bloom, 20% during bloom and pod-fill, or 35% from pod-fill to harvest (Hadi et al., 2011).

Control: beneficial insects and pathogens such as the fungal pathogen *N. rileyi*, B.t, parasitoid *Cotesia marginiventris* (Cresson), and *Rogas noloophanae* (Ashmead), can control

clover worms population. If the threshold is exceeded application of insecticides is advised. Azinphos-methyl, (Sniper®2-E), Carbaryl (Sevin XLR Plus), and Lorsban 4E are common chemicals labeled for green cloverworm control (Daigle et al., 1988; Gouge et al., 1999).

4.16 *Pseudoplusia includens* (Walker) (Lepidoptera: Noctuidae)

Identification: Soybean looper moth has mottled brown forewings with a bronze to golden glitter. At the center of the forewings, two prominent silver markings are usually visible. The larva is light green with several thin light lines in the body length. The body of caterpillar is largest at the rear and tapering to the head. Loopers form the characteristic hump or "loop" when crawling. They have three pairs of prolegs (Hadi & Bradshaw, 2011).

Life cycle and damage: females lay eggs on the underside of soybean leaves. After 3 days the eggs hatch and first instar larvae feed on soybean leaves. The larvae start feeding with leaves at the middle of the plants and working upward. The larvae have 6 instars. Loopers eat large holes in the leaves and, under high populations, can strip an entire field. The pupae are covered by silken cocoons attached on the underside of soybean leaves. This pest usually occurs in fields that have been previously sprayed. Soybean loopers usually reach higher populations in areas where cotton and soybeans are grown together. Their infestations is not as explosive, but they can build up to the economic threshold (Baldwin et al., 2011).

Monitoring: monitor population of moths with pheromone traps to attract, collect and count number of moths.

Economic and action thresholds: ETL is when defoliation reaches 40% pre-bloom, 20% during bloom and pod-fill, or 35% from pod-fill to harvest (Hadi & Bradshaw, 2011).

Control: Planting an early maturing soybean variety will allow the soybean crop to escape damaging populations of the loopers. Pheromone traps can use as control tools to capture insects, disrupt insect mating and as lures to attract insects to insecticidal baits. Application of foliar insecticides is advised if the threshold is exceeded (Baldwin et al., 2011).

4.17 *Anticarsia gemmatilis* (Hübner) (Lepidoptera: Noctuidae)

Identification: The moths have ash gray, light yellowish-brown, or dark reddish brown forewings and light brown hindwings with a row of light colored spots near the margin. The eggs are white, slightly oval, about 1-2 mm diameter and flattened on its lower surface. Velvetbean caterpillar is greenish, brown, or almost black caterpillars with a broad lighter band down each side. Head is prominent and yellow or orange. Caterpillars have five pairs of prolegs and the last pair looks like forked tail. When disturbed, they wiggle violently. The pupa is light green at first and turns brown then (Baldwin et al., 2011; Kathryn, 2008).

Life cycle and damage: females lay eggs on the underside of leaves or maybe on the upper surfaces of leaves, on the petioles and even on the stems. After about 3 days eggs hatch. This caterpillar eats the entire leaf and will strip whole fields when high numbers are present. They move downward and defoliate the plants if uncontrolled. It has six instar larvae and the pupae will form below the soil. The pupal stage usually lasts about 7 to 11 days due to the weather conditions. The life cycle is completed in four weeks. Pods sometimes will be attacked when defoliation is severe. Damaging populations usually limited to late-planted fields, especially double-crop soybeans (Baldwin et al., 2011; Kathryn, 2008).

Monitoring: Direct observation of caterpillars on the plant is the best method of sampling for early stages of plant growth. Sweep net, black light and pheromone traps are good indicators of moth presence. If the moths are detected, searching for eggs and larvae and counting them is the next step.

Economic and action thresholds: ETL in vegetative and flowering stage of the crop are 33% and 20%, respectively or the presence of three larvae per square meter (Bailey, 2007).

Control: planting or use of early maturing varieties of soybean, and use of trap crops are the cultural techniques appropriate for reducing pest's populations. Caterpillars can be controlled by pathogens such as NPV and B.t or the parasitoid *Winthemia rufopicta* (Bigot). Application of Dimilin at 2 ounces product per acre will provide preventive control of *A. gemmatilis*. Dimilin should be applied at the vegetative growth of soybeans and as pod formation begins (at or shortly after bloom). The probability of a velvetbean caterpillar problem is higher on later maturing soybeans (Baldwin et al., 2011; Kathryn, 2008).

5. Mustard

Brassica napus L.: known as Canola, Rapeseed, Rutabaga, and Swede.

Brassica juncea L.: known as Brown and Oriental mustards, is grown commercially in Canada, the UK, Denmark and the USA.

Brassica nigra L.: known as Black mustard, is grown in Argentina, Chile, the USA and some European countries.

Brassica alba L. or *Brassica hirta* Moench.: known as White and yellow mustards, is grown wild in North Africa, the Middle East and Mediterranean Europe.

Brassica rapa L. or *Brassica campestris* L.: known as field mustard and turnip mustard.

5.1 Snails: *Cernuella virgata* (Da Costa), *Cochlicella acuta* (Müller), *Prietocella barbara* (Linnaeus) (Eupulmonata: Hygromiidae), and *Theba pisana* (Müller) (Eupulmonata: Helicidae); Slugs: *Limax cinereoniger* (Wolf) (Eupulmonata: Limacidae) and *Deroceras reticulatum* (Müller) (Eupulmonata: Helicidae)

Identification: snails are known as common white snail, pointed snail, small pointed snail and white Italian snail, respectively. The common names of slugs are black keeled slug and reticulated slug, respectively. Shell diameter of common white snail ranges from 10 to 15 mm. The coiled white shell has a brown band around the spiral in some individuals while others completely lack this banding. The umbilicus is open and circular. Under magnification, regular straight scratches are visible across the shell. The common white snail and white Italian snail are the same just umbilicus are different and the scratching per etches on the shell. Pointed snail is fawn, grey or brown with some white markings. The shell is conical in shape. The length of the shell of a mature snail is up to 18 mm. The ratio of the shell length to its diameter at the base is always greater than two. Small pointed snail shell is fawn, grey or brown in color. The length of the shell of a mature snail is up to 10 mm. The ratio of the shell length to its diameter at the base is always two or less. The black keeled slug is longer than 20 mm and has a uniform grey to black body color. This species has a prominent ridge (keel) running along the mid-dorsal line, from the mantle to the tip of the tail. The reticulated slug is black to brown, with elongated soft and slimy body about 40-60 mm long with a ridge down its back (Bailey, 2007).

Life cycle and damage: They are hermaphrodite so both male and female can lay eggs. Eggs are laid into moist soil and hatch after 2–4 weeks. They usually become sexually mature after one year. Feeding of these pests may retard development of young crops. They destroy crops by eating roots, leaves, stems and fruits. Damage to the canola during emergence, is usually difficult to detect if seedlings are chewed to the ground. Black keeled slug feed on the soil surface, as well as below the ground where they burrow down and attack germinating seeds. Young canola seedlings are particularly vulnerable. This species is of relatively greater importance in drier areas. For reticulated slug egg clusters are laid in the top soil. After 2 weeks the eggs hatch and the juveniles feed in winter and spring and aestivate over summer to become sexually mature at one year old (Micic et al., 2007).

Monitoring: monitor snails by square sampling quadrates. Quadrates are placed on the ground, the number of snails counted and convert to snails per square meter (Bailey, 2007).

Economic and action thresholds: action thresholds is observing 5 snails per m² in emerging canola crops (Bailey, 2007). Micic et al., (2007) declared that action threshold for small pointed snail is 20 snails per m², for common white snail 5 per m², black keeled slug 1-2 per m², reticulated slug 1-2 per m² and in the case of white Italian snail it is 5 snails per m².

Control: They can be controlled by birds and lizards. A parasitic fly, *Sarcophaga penicillata* (Villeneuve) is a bio-control agent for controlling pointed snail. However, the best way is baiting but it should be done in the cool moist condition, when snails are active. As bait may have some residue contamination in kernels so it must be completed at least 8 weeks before harvest. For 5-80 snails per m² apply bait at 5 kg/ha and over 80 snails per m² apply bait at 10 kg/ha. Metaldehyde-containing baits are frequently used for snail control (Bailey, 2007).

5.2 *Lipaphis erysimi* (Kalt) (Homoptera: Aphididae)

Identification: Aphids are small, soft-bodied, pearl-shaped with a pair of cornicles projecting out from the fifth or sixth abdominal segment. Wingless female aphids are yellowish green, gray green or olive green with a white waxy bloom covering the body. The winged females have a dusky green abdomen with dark lateral stripes separating the body segments and dusky wing veins. Males are olive-green to brown in color (TIFP, n.d.-b).

Life cycle and damage: Mustard aphids infest the crops right from vegetative stage to pod stage. Both nymph and adults suck the sap from leaves, buds and pods. Curling may occur for infested leaves and at advanced stage plants may wither and die. Plants remain stunted and sooty molds grow on the honey dew excreted by the insects. The infected field looks sickly and blighted in appearance. Rainy and humid weather help in accelerating the growth of insects. They have four nymphal instars (TIFP, n.d.-b).

Monitoring: install yellow stick trap to monitor aphid population (TIFP, n.d.-b).

Economic and action thresholds: The economic threshold level for mustard aphid for different regions of India is 23–25 aphids per plant (Chattopadhyay et al., 2005).

Control: planting tolerant or resistant varieties can reduce population build up. *Cocciniella septempunctata* (L.), *Menochilus sexmaculata* (F.), *H. variegata*, *Cheilomenes vicina* (Mulsant), *Sphaerophoria* spp., *Eristalis* spp., *Metasyrphus* spp., *Xanthogramma* spp. and *Syrphus* spp. are most efficient predators of the mustard aphid (TIFP, n.d.-b).

5.3 *Myzus persicae* (Sulzer) and *Brevicoryne brassicae* (Linnaeus) (Homoptera: Aphididae)

Identification: They are known as peach potato aphid and cabbage aphid, respectively. The eggs are usually elliptical in shape, initially yellow or green, but soon turn black. Nymphs look like to the viviparous adults. Winged aphids of *M. persicae* have a black head and thorax, and a yellowish green abdomen with a large dark patch dorsally. They measure 1.8-2.1 mm in length. The wingless forms are yellowish or greenish in color and about 1.7-2.0 mm long. They may have a medial and lateral green stripes. The cornicles are moderately long, unevenly swollen along their length, and match the body in color. The appendages are pale (Capinera, 2005). Wingless females of *B. brassicae* are about 2.1-2.6 mm long oval shaped and the posterior end of the body tapers greatly. The pale green body is usually covered by white waxy powder. Underneath the wax there are eight dark brown or black spots located on the upper abdominal surface. They increase in size toward the posterior end. Winged females are a little smaller than the wingless forms and they are not covered with waxy powder. The head and thorax are dark brown to black. The yellowish green abdomen is with two dark spots on the dorsal anterior abdominal segments. Antennae are dark brown. Wings are short and stout with prominent veins (Kessing & Mau, 1991).

Life cycle and damage: Eggs of *M. persicae* are deposited on *Prunus* spp. trees, where they overwinter. After several generations when the aphid densities increased the winged forms produced and disperse to the summer hosts. However, *B. brassicae* is restricted to herbaceous Brassicaceae throughout its life cycle. They lay their eggs on the stems and leaves of cruciferous crops that remain in the field through the winter. Both of these aphids overwinter in the egg stage. Generally aphids feed by sucking sap; infested seedlings may become stunted and distorted. Continued feeding on mature plants causes wilting, yellowing and general stunting of the plants. For peach potato aphid only very heavy infestations cause direct damage. Numbers may increase after serious outbreaks of insecticide-resistant aphids on potatoes. Peach potato aphids transmit the beet western yellow virus, which causes temporary reddening of infected plants in spring. In the case of cabbage aphid, spring rape can become severely infested after mild winters and allow infestations on winter rape to increase to damaging levels. The cabbage aphid is a vector of 23 virus diseases of Brassicaceae. It carries cauliflower mosaic virus. Also, turnip mosaic virus is carried by cabbage aphid and green peach aphid (Jellis, 2003).

Monitoring: monitor weekly from flowering to grain fill of the crop. At least four sampling points of random 20 plants should be spread over the field and estimate the number of aphids per plant. Also, yellow traps can use for monitoring aphids (Bailey, 2007).

Economic and action thresholds: *B. brassicae* action threshold is if over 13% of winter rape plants or over 4% of spring rape plants are infested before petal fall (Jellis, 2003). The threshold for *M. persicae* is correspondingly lower, at 25% of plants infested (Bailey, 2007).

Control: The parasitoid, *Diaeretiella rapae* (McIntosh) normally provides good control of cabbage aphid. Insecticide resistance has been observed for *M. persicae*; so expert advice on alternative insecticides should prepare. In the case of *B. brassicae* using a higher rate of pirimicarb plus added wetter is recommended (Jellis, 2003).

5.4 *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae)

Identification: painted bug adult is black with orange spots and markings called painted bug. These stink bugs are about 5–7 mm long. Females are larger than the males and both have distinctive black. The eggs are oval-shaped and off-white in color developing to an orange color when growth. Nymphs color changed as they develop from bright orange to red with dark markings, gradually acquiring the coloration of the adult. Wing pads are visible in the last instar nymph and gradually developed as they grow (Barlow, n.d.).

Life cycle and damage: Females lay about 50-80 eggs singly or in clusters of approximately 2-4 eggs during their lifetime. The eggs are laid on leaves or on the soil underneath host plants which hatch after 5-8 days. It has five nymphal stages. All stages of painted bugs can be found on a plant and both adults and nymphs suck sap from all parts of the plant. Young plants wilt and wither as a result of the attack. Also, adults excrete a resinous substance which spoils the pods. They often stunt the growth of newly formed central shoots or heads of plants. Quality and quantity (31% losses) of yield is affected when grown up plants are infected. Harvested crop in threshing floor is also infested (TIFP, n.d.-b)

Monitoring: monitor egg masses; if parasitized egg masses (black ones) are found, treatment for newly hatched nymphs might not be necessary. Also, monitor by beating or by shaking the vines on the cloth and count number of nymphs and adults.

Economic and action thresholds: In Africa where this insect comes from originally, the economic threshold is one bug/10 ft.² on plants in the early growth stage increasing to 3 bug/10 ft.² on mature plants (Barlow, n.d.).

Control: Deep ploughing; early sowing; irrigation of the crop and quick threshing of the harvested crop are the cultural techniques that can reduce pest attack. Burn the remains of mustard crop and conservation of bio-control agents like *Alophara* spp. can control painted bug population. Spraying malathion 50 EC, Endosulphan 35 EC, and Dimethothiate 30 EC should be considered if the threshold is exceeded (TIFP, n.d.-b).

5.5 *Psylliodes chrysocephala* (L.) (Coleoptera, Chrysomelidae)

Identification: Cabbage stem flea beetle is about 3-4.5 mm long, blue-black or light brown. Eggs are oval-shaped and about 0.9 x 0.4 mm, pale orange. The larvae are distinguished from other pests by their black head and black plate at the tail end (Jellis, 2003).

Life cycle and damage: females lay their eggs on the surface or in the cracks of the ground, singly or in clusters of 2 to 8 in the immediate vicinity of the stems of plants. The hatching larvae bore into petioles and continue feeding close under the surface. Later, larvae move into the main stem to feed under the growing point. The feeding injury appears as holes or small pits in the cotyledons and leaves. The beetles fly to canola, rapeseed and other mustards, moving into fields just as the seedlings emerge. They feed on the emerging cotyledon and first true leaves of the young plant. Feeding injury can result in plant death and stand loss. Flea beetles feed most actively when the weather is sunny, warm and dry. They overwinter as adult and have one generation per year.

Other flea beetles that are of increasing importance are: *Psylliodes luteola* (Müller) (Wessex flea beetle) which attacks crops in the autumn; *Phyllotreta cruciferae* (Goeze), *Phyllotreta*

nigripes (Fabricius), (turnip flea beetles) attack crops in autumn and spring; and *Phyllotreta nemorum* (L.) (large striped flea beetle) which attacks crops in spring (Jellis, 2003).

Monitoring: mobile D-vac suction sampler can be used to sample cabbage stem flea beetles. Shoots enclosed within cylinders (0.25 m² area) are shaken and excised on the ground and subsequently the area should vacuum for three minutes. Water traps can be placed on the ground around field perimeters to monitor their immigration to the crop. Also, damage level should be determined for estimating time of management (Alford, 2003)

Economic and action thresholds: action threshold is over 25% of the leaf area at the 1–2 true leaf growth stage; or over 50% of the leaf area at the 3–4 true leaf stage; or when the crop is growing more slowly than it is being destroyed. Also, if over 5 larvae/plant are present in the field or over 50% petioles damaged (Jellis, 2003; Knodel & Olson, 2002).

Control: early planting can protect crops from pest's infestations. The larvae are biologically controlled by *Tersilochus microgaster* (Szépligeti). Seed Treatment with Chinook, Gaucho®, Helix®, Poncho® and Prosper® protect crops from early season infestation. If the threshold is exceeded application of a foliar insecticide reduce flea beetles population. Pyrethroid spray controls feeding adults and larvae that have not entered the main stem (Jellis, 2003).

5.6 *Meligethes aeneus* (F.) (Coleoptera: Nitidulidae)

Identification: Pollen beetles are about 2-3 mm long, and black with a hint of metallic green. The eggs are elongated, glassy appearance verging on the milky-white. The larvae are up to 3 mm long and have a head capsule and six legs (Jellis, 2003).

Life cycle and damage: females lay their eggs in the buds and after 4-9 days the eggs hatch. The common name of pollen beetle is because both adults and larvae feed on the flowers, pollen and nectar and contributes to the pollination of the crop. Loss of pod sites albeit sometimes severe, rarely reduces winter oilseed rape yields. After opening all buds of winter crops, beetles migrate to other egg-laying sites, causing a second flush of migration to spring crops. Crops usually compensate for earlier losses, producing more and larger seeds on lower racemes. The adult overwinters at the edge of woodlands or in undergrowth. *M. aeneus* has two generations per year. Varietal associations and restored hybrids may lose more yields because male fertile plants are attacked and crosspollination is reduced. Spring crops are much more vulnerable than winter crops (Jellis, 2003).

Monitoring: During flowering, the beetles are attracted by the yellow color of host plants. So, *M. aeneus* can be monitored by yellow traps. Also, beat the main flowering racemes of plants over a white tray and count insect's number (Alford, 2003; Ruther & Thiemann, 1997).

Economic and action thresholds: For winter oilseed rape the action threshold is when: over 15 beetles/plant at green-yellow bud stage; over 5/plant for backward crops; over 2/plant for varietal associations is recorded. In the case of spring oilseed rape observing over 3beetles/plant at green bud stage is the time of controlling pollen beetles (Jellis, 2003).

Control: *Phradis interstitialis* (Thomson), *Phradis morionellus* (Holmgren) and *Tersilochus heterocerus* (Thomson) can biologically control the larvae of pollen beetle. If thresholds are exceeded application of pyrethroid in green to yellow bud stages is advised (Jellis, 2003).

5.7 *Ceutorhynchus assimilis* (Paykull) (Coleoptera: Curculionidae)

Identification: Adults of cabbage seed weevil are matt grey about 2-3.5 mm long, with a distinctive, long, narrow, downward-curved rostrum (snout) on the front of the head. The prothorax has a notch in the middle of the underside front edge where the rostrum can rest. There are seven segments in the antennal funiculus. The elytra are black, but the elytral interstices have fine hairs and greyish white scales which results in an overall grey appearance. Near the mid-line of the elytra, the interstices have 1-3 irregular rows of scales along their length. There is no tooth on the hind femora and all tarsi are black to dark brown, similar in color to the femora and tibiae. The tarsal claws are simple, not toothed. The eggs are creamy white, smooth, cylindrical with rounded ends, and about 0.6 mm long by 0.4 mm wide. They are often covered with a mucus-like material. The larva is vermiform, white with a brown head capsule. Pupae are about 2 mm long and occur in earthen cells in the soil. They are initially white, but then turn yellow (CABI, 2008).

Life cycle and damage: Cabbage seed weevil is univoltine; adults emerge from overwintering sites in the spring and migrate to rape crops to feed and oviposit. Females lay eggs into developing oilseed rape pods during flowering. A brown scar indicates the egg-laying puncture, usually causing a kink in the pod. The larvae develop inside the pod and cause economic damage by eating the seeds. The abundance of cabbage seed weevil is greater in winter than spring. It has three larval instars (Jellis, 2003; Murchie et al., 1999).

Monitoring: installation of yellow water traps and beating the main flowering racemes of plants over a white tray and counting number of insects are techniques for monitoring cabbage seed weevil (Alford, 2003; Murchie et al., 1999).

Economic and action thresholds: action threshold is when over 0.5 beetle/plant in northern Britain or 1/plant elsewhere is observed (Jellis, 2003).

Control: Delaying sowing of spring crops reduces numbers of adults attracted and subsequently the number of laid eggs. *Trichomalus perfectus* (Walker), *Mesopolobus morys* (Walker) and *Stenomalina gracilis* (Walker) can biologically reduce the population. If the threshold is exceeded application of pyrethroid by petal fall and before too many eggs are laid can decrease the population buildup (Jellis, 2003).

5.8 *Ceutorhynchus quadridens* (Panzer) (Coleoptera: Curculionidae)

Identification: Cabbage stem weevil adult is about 2 to 3.5 mm long, ashy grey. The Elytra is dorsally with a white rectangular spot; striae much narrower than the interstices which are covered in whitish scales. Larvae are about 3 to 5 mm, relatively elongated, white; with small light yellow head (Evans, 2007).

Life cycle and damage: females lay eggs in the petioles, young stems or along the main veins of the leaves over a period of weeks, depending both on temperature and crop stage. The eggs hatch after 5-8 days. The larvae tunnel their way into the mid rib of the leaf or the stem. Some diseases such as stem canker can gain access to the stem through the holes made by larvae as they leave the plant to pupate. Larval growth lasts 3 to 6 weeks until pupation, which takes place in the ground. Adults cause no obvious damage but can be found on plants. They infest a large percentage of plants and reduce vigor and yield. They overwinter as adult under lumps of earth or under plant debris (Evans, 2007).

Monitoring: monitor directly the crop from emergence and look for signs of pests activity, presence of beetles, and shot holding of leaves.

Economic and action thresholds: ETL is when up to 26 larvae per plant is observed (Winfield, 1961).

Control: seed treatments by gamma-HCH or sprays of gamma-HCH, azinphos-methyl, azinphos-methyl plus demeton-S-methyl sulphone, chlorpyrifos or triazophos are effective against stem weevils (Graham & Gould, 1980). Carbofuran or phorate granules reduce larval infestations, but thiofanox granules and dimethoate sprays are ineffective (Evans, 2007).

5.9 *Delia radicum* (L.) (Diptera: Anthomyiidae)

Identification: Cabbage maggot or root maggot adults look like house flies but smaller, about 5 mm long, dark ash grey with a dark stripe along the top of the abdomen, and covered with black hairs and bristles (setae). The reddish purple eyes on males nearly touch in the centre of the head while female eyes are separated. In males, the presence of the basal brush of long setae (anteroventral setae) on the hind femur and by relatively shorter lateral setae of the 5th sternite processes. In the hind femur of females, the row of anteroventral setae is normally uneven and posteroventral setae are lacking. The eggs are white and about 1 mm diameter. The larva posterior extremity bears a crown of 10 small black membranous points, which is also visible on the pupae. The pupae are reddish brown (Wikipedia, 2011b).

Life cycle and damage: The adults feed on nectar and lay their eggs close to plants of the genus *Brassica* on cool, moist soil. The eggs hatch into white maggots after about six days and the larvae feed for about three weeks on the roots and stems of the cabbage plants. The presence of larvae cause delay in plant growth accompanied by the withering of leaves which develop a bluish tinge. Sometimes 300 larvae can be found on one plant, damaging the inner parts of the main root and disrupting the transport of water and nutrients to the stem and leaves causing the death of many plants. The larvae mature in about 3-4 weeks, then leave the roots and pupate about 5-20 cm deep in the soil. This species has one or two generation a year (Wikipedia, 2011b). Dosdall et al., (1994) stated that the susceptibility of *Cruciferae* species to *D. radicum* is different. Plants of *B. rapa* were most susceptible to *Delia* spp.; intermediate susceptibility was observed for plants of *B. napus* and *B. juncea*; and plants of *B. alba* were least susceptible. The mechanism of resistance by cruciferous species to infestation by *Delia* spp. is antixenosis or non-preference.

Monitoring: monitoring can be done by combination of yellow water pan traps and yellow sticky traps over an entire growing season (Broatch & Vernon, 1997).

Economic and action thresholds: 21 eggs per plant is economic threshold for two week old plants and about 100 eggs per plant, 4 weeks after planting (Bligaard et al., 1999).

Control: remove weeds from the field two weeks before planting. Plant when there are fewer flies around to deposit eggs. If infested plants are found, they should be removed to prevent contamination of other plants.

5.10 *Dasineura brassicae* (Diptera: Cecidomyiidae)

Identification: The adults are 1-1.5 mm long, female with reddish abdomen; male, blackish. The larva is about 1.5 mm long, white or yellowish-white. Pupa is inside whitish cocoon about 1.4 to 2.1 mm long, at a depth of 3 cm, in the soil (Pavela & Kazda, 2007).

Life cycle and damage: Brassica pod midge females lay eggs in clusters through holes left by seed weevils in developing pods. After 4 days the eggs hatch and many small, white larvae occur in each affected pod. Midges appear during flowering; they feed on the internal wall of the pod valve (or on the seeds) by discharging saliva. They cause swelling and eventually pod burst. The larvae have 3 instars and they develop through 9 to 15 days, when they drop to the ground, bury themselves and form cocoons. Some will pupate; others may undergo diapauses for 1 to 4 years. They have about 3 to 4 generation (Jellis, 2003).

Monitoring: monitor *D. brassicae* by yellow or suction traps. Cardboard delta traps with sticky base plates have been used to monitor males (Alford, 2003; Pavela & Kazda, 2007).

Economic and action thresholds: No thresholds for treatment exist (Jellis, 2003).

Control: Blocking oilseed rape fields and rotation around the farm will reduce the impact of immigrant pests. *Omphale clypealis* (Thomson) and *Platygaster subuliformis* (Kieffer) may attack pod midge, killing up to 75% of larvae (Jellis, 2003). Calypso 480 SC has effects as contact and feeding poison with systemic impact, a non systemic pyrethroid insecticide protect the plants from beginning of flowering to full flowering (Pavela & Kazda, 2007).

5.11 *Athalia proxima lugens* Klug (Hymenoptera: Tenthredinidae)

Identification: Adults are orange colored wasps with black head and smoky transparent wings. Larva is greenish black wrinkled body, with three legs of thoracic legs and seven pairs of prolegs. On slightest touch the larva falls to round and feigns death. The pupae formed in an earthen cocoon in the soil (Chowdhury, 2009; Navarajan, 2007).

Life cycle and damage: Mustard sawfly females lay eggs near the leaves margin. They attack the crop at early growth period when the seedlings are 3-4 week old. The larvae feed on the leaves of rapeseed and mustard making holes. In severe case larvae eat up entire lamina of leaf leaving behind the midribs. In extreme cases, this pest defoliates the plants completely. They devour the epidermis of the shoot, resulting in drying up of seedlings and failure to bear seeds in older plants. The yield loss is up to 5 to 18 % (Chowdhury, 2009).

Monitoring: monitor directly and count the number of larvae. Also, sweep netting and counting the number of adults can be used for monitoring sawflies.

Economic and action thresholds: no action threshold has been set for sawflies in mustard.

Control: Summer ploughing to destroy the pupae; early sowing; irrigation in seedling stage and severe cold reduce pest growth and are crucial for sawfly management. Conserving *Perilissus cingulator* (Morley) (parasites the grubs), and the bacterium *Serratia marcescens* (Bizio) infect the larvae of sawfly. Apply insecticides such as methyl parathion dust at the rate of 20-25 kg per hectare or Malathion 50 EC if the threshold is exceeded (TIFP, n.d.-b).

5.12 *Plutella xylostella* (L.) (Lepidoptera: Plutellidae)

Identification: Diamondback moth is small greyish with three white triangular spots along the inner-margin of the forewings. At rest the triangular markings of opposite wings appear as diamond shaped markings and hence the name. The larvae are pale green, body tapering slightly at both ends (TIFP, n.d.-b).

Life cycle and damage: females lay eggs on the lower leaves. The first instar larvae make tiny, irregular holes in the leaves. Diamondback moth is the most destructive pest of brassicasea throughout the world. Caterpillars feed on the foliage and make the leaves a withered appearance. Moths of later generations lay eggs higher on the plant and the larvae feed first on leaves, moving later to buds, flowers and developing seedpods. In later stages larvae bore holes in the leaves and the leaves may be eaten up completely. They also bores into pods and feeds developing seed (TIFP, n.d.-b).

Monitoring: monitor the presence of *P. xylostella* by pheromone traps or yellow sticky traps. Traps should be checked weekly and count the number of moths (TIFP, n.d.-b).

Economic and action thresholds: economic threshold is when 25-30 larvae observed per square foot or 1-2 larvae per plant, and there is significant evidence of damage to flowers or pods (Knodel et al., 2010).

Control: bio-control agents such as *Cotesia plutellae* (Kurdjumov), *Diadegma mollipla* (Holmgren), *Oomyzus sokolowski* (Kurdjumov), and *Apanteles* sp. can control diamondback moth. When the threshold exceeded application of malathion, Trichlorfon, Endoslfan 35 EC, Diazinon 20 EC or triazophos is recommended (Manyangarirwa et al., 2009; TIFP, n.d.-b).

5.13 *Pieris brassicae* (Linn) (Lepidoptera: Pieridae)

Identification: it is known as large white or cabbage butterfly. Forewings of the moth is mealy-white with dark pollination at base (wingspan 55-60 mm); females are larger than males. Wings at top with intensive black crescent limb reaching middle of outer margin and with 2 black rounded spots. They have sexual dimorphism and males just have 2 spots on the lower side of forewings. Hindwings have black stroke at anterior margin from above; grayish-yellow from below, with dense black pollination. The eggs are yellow skittle-shaped. The larvae are yellowish green with yellow lines and black spots. Pupae are greenish-yellow with black dorsal and lateral dots (Navarajan, 2007).

Life cycle and damage: females lay eggs in batches on the lower side of leaves. After 4 to 16 days the eggs develop. Young caterpillars aggregate and scraping the lower side of leaves; older ones live individually, gnawing holes in leaves, contaminating the latter with excrement. In severe attacks thick veins only leave. Caterpillars have 5 instars and develop in 13-38 days. The pupa phase lasts 8-15 days. Diapausing pupae do not hibernate far from host plant localities on tree trunks and branches, fences etc. They have the ability to migrate in large numbers during the spring and autumn and have 2-3 generation (Navarajan, 2007).

Monitoring: install pheromone traps for monitoring male moths and check the crop weekly after peak trap catches for the presence of larvae.

Economic and action thresholds: no action threshold has been set for *P. brassicae*.

Control: Caterpillars can be controlled biologically by *Apanteles glomeratus* (L.). Spray 0.05% dichlorvos, acetamiprid or 1% malathion if the threshold is exceeded (Navarajan, 2007).

5.14 *Hellula undalis* (F.) (Lepidoptera: Pyralidae)

Identification: Moths of *H. undalis* are pale greyish-brown, suffused with reddish color. Their forewings have wavy gray markings, a curved pale patch sub terminally, and a kidney shaped mark one third length from the tip. The wingspan is about 18 mm. Hindwings are pale, with the tip being lightly colored. The eggs are small, oval and slightly flattened upon the plant surface. They are creamy white when freshly laid, become pinkish the next day and then turn brownish-red. Larvae are pale whitish brown with 4 or 5 pinkish-brown longitudinal stripes. Pupation occurs in a silk cocoon and early stage pupae are soft and very pale yellowish-white in color with a bright red, dorsal blood (TIFP, n.d.-b).

Life cycle and damage: females lay eggs singly, or in groups or chains of 2 or 3 on the leaves near the bud and after 4 to 5 days the eggs hatch. Cabbage head borer caterpillars initially mine the leaves and make it white papery. Later they feed on leaves and bore into stems, entrance hole is covered with silk and excreta (TIFP, n.d.-b).

Monitoring: Regular monitoring of young plants in the nursery and after transplant is important. Install pheromone traps and detect larvae (Kessing & Mau, 2007).

Economic and action thresholds: ETL is when 15-25% of plants infested in a random pattern (Kessing & Mau, 2007).

Control: *B. hebetor* and *C. blackburni* can control *H. undalis*. Screening of seedling beds and clean culture are helpful in reducing damage caused by cabbage webworm. Biopesticides such as B.t. and spinosad are useful for the management of caterpillars. If the threshold is exceeded application of 5% malathion dust, Trichlorfon or carbaryl 50 WP, endosulfan (0.05%), cypermethrin (0.005%), and neem are advised (Navarajan, 2007; TIFP, n.d.-b).

5.15 *Crociodolomia binotalis* (Zeller) (Lepidoptera: Pyralidae)

Identification: leaf webber moths are yellowish-brown, forewings in parts have reddish-brown distinct and in distinct wavy lines and prominent white spots. Near to the thorax forewing and black tuft of hair and hindwings are white with dark brown apical area. The eggs are brown furry, flat and placed in masses. The larvae are pale yellowish-brown, with a series of lateral and sub-lateral black spots and specks. The pupa is yellowish green when formed and turns dark brown later and it is about 1 cm long (TIFP, n.d.-b).

Life cycle and damage: females lay eggs in masses and each mass containing 40-100 overlapping eggs. After 5-15 days, depending on whether conditions the eggs hatch. The newly hatched larvae feed initially on the chlorophyll of young leaves and later on older leaves, buds and pods, make webbings and live within. Severely attacked plants are defoliated and seeds in the pods are eaten away. Leaf webber is the secondary pest and may become a serious problem, particularly during the dry season. The larvae develop after about 24-27 days during summer; or about 51 days in winter. Leaf webbers pupate in an earthen cocoon, 2 to 6 cm below soil surface (TIFP, n.d.-b).

Monitoring: Monitoring is very important in the first stages of the crop. Check the crop weekly after peak trap catches in order to detect the caterpillars. Scout the plants with

quarter-meter square (50 cm by 50 cm) and beat them within that area to dislodge the larvae. Count the fallen larvae and multiply by 4 to get the number per meter square (kalita, 2004).

Economic and action thresholds: ETL is one larva per meter row of length (kalita, 2004).

Control: field sanitation, crop rotation and intercropping are cultural techniques for controlling leaf webbers. *Apanteles* sp. is the pupal parasitoid of *C. binotalis*. Neem, B.t., carbaryl, cypermethrin, fenvalerate, or monocrotophos sprays are effective (kalita, 2004).

5.16 *Mamestra configurata* (Walker) (Lepidoptera: Noctuidae)

Identification: It is known as Bertha armyworms. The forewings of moths are predominantly gray, and flecked with patches of black, brown, olive and white scales. Near the middle of the forewing, there is a prominent, white, kidney-shaped marking defined with a ring of whitish scales. Near the tip of the forewing, there is a conspicuous white and olive-colored, irregular transverse marking that is characteristic of the species. The moth wingspan is about 4 cm. The eggs are sculptured, ridged; white at first but become darker as they develop. The larvae are pale green when they first hatch. Older larvae will be velvety brown to black with a yellowish band along each side of the body (Knodel et al., 2010).

Life cycle and damage: females lay eggs in single-layered clusters of about 50-500 eggs on the lower surface of the leaves. First instar larvae feed on the leaves. As leaves dried, the old larvae begin feeding on seeds and flowers which are more succulent. Early seeded canola often has been swathed prior to the occurrence of significant feeding injury. They cause serious damage by chewing through the stems below the bolls, causing them to drop to the ground. The larvae have six instars and at maturity, burrow into the ground and form pupae, their over-wintering stage. Bertha armyworm attacks many kinds of broadleaf plants, including canola, flax and beans (Knodel et al., 2010).

Monitoring: monitor the caterpillars and count the number of them on crops according to the method of leaf webbers.

Economic and action thresholds: Thresholds is when 18-22 larvae is observed per square yard, as long as leaf feeding is the extent of the damage observed. Thresholds may be adjusted lower if larvae are found feeding on maturing seed pods (Knodel et al., 2010).

Control: If the threshold exceeded apply insecticides such as: bifenthrin, deltamethrin, gamma cyhalothrin or lambda-cyhalothrin (Knodel et al., 2010).

6. Sunflower

Helianthus annuus L.: known as common sunflower, about 60% of the world's production is in Europe and the USSR (Union of Soviet Socialist Republics) (Putnam et al., 1990).

6.1 *Pseudoheteronyx basicollis* (L.) (Coleoptera: Scarabaeidae)

Identification: it is known as black scarab beetles or black sunflower scarab. Beetles are 13 mm long, shiny black with very short hairs. Eggs are cream and spherical, about 1.5 mm in diameter. The larvae are creamy with a grey rear end, brown head capsule and up to 25 mm long. They are C-shaped with wrinkly bodies and Y-shaped palidia (Franzmann, 2011).

Life cycle and damage: females lay their eggs under seedlings. Young larvae feed on taproots causing wilting and deaths of seedlings, older larvae attack the pods. Adult beetles can defoliate and kill plants up to 40 cm tall. Larvae overwinter in the soil and pupate in the spring. Adults often feed in a line across the field. Beetles hide in the soil during the day and emerge in late afternoon to feed. Heavily infested crops may suffer over 30% yield loss. They have one generation per year (Bailey, 2007).

Monitoring: check in the soil by digging and sieving for the presence of larvae prior to planting, and at all stages for adults. Count the number of beetles per m² (Brien, 2011).

Economic and action thresholds: action threshold is when four beetles is observed per square meter which can cause severe losses to young seedlings (Franzmann, 2011).

Control: Removal of the host parthenium weed is advised. Spray appropriate insecticides when beetles are active on the soil surface. Beetles can also be controlled by application of pelleted baits (alfalfa or similar meal) at planting. Damage is most prevalent where sunflowers follow wheat, sorghum or grass pasture (Brien, 2011).

6.2 *Dectes texanus* (LeConte) (Coleoptera: Cerambycidae)

Identification: *Dectes* stem borer is bluish-gray, about 1-2 cm, with antennae as long, or longer than the body. They are generally cryptic in behavior and can often be found hiding under leaves within the plant canopy during daylight hours, but also may be seen actively flying and running around on plant surfaces. The eggs are like small bananas with rounded ends. The larvae are pale, legless, cylindrical, and deeply segmented. They are creamy and tapered towards the rear so that final segments are narrower (Michaud et al., 2011).

Life cycle and damage: Females become reproductively active about one week after emergence, and require another week or so to mature eggs. Eggs are normally laid in leaf petioles deep in the central pith. After six to 10 days the eggs hatch and newly hatched larvae pass the first instar in the leaf petiole and then tunnel down into the main stalk where they feed selectively on the pith in the central core. Larvae develop through six instars. The effect of larval feeding on yield is negligible in healthy plants, but reduces plant resistance to other insects such as stem weevils. As stalks dry down, mature larvae of *Dectes* descend to the base of the stem, begin to girdle the interior surface near the soil line, and then plug the tunnel with chewed fibers that resemble sawdust before retreating to the base of the plant to overwinter. Plants weakened by complete or partial girdling snap off easily when pressure is applied laterally to the stem. Adults mate and feed on plants, leaving longitudinal feeding scars on stems and petioles. Infestations approaching 100 percent of plants may go completely unnoticed when fields are harvested early, but any delay in harvest can result in serious losses due to lodging. They have only one generation per year (Michaud et al., 2011).

Monitoring: monitor in late summer by splitting stalks to determine if *Dectes* stem borers are present, and harvest as soon as possible if infestation is extensive (Michaud et al., 2011).

Economic and action thresholds: no action threshold has been set for *Dectes* stem borer.

Control: Crop rotation may reduce damage from *Dectes* when the acreage of soybeans and sunflowers in an area is low. Stalk desiccation is an important cue triggering the girdling behavior of *D. texanus* larvae. Later planting dates, fall or winter tillage and irrigation of

sunflowers have reduced infestations by this pest. There is no varietal resistance to stem borers in sunflowers and chemical treatments are not recommended. Although adults are susceptible to many foliar insecticides, their extended activity period means that a single application will not provide control. However, larvae feed within the plant and are protected from contact insecticides, and even repeated applications of systemic materials fail to provide adequate control in most years (Knodel et al., n.d.; Michaud et al., 2011).

6.3 *Cylindrocopturus adspersus* (LeConte) (Coleoptera: Curculionidae)

Identification: Sunflower stem weevil adults are less than 4-5 mm long and grayish brown with white markings on the wing covers and thorax. The snout, eyes and antennae are black. Eggs are very small about 0.51 mm long by 0.33 mm wide, oval and yellow, and are difficult to see. Larvae are approximately 6 mm long at maturity. Larvae are legless and creamy white with a small, brown head capsule. They are normally in a curled or C-shaped. Pupae are similar in size to the adult and are creamy white (Knodel et al., n.d.).

Life cycle and damage: adult emerge from overwintered stalks or root crowns and mating occurs soon after emergence. Adults feed on stem and leaf tissues which causes minor damage to them. Females lay eggs individually in the stem tissue around the first node (cotyledon) or inside the epidermis of sunflower stems. First instar larvae feed on sub epidermal and vascular tissue in the stem. Feeding is concentrated in the pith tissue as the larvae develop to third and fourth instar stages. It has about five to seven larval instars. Larvae feed apically and last instars descend to the lower portion of the stalk or root crown and excavate overwintering chambers by chewing cavities into the stem cortex. They have only one generation per year. The stem may break, causing a loss of the entire head prior to harvest. Stalk lodging is most severe during drought stress or when high winds occur as plants are drying prior to harvest. Lodging typically occurs at or slightly above the soil line, in contrast to breakage attributed to stalk diseases. Lodging is a good indicator of larval densities; however, lodging is influenced by other factors, including stalk diameter, cortex and pith thickness of the stem, weight of sunflower heads, wind velocity and direction, position of larvae in overwintering chambers in the stalk (Knodel et al., n.d.).

Monitoring: monitor the field and count number of weevils. Adults can be found on both surfaces of the leaves, the lower portions of the stem, in leaf axils, within the dried cotyledons or in soil cracks at the base of the plant. Field scouting for adults should begin when plants are in the eight to 10 leaf stages. Five randomly sampling sites are determined 70-100 feet in from the field margin and in each sample site, five plants is selected. It is recommended to use an X pattern (or W pattern) to space sample sites throughout the entire field (Knodel et al., n.d.). According to the Michaud et al., (2011) scouting adults is really difficult and not recommended in many cases. So, in a region with a history of stem weevil problems growers may assume that any dry land sunflowers will be at risk, and that their impact on the crop will increase with adversity of growing conditions.

Economic and action thresholds: The economic threshold is one adult per three plants, or about 40 larvae per stalk at the end of the season (Knodel et al., n.d.).

Control: delayed planting and reducing plant population increases stalk diameter which is useful for controlling *C. adspersus* (Knodel et al., n.d.). Systemic pesticides such as carbofuran give simultaneous control of stem weevils and most other stem-infesting insects,

and may also preserve stalk integrity by delaying processes of deterioration. Although seed treatments can be useful for improving seedling establishment, their duration of activity within the plant is not sufficient to provide control of stem weevils. Applying insecticides such as Beta-cyfluthrin, Chlorpyrifos, Chlorpyrifos plus gamma-cyhalothrin (Cobalt), Chlorpyrifos plus zeta-cypermethrin, Deltamethrin, Esfenvalerate, and Gamma-cyhalothrin (Proaxis) is recommended if the threshold is exceeded (Michaud et al., 2011).

6.4 *Apion occidentale* (Fall) (Coleoptera: Curculionidae)

Identification: It is known as black sunflower stem weevil. Adults are shiny black and less than 3 mm long. The snout is very narrow and protrudes forward from the head, which is small in relation to the rather large, almost globosely body. Larvae are similar in appearance to the sunflower stem weevil larvae, except they are only 3 mm long at maturity and more yellow with a more pointed posterior (Knodel et al., n.d.).

Life cycle and damage: Adults overwinter in soil or plant residue; after they emerge they feed on leaf and stem tissue. Females lay eggs under the epidermis in leaf petioles or stems near leaf axils. Larvae feed in vascular and pith tissues of stems and petioles. Newly emerged larvae tunnel in the pith of the stem, pupate and emerge as adults. second generation adults feed on the leaves and stems of the plant, but as the plant matures and the leaves begin to die, adults move under the bracts of the sunflower head, where they can be observed feeding until the plants are harvested. Adults move into the soil to overwinter. Although feeding damage is seldom significant, however, this species has been associated with the transmission of the pathogen *Phoma macdonaldii* (Boerma), the causal agent of phoma black stem. Stand loss can occur where extremely high populations are feeding on sunflower seedlings. In most cases, however, populations are too low to cause economic damage, and stalk tunneling only results in minor injury to the plant (Knodel et al., n.d.).

Monitoring: refer to the monitoring section for *C. adspersus*.

Economic and action thresholds: no action threshold has been set for this species.

Control: This species, has not been considered as an economically important pest in cultivated sunflower fields. Controlling other pests such as *C. adspersus* appears to give simultaneous control of *A. occidentale*.

6.5 *Baris strenua* (LeConte) (Coleoptera: Curculionidae)

Identification: Sunflower root weevil adults are rather robust weevils, with a somewhat oval-shaped body. Adults are dull black and 6 mm long with a short, almost blunt, downward projecting snout. Larvae are 6 mm long at maturity, legless, and have a white body with a small, brown head capsule (Knodel et al., n.d.).

Life cycle and damage: Adults feed on sunflower foliage in early morning and late afternoon. About two weeks after emergence, adults begin to congregate around the root zone near the soil surface. They continue feeding and mating occur during this period. Feeding activity produces callus tissue, under which the bright yellow eggs are deposited two or three at a time. First instar larvae are not very mobile and feed on the epidermal and cortical cells of the roots. Most feeding (consisting of circular tunnels) and development to fourth instar takes place in the same area where egg hatching occurs. In the fourth larval

stage, the plant becomes significantly dehydrated and encapsulation of the larvae within a soil cocoon begins. Larvae overwinter within the cocoon among the remaining roots in the soil and it has one generation per year (Knodel et al., n.d.). When larvae are exceptionally abundant, they may cause plant wilting and lodging (Michaud et al., 2011).

Monitoring: monitoring is not so important for this pest species.

Economic and action thresholds: No economic thresholds have been established for root weevils.

Control: There are currently no management recommendations for sunflower root weevil. However, growers should realize that significant burrowing in sunflower fields and numerous uprooted plants are often caused by mammals foraging for root weevil larvae (Michaud et al., 2011).

6.6 *Smicronyx sordidus* (LeConte) and *Smicronyx fulvus* (LeConte) (Coleoptera: Curculionidae)

Identification: They are known as the gray seed weevil, and the red seed weevil, respectively. The gray seed weevil is about 8 mm long and pale gray, with a gently curving snout. Adults can frequently be found hiding under the bracts of sunflower buds either prior to or during bloom. *S. fulvus* is a small, reddish-brown weevil, about 3-4 mm long. Adults are most easily seen on the faces of blooming sunflowers feeding on pollen, or hiding behind the flower bracts. Infested seeds are not noticeably different from healthy ones, but display an exit hole near the top once the larva has matured and left (Michaud et al., 2011).

Life cycle and damage: *S. sordidus* females favor flowers in the late bud stage for oviposition, laying their eggs singly at the base of the developing seeds. Upon hatching, larvae bore into the seeds at their base, destroying the ovaries. At maturity, larvae exit the seeds and drop to the ground where they seek overwintering sites in the soil. The larvae feed within developing seeds and cause a galling response, leaving affected seeds swollen in appearance, but empty. Adult weevils of *S. fulvus* seek sunflowers in bloom and females must feed on pollen for at least four days before they can produce eggs. Females lay egg individually and directly into a seed and this requires a seed in the appropriate developmental stage. Developing larvae do not usually consume the seed completely, but significantly reduce kernel weight and oil content. The time frame of larval development is such that a percentage of larvae may still be present in seed at harvest, leading to temperature and moisture problems in storage. Larvae often can be found in seeds at harvest, especially when harvest is early, but most die in storage without causing further damage. They can result in yield reductions. However, the red seed weevil is more commonly responsible for economic damage than the gray seed weevil. Both of them have one generation per year (Michaud et al., 2011).

Monitoring: monitoring should be done as the field approaches 85 % bloom, or when 80 % of plants are past the R4 stage. Count the number of weevils on the faces of five of the most mature flowers at each of five sites. This process can be facilitated by spraying the faces of each flower with a DEET-containing mosquito repellent that will cause weevils to quickly exit the flower. For more information refer to the monitoring section of *C. assimilis* in mustard (Michaud et al., 2011).

Economic and action thresholds: No economic threshold has been established for the gray seed weevil and it is generally considered a less serious pest than the red seed weevil. Thresholds calculated for red seed weevil are sometimes used for gray seed weevil and control of gray seed weevil requires pesticide applications prior to bloom, when about 10-15% of plants have reached the R4 stage. Generally, the threshold for oilseed sunflowers falls somewhere between 10 and 20 weevils per flower, but the threshold is much lower for confection sunflowers (usually 1 or 2 weevils per flower) because of industry standards that demand seed damage remain below 3-4 % of kernels. Research suggests that approximately 27 damaged kernels result for every adult weevil observed at the early bloom stage. An early treatment should be followed by continued scouting at 4-5 day intervals, as adult emergence continues over several weeks (Michaud et al., 2011).

Control: tillage has been shown to reduce survival of overwintering weevils. Chemical treatments are recommended if the threshold is exceeded. Beta-cyfluthrin (Baythroid XL); Chlorpyrifos; Chlorpyrifos plus gamma-cyhalothrin (Cobalt); Chlorpyrifos plus zeta-cypermethrin (Stallion); Deltamethrin (Delta Gold); Gamma-cyhalothrin (Proaxis); Lambda-cyhalothrin, Parathion, methyl (Cheminova Methyl 4EC) are appropriate for controlling seed weevils (Michaud et al., 2011).

6.7 *Pterohelaeus alternatus* (Pascoe), *Pterohelaeus darlingensis* (Carter) and *Gonocephalum macleayi* (Blackburn) (Coleoptera: Tenebrionidae)

Identification: They are known as striate false wireworm, Eastern false wireworm and Southern false wireworm, respectively. Adult beetles of *Pterohelaeus* spp. are 20 mm long and dark grey-black with a distinctive 'pie-dish' shape formed by flanges around the outline of the beetle. Adults of *Gonocephalum* spp. are 9 mm long, dark grey-black and often covered in soil. There are flanges around the outline of the thorax (behind the head). Larvae are up to 30 mm long, shiny and cream, yellow or tan with three pairs of legs behind the head. They are hard-bodied, cylindrical and segmented with a rounded head (Murray, 2010).

Life cycle and damage: females lay eggs singly in moist soil, usually under trash or low-growing weeds. Both adults and larvae attack sunflower and damage of them may necessitate replanting. The larvae feed on decaying vegetable and crop residues in the soil; they also feed on newly germinating seed and the growing points of seedlings which results in patchy stands. Damage is most common in early-planted crops where crop residue has become scarce. They are major pests of seedling field crops and especially attack sunflower, soybeans, and mungbeans. They usually have one generation per year (Brien, 2011).

Monitoring: monitoring can be difficult; either hand sift 10 soil samples (30 x 30 cm) or place 10 germinating seed baits monitoring for soil-dwelling insects throughout the paddock. Pitfall traps can be used for counting the number of false wireworms (Brien, 2011).

Economic and action thresholds: The action threshold is observing more than 25 wireworm larvae in 20 germinating seed baits (Murray, 2010).

Control: Use of press wheels at planting; clean cultivation during summer can be effective against wireworms. Control of adults is obtained by baiting with insecticide-treated cracked and larvae can be controlled by insecticide applications at planting or insecticide-treated seed (Brien, 2011).

6.8 *Strauzia longipennis* (Wiedemann) (Diptera: Tephritidae)

Identification: Sunflower maggot is the only tephritid species found in the stalks of cultivated sunflowers. The showy yellow adult has a wing span of about 13 mm and a body length of 6 mm. The eyes are bright green and the wings bear broad dark bands that form a fairly distinct F pattern near the wing tip. Eggs are 1 mm long and are white and elongated. Larvae are yellow-white, headless and legless, tapered from anterior to posterior and approximately (7 mm) long at maturity (Knodel et al., n.d.).

Life cycle and damage: Adults emerge and flies have been noted in shelterbelts and field margins. Females lay eggs singly in stem tissue near the apical meristem, and larvae feed in the stalk pith, creating large tunnels. The maggots, when fully developed, emerge from the stalk. Larvae develop through three instars in approximately six weeks. This species overwinters as a larva in plant debris in the soil. The sunflower maggot has one generation per year. Feeding is confined to the pith, which acts as a supporting structure, and is not critical to plant nutrition. Secondary fungal infections also are associated with tunneling by the larvae within the stalk. Stalks are not weakened and seed yield is not reduced, even with severe pith destruction (Knodel et al., n.d.).

Monitoring: no scouting methods have been established for sunflower maggot.

Economic and action thresholds: no thresholds has been established for sunflower maggot.

Control: controlling other pests of sunflower will manage maggot infestations.

6.9 *Trichoplusia ni* (Hübner), *Thysanoplusia orichalcea* (F.) (Lepidoptera: Noctuidae)

Identification: *T. ni* is known as cabbage loopers. Moths are dark, smoky, and gray variegated with light grayish brown. Characteristic small silvery oval spots and U-shaped silvery white marks are on the middle of the forewings. Hind wings are pale brown with the veins conspicuously visible. Males have tufts of gold hair at the tip of the abdomen. Eggs are hemispherical, pale green or white with shallow ridges that meet at the center of the egg. The newly emerged caterpillars are translucent white. Once feeding starts the larvae become pale green, with a thin white line running lengthwise down each side of the body and two white lines along the middle of the back. Pupae are yellow green with a few brown patches when newly formed and gradually darken to dark brown before adult emergence. The pupation occurs in white transparent silken cocoon in folded leaf (Mau et al., 2007). *T. orichalcea* is known as soybean looper, but larvae are an occasional pest of sunflower. The moth forewings are brown with a large, bright gold patch. Hind wings are fawn-colored, darkening towards the outer margins. The Eggs are pale yellow-green, ribbed and flat. Very small larvae are green all over but medium larvae usually have prominent dark and white striping. Larvae pupate under leaves in a thin silken cocoon. Pupae are dark above and pale underneath (Brier, 2010).

Life cycle and damage: females of *T. ni* lay eggs singly on the lower leaf surface near the leaf margin. Eggs hatch in 3-4 days. This is one of the major pests of sunflower. The young larvae feed on chlorophyll contents and make part of leaf transparent. As the larvae grown they feed on the leaf margins and during severe infestation only midribs are left. The presence of small transparent leaf spot, devoid of chlorophyll symbolizes the beginning of pest population. The caterpillar stage lasts for 12-20 days. The pupal stage lasts for 9 days

(Mau et al., 2007). *T. orichalcea* small larvae feed on only one side of the leaf. Developed larvae chew holes in the leaf, and then feed from the leaf margin. Larvae are primarily foliage feeders in soybeans but will attack the flowers and developing pods (Brier, 2010).

Monitoring: Beat-sheet is preferred sampling method for loopers. Also, light and pheromone traps can be used for monitoring and determining the moths peak (Brier, 2010).

Economic and action thresholds: An action threshold for *T. ni* is observing 0.5 cabbage looper per plant. In the case of *T. orichalcea* in pre-flowering crops, looper control is warranted if defoliation exceeds 33%. Tolerable defoliation drops to 15-20% once flowering and podding commences (Brier, 2010; Maxwell & Fadamiro, 2006).

Control: loopers can be controlled biologically by releasing *Copidosoma floridanum* (Ashmead), *Voria ruralis* (Fallen), *Hyposoter exiguae* (Viereck), *Enicospilus* sp. and *Disophrys lutea* (Brulle). Also, conservation bio-control agents like green muscardine fungus, NPV, B.t. may be effective for reducing population build up. If the threshold is exceeded applying insecticides such as quinalphos 25 EC and Endosulfan 4% is recommended (TIFP, n.d.-c).

6.10 *Vanessa cardui* (L.) (Lepidoptera: Nymphalidae)

Identification: The painted lady adult has a pointed forewing with a distinctive transverse white bar. The intensity of reddish coloration on the wings varies greatly, with some individuals brightly colored and others appearing quite drab. The eggs are green and barrel-shaped. The larvae are spiny, covered with bristles, and range in background coloration from mottled, pale green to dark, purplish hues (Michaud et al., 2011).

Life cycle and damage: During summer, loosely-knit swarms migrate northward in search of suitable food plants. When large numbers of adults arrive in sunflower fields there is the potential for substantial defoliation to occur. Females lay eggs singly on the upper surfaces of leaves and the eggs hatch after 3-5 days. The larvae feed singly, skeletonizing leaves and tying up silken nests that typically accumulate piles of larval frass. So, damage is normally confined to individual plants, but when many plants are affected, an effort to estimate percent defoliation in the field may be justified. The caterpillar takes 7-11 days to turn into a chrysalis and 7-11 days for the chrysalis to turn into a butterfly (Michaud et al., 2011).

Monitoring: monitor by walking and examining 20 plants at each of five separate locations and determine percentage of defoliation in each location (Michaud et al., 2011).

Economic and action thresholds: action threshold is when plants have sustained 25% defoliation and larvae are still less than 3 cm long (Michaud et al., 2011).

Control: Applying insecticides is advised if the threshold is exceeded. Chlorpyrifos plus gamma-cyhalothrin (Cobalt); Chlorpyrifos plus zeta-cypermethrin (Stallion); Gamma-cyhalothrin (Proaxis) and Lambda-cyhalothrin are recommended (Michaud et al., 2011).

6.11 *Chlosyne (Charidryas) nycteis* (Doubleday) (Lepidoptera: Nymphalidae)

Identification: Silvery Checkerspot is similar in appearance and biology to the painted lady, just the silvery checkerspot has more yellow and less red coloration on the wings. The lower surface of the hind wing bears a large, white crescent on its margin. The larvae are dark and covered with branching bristles with a distinctive yellow line running down each side of the

body. There are initially gregarious, but disperse once their initial food plant is consumed (Michaud et al., 2011).

Life cycle and damage: Females lay their eggs in large clusters, often as many as 100. Even large plants can be completely skeletonized by larval feeding, but more damage can occur when egg clusters are laid on young plants in the V4-V6 stage, in which case the entire plant is quickly consumed and larvae migrate to neighboring plants, sometimes creating a bare hole in the field. They have typically two generations per year (Michaud et al., 2011).

Monitoring: refer to the *V. cardui* monitoring in sunflower.

Economic and action thresholds: The action threshold for defoliation of established plants is 25%, but treatment can only be justified if larvae are still less than 3 cm long, as larger larvae will soon cease feeding (Michaud et al., 2011).

Control: Use materials registered for painted lady caterpillars on sunflower.

6.12 *Euxoa messoria* (Harris), *Euxoa ochrogaster* (Guenee), *Feltia jaculifera* (Walker) (Lepidoptera: Noctuidae)

Identification: They are known as darksided cutworm, redbacked cutworm and dingy cutworm, respectively. The adult of darksided cutworm has light and grayish brown forewings with indistinct markings. Larvae are pale brown dorsally and white on the ventral areas. The sides have numerous indistinct stripes. At maturity, they are about 32 to 38 mm long and 6 mm wide. Redbacked cutworm moth has reddish brown forewings with characteristic bean-shaped markings. Larvae are dull gray to brown and are about 25 to 32 mm long when mature. Larvae can be distinguished from other cutworm species by two dull reddish stripes along the back. Dingy cutworm forewings are dark brown with bean-shaped markings as in redbacked cutworm adults. Hind wings of the male are whitish with a broad, dark border on the outer margin; in the female, they are uniform dark gray. Larvae are dull, dingy brown body mottled with cream color and have a thin light line down the middle of the back with a series of diagonal markings on either side (Knodel et al., n.d.).

Life cycle and damage: Females of darksided and redbacked cutworm moths lay their eggs in the soil. The larvae continue to feed and grow until when mature; mature larvae pupate in earthen cells near the soil surface. The pupal period lasts about three weeks. Both species have one generation per year. Adult dingy cutworms lay eggs on plants in the family Asteraceae in the fall. Larvae develop to the second or third instar in the fall and overwinter in the soil. It has one generation per year. Due to the larval feedings seedlings being cut off from 25 mm below the soil surface to as much as 25-50 mm above the soil surface. Young leaves may be severely chewed from cutworms (notably the darksided cutworm) climbing up to feed on the plant foliage. During the daytime, cutworms usually are found just beneath the soil surface near the base of recently damaged plants and feed at night. Wilted or dead plants indicate the presence of cutworms. Cut plants may dry and blow away, leaving bare patches in the field as evidence of cutworm infestations (Knodel et al., n.d.).

Monitoring: monitoring should be done as soon as sunflower plants emerge, and fields should be checked at least twice per week. A trowel or similar tool should be used to dig around damaged plants to determine if cutworms are present. The Z pattern should be used to determine cutworm population levels by examining five 1-square-foot (30 by 30 cm) soil samples per site (in the row) for a total of 25 samples (Knodel et al., n.d.).

Economic and action thresholds: The economic threshold is one larva per square foot (30 by 30 cm) or 25-30% stand reduction (Knodel et al., n.d.).

Control: Several insecticides are registered for cutworm control in sunflowers. Post emergent treatment with an insecticide provides quick control of surface feeding cutworms. Best results occur if insecticide applied at night. Seed treatment will provide suppression of cutworm activity (Knodel et al., n.d.).

6.13 *Psittacula krameri krameri* (Scopoli), *Psittacula krameri manillensis* (Bechstein) and *Psittacula krameri borealis* (Neumann)

Identification: They are known as African ring-necked parakeet, Indian ring-necked parakeet and Neumann's ring-necked parakeet, respectively. *P. K. krameri* is green, face, abdomen and under wing-coverts yellowish-green; nape and back of head variably washed with blue; chin, broad cheek-stripe; narrow band to nape pink; upperside of middle tail-feathers blue with greenish-yellow tips, outer feathers green; underside of outer tail-feathers olive-yellowish, middle feathers blackish; bill blackish-red with black tips; iris yellowish-white; feet greenish-grey. *P. K. manillensis* is much darker; face stronger green; blue tinge to nape extends in many birds to back of head; breast and abdomen feathers tinged bluish-grey; upper mandible red, lower mandible black; larger. However, *P. K. borealis* is as *krameri*, but face pale green; breast and abdomen feathers in both sexes with marked grey-white tinge; smaller upper mandible red with black tip (Rana, n.d.).

Life cycle and damage: They mostly observed in small groups. They clutch 2-6 eggs; which incubated in 21 to 24 days; and fledging period is about 6 to 7 weeks. The birds' damage starts from the milky stage and continues till harvest. They consume an average of 152 seeds per day. The damage of the birds was highest at the mature stage, 23.8%, and minimum, 7.60%, on the emerging stage of sunflower. Also, other birds such as sparrows, crows and blackbirds can damage sunflower crops (Ahmad et al., 2011; TNAU, n.d.-b).

Control: Establishment of scare crows in the field; bursting of crackers and carbide guns, tying polythene bags may decrease birds' infestations. Destruction of bird nest in and around the field and deploying two laborers per hectare to scare away the birds may be effective. Spraying of neem kernel powder solution at 10 g/liter of water after seed shedding for repelling the birds can be applied (TNAU, n.d.-b).

7. Safflower

Carthamus tinctorius L.: known as safflower, Safflor, Bastard saffron. Safflower has worldwide production, especially in several Western states and Canadian Prairie provinces.

7.1 *Camnula pellucida* (Scudder), *Melanoplus packardii* (Scudder), and *Melanoplus sanguinipes* (F.) (Orthoptera: Acrididae)

Identification: The clear-winged grasshopper, *C. pellucida* is a small but severe species of grasshoppers. *M. packardii* are strong fliers with long wings; the striped sand grasshopper. *M. sanguinipes* is named the Nevada sage grasshopper (Zinni, 2011)

Life cycle and damage: The *Melanoplus* species fed preferentially on leaves, floral parts, and capitula, while *C. pellucida* exhibited only peduncle feeding, which resulted in head clipping.

Defoliation of 20 to 30% was associated with significant increases in total dry matter, seed yield, and number of capitula. Further defoliation resulted in decreases of dry weight, seed yield, and capitula number (Mundel & Johnson, 1987).

Monitoring: refer to the monitoring section for grasshoppers in cotton.

Economic and action thresholds: action threshold is when 8 or more grasshoppers per square yard occur in the field (Knodel et al., 2010).

Control: refer to the control section for grasshoppers in cotton.

7.2 *Dactynotus carthami* (Hille Ris Lambers) [basionym] (Homoptera: Aphididae)

Identification: the synonym of safflower aphids is *Uroleucon compositae* (Theobald). Adults are about 1.5-2 mm long, black with pear-shaped body and conspicuous cornicles. Nymphs are reddish brown (Martínez, 1999).

Life cycle and damage: It is a serious pest of safflower. During pre-flowering stage both nymphs and adults suck the cell sap from shoot apices, peduncles, leaves and stem, secrete a honey dew like secretion on upper surface of the leaves and plant parts forming a black sooty mold which hinders photosynthetic activity resulting in stunted growth. In severe attacks the plants dry up. Yield losses caused by aphids is about 40-50% and infestation may occur 30-45 days old crop. It has four nymphal stages (TNAU, n.d.-a). There are other major aphids species that cause severe or moderate damage to safflower such as *Uroleucon compositae* (Theobald), *Dactynotus orientalis* sp., *Dactynotus jaceae* (Linn.), *Macrosiphum sonchi* (H.R.L.), *Macrosiphum sonchi* (Linn.), *Macrosiphum compositae* (Theobald), *Macrosiphum* spp.(jaceae), *M. persicae*, *Aphis fabae* (Scop) and *Capitophorus eleagni* (Del Guercio) (Hanumantharaya et al., 2008).

Monitoring: install yellow traps for monitoring aphids.

Economic and action thresholds: The economic threshold level is observing 50-60 aphids/5cm twig/plant (Martínez, 1999). However, the economic threshold level differs according to the variety. For *U. compositae* ETL was determined 48.78 aphids/5 cm apical twig/plant on Bhima variety of safflower, with exposure periods of about 2-3 weeks from first aphid incidence. On Annigeri-1 variety of safflower, the ETL was estimated at 38.5 aphids/5 cm apical twig/plant with exposure periods of 2-3 weeks from first aphid appearance (Hanumantharaya et al., 2008).

Control: planting resistant varieties and early sowing escape the peak pest incidence. Application of balanced fertilizer, intercropping and mixed cropping reduces the pest population. Intercultural operations like harrowing; hoeing can reduce the weeds which are host plants for safflower aphids. Also, releasing natural enemies can be used in augmentation programs (Hanumantharaya et al., 2008).

7.3 *Acanthiophilus helianthi* (Rossi) (Diptera: Tephritidae)

Identification: Capsule fly or safflower bud fly adults are ash colored; black obscured by a dense gray microtrichia and wing with characteristic diffused pattern. They have light brown legs. Maggot is dirty white in color (Martínez, 1999).

Life cycle and damage: females lay eggs in clusters of 6 to 24 inside the young flower buds which hatch in 1-3 days. Newly hatched larvae feed on the soft parts of the capsules and later instars feed on the soft part within. Larval period lasted about 7 days in early summer. The infested buds rot and give an offensive smelling fluid. Losses leads to disrupted plant activities, reduction in flower buds, and, ultimately, to decreased quality and quantity of crop. The flies spent their entire lifespan from egg to adult inside the flower heads of safflower plants. Pupation takes place in flower buds and lasted for 5-7 days. The fly overwintered as pupae inside flower heads left in the field after harvest. They have three generations per year. The pest infestation leads to a yield loss ranging from 38.6 to 93.2% (Saeidi & Nur Azura, 2011; TNAU, n.d.-a).

Monitoring: modified Steiner traps baited with methyl eugenol, water traps and sticky traps can be used to monitor bud flies and their immigration to the crop (Alford, 2003).

Economic and action thresholds: no action threshold has been set for safflower bud fly.

Control: sowing of the crop; clean cultivation and using resistant varieties are cultural techniques for controlling safflower bud flies. Some bio-control agents such as *chrysopa* sp., *Orymurus* sp., *Eurytoma* sp., *Stenomalus muscarum* (L.), *Syntomopus* sp., *Bracon* sp., *Pronotalia* sp. and *Antistropheplex conthurnatus* (Masi) can reduce the population build up. Application of insecticides such as dimethoate 30 EC, malathion 50 EC and phosphomidon 100 EC is recommended if the threshold is exceeded (TNAU, n.d.-a).

7.4 *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidea)

Identification: *H. armigera* is known as gram pod borer or capsule borer. Refer to the identification section for *H. armigera* in cotton.

Life cycle and damage: The life cycle is more or less the same as on cotton but differ due to the weather conditions. In early stage of crop growth larvae feed on leaves and shoot apices. Later, the larvae shift to the developing capitula. The symptoms are perforated leaves, perforated involucres bracts, partially or completely eaten capitula in the bud stage and bored developing capitula (TNAU, n.d.-a).

Monitoring: refer to the monitoring section for *H. armigera* in cotton.

Economic and action thresholds: The ETL of capsule borer is 50 larvae per 100 plant (TNAU, n.d.-a).

Control: refer to the control section for *H. armigera* in cotton.

7.5 *Perigea capensis* (Guen) (Lepidoptera: Noctuidea)

Identification: the synonyms of the species are *Perigea illecta* (Walker) and *Platysenta illecta* (Walker). The adult is dark brown and forewings are dark brown with pale wavy marks; Hind wings are light brown. Safflower caterpillars are stout, green and smooth. The anal segment is humped and the body has some purple markings (TNAU, n.d.-a).

Life cycle and damage: The larva feeds on the leaves, bracts, flowers, capsules and sometimes on capitulum too. They also bore into the stem and flower-buds and feed on the contents (TNAU, n.d.-a).

Monitoring: larvae can be monitored by directly observations and counting the number of larvae per plant on 10 randomly selected and tagged plants.

Economic and action thresholds: no action threshold has been established for *P. capensis*.

Control: Intercropping with non-host crop like wheat can be effective. They can be controlled biologically by *Apanteles ruficrus* (Haliday), *Hetergamus* sp., *rogas* sp. and *Euplectrus euplexiae* (Rohwer), green muscardine fungus (*Metarhizium anisopliae*) and NPV. If the threshold is exceeded spraying Indoxacarb 15 EC, Spinosad 45 SC, Carbaryl 50 WP, Endosulfan or Fenvalerate 20 EC is advised (TNAU, n.d.-a).

7.6 *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae)

Identification: moths have a wingspan of 25-30 mm. Forewings have a lighter spot near the center. Hindwings are paler with darker borders; however, a light band occurs at the wing edges. Eggs are flattened half-spheres, white to pinkish, with fine radiating lines from the top center. They are covered by the white, hairs like that give a cotton ball appearance to the egg cluster. The larvae color ranges from bright green to purplish green to blackish. The most common phase is light olive green with a darker strip down the back and a paler stripe along each side. Pupation occurs on or under the soil surface. Pupae are brownish, typical of all close relatives (Mau & Kessing, 2007b).

Life cycle and damage: females lay eggs in clusters that may be several layers deep. They hatch in 5-7 days in warm weather. Young larvae feed gregariously and skeletonize foliage. As they mature, larvae become solitary and eat large irregular holes in foliage. They are a serious defoliator of flower crops, safflower and cotton. The larvae have sixth instars (Capinera, 2010a).

Monitoring: Pheromone traps can be used to detect the presence and intensity of moths.

Economic and action thresholds: action threshold is 0.3 larvae per plant (Capinera, 2010a).

Control: controlling broad leaf weeds and rapid disposal of crop residues after harvesting may reduce population buildup. If the threshold is exceeded application of insecticides is advised. However, insecticides should be applied in early larval stages and achieve good coverage of targeted plants (Mau & Kessing, 2007b).

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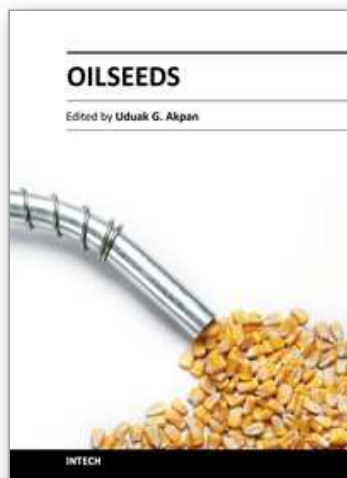
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