Chapter 11
Insect Pests of Cotton and Their Management

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Abstract Cotton is a cash and industrial crop in many parts of the world. Nowadays, production of cotton is very low, and issues of yield stagnation exist in many developing countries. Major causes of lower yields are climate change soil salinity, lack of adaptation of agronomic practices, pathological, and entomological problems in nature. Insect pests of cotton crop, are categorized in sucking and chewing in nature. In order to harvest high yield, it is recommended to control all types of insect pests of cotton through integrated pest management techniques.

Keywords American bollworm · Armyworm · Spotted bollworm · Pink bollworm · Jassid · Whitefly · Cotton mealybug

11.1 Insect Pests of Cotton

Insect pests of cotton are categorized into two categories.

1. Chewing insect pests.
2. Sucking insect pests.

11.1.1 Chewing Insect Pests

11.1.2 American Bollworm/Fruit Borer

1. **Scientific Name:** *Helicoverpa armigera* Hubner.

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Fig. 11.1 Egg of American bollworm

2. **Common Names:** American bollworm, African bollworm, cotton bollworm, tomato bollworm, corn earworm, tobacco budworm, common bollworm, bean pod borer, etc. (Broadley 1977).
3. **Family:** Noctuidae **Order:** Lepidoptera.
4. **Identification.**
   (a) **Eggs:** Spherical in shape and creamy white in color. Females lay eggs singly (Fig. 11.1).
   (b) **Larvae:** Variety of colors from greenish to brown. The body of larvae has dark brown-gray line with precise white lines. The body has dark and pale bands. On first abdominal segment of dorsal surface, saddle markings are present and legs have dark pigmentations (Stanley 1978). White color cervical shield hair is present in sixth instar larvae on the anterior dorsal side (Zalucki et al. 1986) (Fig. 11.2).
   (c) **Pupae:** Pupate in crop debris, soil, leaf, and pods. Mostly brown in color. The distance between the outer edges of the cremaster spines at the junction is >0.22 mm (Cantrell 1980; Kirkpatrick 1961) (Fig. 11.3).
   (d) **Adult:** Brownish yellow light pale with stout mouth. Forewings are olive green to pale brown in color with dark brown circular spot in the center. Hind wings are pale smoky white with blackish outer margin. Pale patch between M3 and Cu2 present in hind wings. Genital plate is cup shaped (Common 1953) (Fig. 11.4).
5. **Biology.**
   (a) **Adult:** Mostly male moths prefer mating during night time. Female moth starts egg laying from second to seventh day of their life span (Karim 2000) (Fig. 11.4).
   (b) **Eggs:** A female moth lays almost 150–1500 eggs during its life span, but average egg laying is 450 eggs (Karim 2000) (Fig. 11.1).

Fig. 11.2 Larvae of American bollworm

Fig. 11.3 Pupa of American bollworm

(c) **Larvae:** The life cycle of larvae consists of six instars. The size of first instar larvae is1.75 mm, second instar is 3.5–4 mm, third instar is 9–10 mm, and 35–42 mm. Larvae of fourth, fifth, and sixth instars change their color according to food and weather conditions, and larval stage is completed in 15–30 days (Karim 2000) (Fig. 11.2).

(d) **Pupae:** Pupae take 5 to 8 days for their emergence from pupae to adult in summer, but in case of any type of diapause, it takes several months for their emergence (Karim 2000) (Fig. 11.3).

Fig. 11.4 Adult of American bollworm

6. **Number of Generations:** 4–8 per year.
7. **Hosts**

   American bollworm is a polyphagous pest which attacks more than 200 plant species. Cotton, chickpea, pigeon pea, sunflower, sorghum, tobacco, peanut, maize, many fruits, vegetables, and tree plants are important hosts of American bollworm in Asia (Fitt 1989).
8. **Damage**

   Mostly American bollworm larvae feed on reproductive parts (flowers and fruits) of the host plants. Larvae also attacks on foliage. Larvae bore the reproductive parts and feed within the plants. Pathogens may attack the plant due to wounding of plant parts. In cotton, bore holes can be seen at the base of flower buds. Larvae consume the leaves and shoots. Full-grown larvae bore into mature green bolls, and due to the damage caused by larvae, green bolls start to fall. Adults lay eggs on the vertical side of the leaves (CABI 2007) (Fig. 11.5).
9. **ETL:** 3–5 eggs or larvae per 25 plants.
10. **Control.**

    (a) **Chemical Control:** (1) Profenofos + cypermethrin (Polytrin C, 440EC, Syngenta; Basel, Switzerland) 600 ml/acre for American bollworm, eggs.

    (2) Profenofos (Curacron, 500EC, Syngenta; Basel, Switzerland) 1000 ml/acre.

    (3) Emamectin benzoate (Proclaim, 019EC, Syngenta; Basel, Switzerland) 200 ml/acre

    (b) **Nonchemical Control:** Bt cotton has a great potential to resist bollworms, especially American bollworm, so Bt cotton is considered the most effective nonchemical control against *H. armigera* (Fitt 2000). But now a days there are few reports of failure of Bt cotton to control chewing pests due to pest resistance against Bt.

Fig. 11.5 Damage of American bollworm

11. **Natural Enemies:** *Menochilus sexmaculatus*, *Syrphus corolla*, and *Chrysoperla carnea* considered as effective biocontrol agents against American bollworm (Ghosh et al. 2010).

11.1.3 Armyworm/Tobacco Cutworm

1. **Scientific Name:** *Spodoptera litura* Fabricius.
2. **Common Names:** Cotton cutworm, rice cutworm, tobacco budworm, cotton leaf worm, luster caterpillar, Egyptian cotton worm, tobacco caterpillar, tobacco cutworm, and tobacco leaf caterpillar.
3. **Family:** Noctuidae **Order:** Lepidoptera.
4. **Identification.**

   (a) **Eggs:** Spherical, flattened in shape, 0.4–0.7 mm in diameter. Pearly green color that turns into black with changing of stage. Female lays in the form of batches. Eggs are covered with pale orange-brown or pink hair-like scales from the female body (Pearson 1958) (Fig. 11.6).

Fig. 11.6 Eggs of armyworm

Fig. 11.7 (**a–b**) Larvae of armyworm

(b) **Larvae:** First instar larvae are tiny blackish having black band on first abdominal segment. Fully grown larvae are firm and flat with speckled short setae. Head has long hair on each segment with black shiny appearance. The color of full-grown larvae is not constant; it changes dark gray to dark brown or black. In size, mature larvae are 40–50 mm. Two large black spots can be seen on first abdominal segment besides eight abdominal segments (Hill 1975) (Fig. 11.7a, b).

(c) **Pupae:** Pupae are reddish brown in color and with rough earthen cases. It pupates in soil.

Pupae are 18–22 mm long. Two hooks are present on the last abdominal segment (USDA 1982).

(d) **Adults:** Body color is whitish to yellowish, immersed with pale red. Forewings have shaded lines and strips with dark brown color. Hind wings are

Fig. 11.8 Adult of armyworm

whitish with violet sheen; margins are dark brown besides venation brown. Thorax and abdomen have hair-like tufts on the dorsal side with orange to light brown color. Head is covered with tufts of light and dark brown scales. The size of wing span is 28–38 mm, and body length is 14–18 mm (Hill 1975) (Fig. 11.8).

5. **Biology.**
   (a) **Adult:** Females lay 50–300 eggs in masses on the lower surface of the leaves after 5 days of emergence.
   (b) **Eggs:** After 3–4 days, eggs hatch. The capacity of single female to lay eggs is 1500–2500 eggs in about 6–8 days (Chari and Patel 1983).
   (c) **Larvae:** Larval stage of *S. litura* has six instars. It takes 23–24 days for emergence of adults from first instar larvae (Etman and Hooper 1980).
   (d) **Pupae:** Larvae of armyworm pupate in the soil in the form of cocoon, and pupal duration varies from 7 to 11 days (Etman and Hooper 1980).
6. **Number of Generations:** Several.
7. **Hosts**
   Tobacco caterpillar considered is a polyphagous pest (Srivastava et al., 2015). The plant species are considered major host plants for *S. litura* in Pakistan are: cotton, castor, jantar, and cauliflower (Ahmad et al. 2013).
8. **Damage:** Extensive feeding of larvae causes damage in most host plants. Due to feeding of larvae, complete skeletonization of leaves of whole plants can be observed. Usually, larvae are leaf feeders but sometimes also attack seedlings. Heavy feeding of larvae causes stunted growth of young seedlings and small fruits. Larvae of *S. litura* feeds on undersides of the leaves and cause scars and skeletonization of leaves. Damage symptoms of *S. litura* are holes and bare section on leaves, fresh stalks, bolls, and buds on later stages of plant. Mines also can be observed on young shoots (Hill 1975) (Fig. 11.9).
9. **ETL:** On appearance.

Fig. 11.9 Damage of armyworm

10. **Control.**

    (a) **Chemical Control:** (1) Emamectin benzoate 200 ml/acre. (2) Lufenuron 200 ml/acre.

11. **Natural Enemies.**

    (a) **Egg Parasites:** (1) *Chelonus helipae* Gupta, (2) *Trichogramma australicum* Girault, (3) *T. chilonis* Ishii (Rao et al. 1993).
    (b) **Larval Parasites:** (1) *C. carhonator* Marshall, (2) *C. formosanus* (Sonan) (Rao et al. 1993).
    (c) **Predators:** (1) *Liposcelis* sp., (2) *C. carnea* (Rao et al. 1993).

11.1.4 Spotted Bollworm/Spiny Bollworm

1. **Scientific Name:** *Earias vittella* (Fabricius).
2. **Common Names:** Spiny bollworm, okra shoot and fruit borer.
3. **Family:** Noctuidae **Order:** Lepidoptera.
4. **Identification.**

    (a) **Eggs:** Eggs of *E. vittella* are light bluish green in color with longitudinal ridges (Alam 1969).
    (b) **Larvae:** The color of full-grown larvae is green and black besides orange, but in some studies, brownish color of larvae with white streaks dorsally

Fig. 11.10 Larva of spotted bollworm

besides pale yellow ventrally is also reported. The length of full-grown larvae is about 1.64 cm (Alam 1969; Mazed et al. 2016) (Fig. 11.10).

(c) **Pupae:** Larvae pupate in the form of boat-shaped gray cocoon on fruits or in soil, but in some studies, it is described that pupae were chocolate brown and bluntly rounded and enclosed in gray-colored inverted boat-shaped cocoons (Alam 1962; Butani and Jotwani 1984).

(d) **Adult:** The color of head and thorax of spotted bollworm adults is ochreous white. The length of adult is about 1.25 cm across the forewings. Forewings are pale whitish with a wedge-shaped horizontal green patch in middle. Hind wings are silvery white in color (Alam 1962; Butani and Jotwani 1984). In some studies, it is reported that narrow light green bands are present longitudinally on the middle of the forewings (Atwal and Dhaliwal 1997; Mazed et al. 2016). Female is larger in size than male. Female is V-shaped at the end of the anal part, while male has thick hairs on the anal part (Mazed et al. 2016) (Fig. 11.11a–c).

5. **Biology.**

   (a) **Eggs:** A single female can lay 63–697 eggs during oviposition period. The incubation period varies from 3 to 7 days (Kranz et al. 1978).

   (b) **Larvae:** Larvae take 10–19 days for full growth in various seasons (Pant 1960).

   (c) **Pupae:** Pupation period is 8–14 days (Mihra 1935).

   (d) **Adults:** Life of adults is 2–4 weeks as reported in previous studies (Cherian and Kylasam 1947).

6. **Hosts:** Spiny bollworm is considered a polyphagous pest all over the world. The plant species which are considered main hosts of spiny bollworm: cotton, okra, hollyhock, and shoe flower (Syed et al. 2011).
7. **Damage:** In cotton, larvae of spotted bollworm attacks the tender top growing shoots and bore the shoots leading to the tunnel down the stem. As a result, attacked shoots become dry. Larvae of spotted bollworm also attack bolls; enter

Fig. 11.11 (**a–c**) Adults of spotted bollworm

into the bolls and feed internally; after feeding on one boll, they move to another (Ahmed et al. 2012) (Fig. 11.12a–e).

8. **ETL:** 3–5 larvae/25 plants or 10% infested shoots or and squares or and bolls.
9. **Control.**

   (a) **Chemical Control:** (1) Profenofos + cypermethrin 600 ml/acre, (2) Spinetoram 50–60 ml/acre, (3) Gamma-cyhalothrin 100 ml/acre, (4) Cypermethrin 330 ml/acre, (5) Deltamethrin 80 ml/acre.

   (b) **Nonchemical Control:** Control of spotted bollworm through *Bacillus thuringiensis* (Bt) varieties are considered the most effective nonchemical control (Entwistle 1993).

10. **Natural Enemies.**

    (a) **Egg Parasitoids:** (1) *T. achaeae*, (2) *T. chilonis* Ichii.

    (b) **Larval Parasitoids:** (1) *Activa aegypti* Vill and *Activa* sp., (2) *A. hyalinata* Mall, (3) *Agathus aciculatus* (Brues), (4) *Agathus* sp., (5) *Apanteles* spp.

    (c) **Predators:** (1) *Brumoides suturalis* (F.), (2) *Geocoris* sp., (3) *Cartheconidea furcellata* (Woeff), (4) *Eumenes petiolata*, (5) *M. sexmaculatus*, (6) *Phanerotoma hendecasisella* (Kashyap and Verma 1987).

Fig. 11.12 (**a–e**) Damages caused by spotted bollworm

11.1.5 Pink Bollworm

1. **Scientific Name:** *Pectinophora gossypiella* (Saunders).
2. **Family:** Gelechiidae **Order:** Lepidoptera.
3. **Identification.**

   (a) **Eggs:** Eggs of *P. gossypiella* are elongate, oval, flattened, and about 1 mm long; 0.5 mm broad. The color of new laid eggs has a slightly greenish shade and becomes reddish on maturity (Busck 1917).

Fig. 11.13 Larvae of pink bollworm

(b) **Larvae:** The first instar larvae are white in color and have black heads. The length of mature larva is 10–12 mm. Full-grown larvae are white in color having red band on the upper side of each segment (Mukuka et al. 2002) (Fig. 11.13).

(c) **Pupae:** The color of pupae is plump, reddish brown and becomes darker on maturity, and the length is 8–10 mm. The posterior end of pupae is pointed and terminating in a short stout looks hooklike; setae and spines are present on the last segment. Imago's eyes can be seen clearly under the gena of pupal skin (Busck 1917).

(d) **Adult:** Adults of pink bollworm are 12–20 mm long having brown and dark brown color. The color of head is reddish brown having pale, rainbow-like scales. Basal segment having brown color antennae bears a pectin of 5 or 6 hair-like scales. Adult forewings are elongated, oval, and pointed at the tips with a wide fringe. In inner side, forewings are in brown color with fine dark scales on medial cells and wing base. Hind wings are broader than forewings, trapezoidal in form, and silvery gray with a darker, iridescent hind margin. Wing fringe is ochreous and darker at the base and apex. Legs are brownish black having transverse, ochreous bands in ring form. Abdomen is ochreous toward the upper side and dark brown laterally and covered with ochreous-brown scales on the underside.

In genitalia, male uncus is broad at base, tapering to a point, and aedeagus has a hooked tip. Female ovipositor is weakly sclerotized (Mukuka et al. 2002) (Fig. 11.14a, b).

4. **Biology.**

(a) **Eggs:** Singly laid eggs are found on green cotton bolls and flowers in the form of batches. Eggs hatch in 3–6 days, and a sole female can lay 300 eggs (Busck 1917; Mukuka et al. 2002; Noble 1969).

(b) **Larvae:** Larval duration is completed in 20–30 days and has four larval instars, and the last instar of larvae is of pink color. That is why it is known as pink bollworm (Busck 1917; Noble 1969).

(c) **Pupae:** Larvae pupate in seed or in soil in the form of cocoon, and pupation duration is 10–20 days (Busck 1917; Noble 1969).

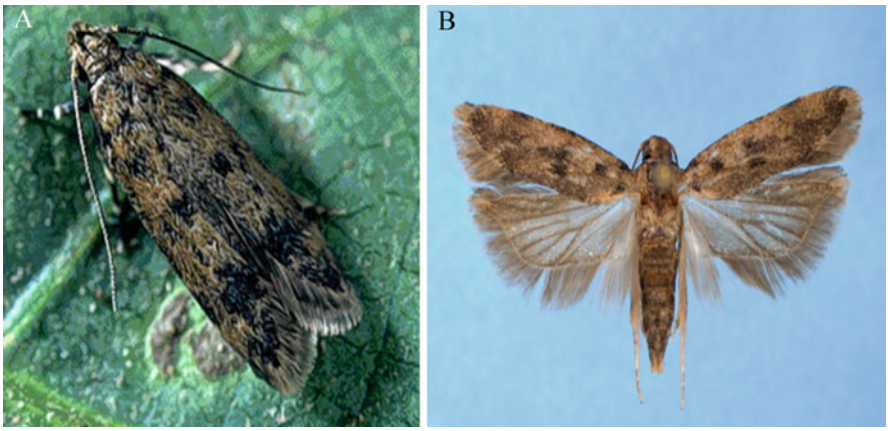

Fig. 11.14 (**a–b**) Adults of pink bollworm

(d) **Adult:** Life period of adults is 1.5–2 weeks, and whole life cycle is completed in 35 days in favorable conditions (Busck 1917; Noble 1969).

5. **Number of Generations:** 5–6 generations in a cotton season (Kaçkavalci and Öncüer n.d.).
6. **Hosts:** Cotton is considered a major host of *P. gossypiella*, while okra is also reported as a host of that particular pest (Busck 1917).
7. **Damage:** Larvae make tunnels on the bolls after hatching from eggs; usually they feed on the soft portion of the bolls (Busck 1917). It is very difficult to identify the entry point of the larvae. Due to the damage of the larvae, complete opening of bolls failed (Mukuka et al. 2002). Shedding of fruits, lint damage, rotted bolls, seed loss, flower damage, and discolored seed or lint are also caused by larvae feeding (Ingram 1994; Leigh et al. 1996) (Fig. 11.15a–e).
8. **ETL:** 10% boll damage (Mohan et al. 2016).
9. **Control.**

   (a) **Chemical Control:** (1) Lambda cyhalothrin 400 ml/acre, (2) Spinetoram 100–120 ml/acre, (3) Deltamethrin 80 ml/acre, (4) Triazofos 1000 ml/acre.

   (b) **Nonchemical Control:** (1) Mating disruption through the usage of gossyplure in high dose is considered the most successful nonchemical control (Flint et al. 1985; Staten et al. 1987).

   (2) Bt cotton is considered a long-term nonchemical control against pink bollworm (Carriere et al. 2003).

10. **Natural Enemies:** All common predators which are found in cotton field are capable of controlling the pink bollworm, but *Labidura riparia* (Pallas) attack on all stages of pink bollworm (Orphanides et al. 1971).

Fig. 11.15 (**a–e**) Damages caused by pink bollworm

11.2 Sucking Insect Pests of Cotton

11.2.1 Cotton Jassid

1. **Scientific Name:** *Amrasca biguttula* (Ishida), *Amrasca devastans.*
2. **Common Names:** Cotton jassid, cotton leafhopper, brinjal leafhopper.
3. **Family:** Cicadellidae **Order:** Homoptera.
4. **Identification.**

Fig. 11.16 Nymphs of jassid

(a) **Eggs:** Female lays eggs singly. The color of eggs is pale whitish. A hook is present at the anterior end, and the other end is broad pointed. The length of eggs is 0.50–0.63 mm (Jayarao et al. 2015).
(b) **Nymph:** Nymphal period consists of five instars. First nymphal instar is in transparent and yellowish color. The color of second instar is dark reddish with white color eyes, and rudimentary wing pads can be seen on meso- and metathorax. The third instar nymph is in yellowish green color having small wing pads. In fourth nymphal instar, the size of wing pads increases, and fourth instar is in yellowish green color. Fifth and fully developed nymphal instar has greenish yellow color with fully developed eyes, and white color wing pads can be seen up to ninth abdominal segment, while two black dots are present on the base of wing pads (Jayarao et al. 2015) (Fig. 11.16).
(c) **Adult:** Green color adults have conspicuous black spots on the apical part of the wing and top of the head. Females can be identified with the help of genitalia present at the end of the abdomen, and females are larger than males in size. The average length of a female is 2.76 mm (Jayarao et al. 2015) (Fig. 11.17).

5. **Biology.**

(a) **Eggs:** The incubation period is 6–7 days, and a single female can lay 17–18 eggs (Jayarao et al. 2015).
(b) **Nymphal Period:** Cotton jassid completes its nymphal period in 6–11 days, but that period varies host to host (Jayarao et al. 2015).

Fig. 11.17 Adult of jassid

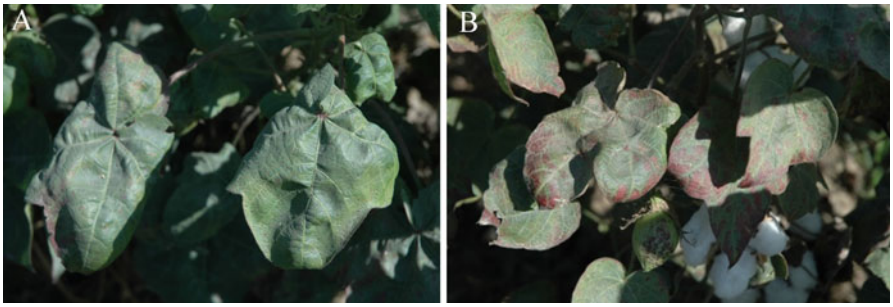

Fig. 11.18 (**a–b**) Damages caused by jassid

(c) **Adult:** Longevity of male and female varies according to their food, so longevity of female is 16–18 days and of male is 14–17 days reported in previous studies. Cotton jassid completes its whole life cycle in 19–35 days (Jayarao et al. 2015; Shivanna et al. 2009).

6. **Number of Generations:** 7 generations per year.
7. **Hosts:** Cotton, sunflower, okra, turnip, sarson, radish, cucumber, watermelon, gourd, sponge gourd, and peas are the common hosts of cotton jassid (Jayarao et al. 2015; Saeed et al. 2015).
8. **Damage:** Cotton jassid is considered a polyphagous pest in Pakistan (Akram et al. 2011; Khan and Khaliq 2004). Cotton jassid caused heavy damage in plants after sucking the sap from leaves and injecting toxic saliva. Due to the heavy damage of cotton jassid, the following symptoms can be observed: stunted plant growth and curling of leaves downward; first, leaves become yellow and then change into brown and become dry, and there is shedding of fruiting bodies (Narayan and Singh 1994; Rehman 1940). In cotton, 37–67% losses are reported in previous studies due to the damage of cotton jassid (Ahmad et al. 1986; Bhat et al. 1984; Manzoor 1982) (Fig. 11.18a, b).

9. **ETL:** 1 jassid per leaf.
10. **Control.**
    (a) **Chemical Control:** (1) Acetamiprid 125 g/acre, (2) dinotefuran 100 g/acre, (3) imidacloprid 80–100 ml/acre, (4) buprofezin 600 g/acre, (5) diafenthiuron 200 ml/acre, (6) nitenpyram 130 g/acre, (7) thiamethoxam 24 g/acre.
    (b) **Non-chemical Control:** Spray of *Bacillus thuringiensis* 500 g/acre can be effective as a nonchemical control against cotton jassid (Mehmood et al. 2001).
11. **Natural Enemies:** *Chrysoperla carnea* is considered an effective predator of cotton leafhopper (Balasubramani and Swamiappan 1994).

11.2.2 Cotton Whitefly

1. **Scientific Name:** *Bemisia tabaci* (Gennadius).
2. **Common Names. Whitefly**
3. **Family:** Aleyrodidae **Order:** Homoptera.
4. **Identification.**
    (a) **Eggs:** Female lays eggs in the form of clusters or scattered on smooth leaves. Eggs are in yellowish white color and become pale brown, semi-transparent, and dark brown after hatching (Morr 2004).
    (b) **Nymph:** Nymphs are yellow or cream in color with oval or elongated shape. Well-developed 1–7 setae are present on the dorsal side (Morr 2004) (Fig. 11.19).

Fig. 11.19 Eggs and nymphs of whitefly

Fig. 11.20 Adult of whitefly

(c) **Adult:** Adults are dark yellow in color, and forewings are straight with anterior margin (Morr 2004). Wings are covered with waxy powder. The color of compound eyes is red (Fig. 11.20).

5. **Biology.**

   (a) **Eggs:** Whitefly complete its life cycle from egg to adult in 15–70 days depending on temperature and host. A single female can lay 28–300 eggs; it also depends on temperature and host (Butler Jr et al. 1983). Eggs hatch in 5–22 days on various temperatures (El-Helaly et al. 1971).
   (b) **Nymph:** The first stage of nymph is known as crawler, and last nymphal instar is named as pupa. Nymphal period is 2–7 weeks.
   (c) **Adults:** Female can lay eggs in 1–8 days post-mating. Total life span is 6–55 days depending upon temperature (Anonymous 2018).

6. **Number of Generations:** 10–12.
7. **Hosts:** More than 500 plant species are the hosts of that particular pest throughout the world (Greathead 1986). Cotton, sweet potatoes, cassava, tobacco, and tomato are major hosts (Li et al. 2011).
8. **Damage:** Damage caused by whitefly is categorized in three ways: (1) direct damage, (2) indirect damage, and (3) virus transmission (Berlinger 1986).

   Direct damage caused by whitefly nymphs and adults through piercing and sucking of the sap from foliage of the plants causes weakness, early wilting, and reduced plant growth and yield (Berlinger 1986).

   Whiteflies excrete the honeydew on the leaves of a plant which is responsible of black sooty mold to grow on it. Due to that sooty mold, photosynthesis slows down and plant yield is low. This known as indirect damage (Berlinger 1986) (Fig. 11.21).
9. **ETL:** 10–15 nymphs or adults per leaf

   More than 40 diseases in plants are caused by the transmission of plant viruses through whitefly (Cohen and Berlinger 1986).

Fig. 11.21 Attack and damage of whitefly

10. **Control.**

(a) **Chemical Control:** (1) Acetamiprid 125 gm/acre, (2) pyriproxyfen 400 ml/acre, (3) imidacloprid 250/acre, (4) spirotetramat 240 ml/acre, (5) buprofezin 600 gm/acre, (6) diafenthiuron 200 ml/acre (7) flonicamid 60 gm/acre.

(b) **Nonchemical Control.**

- **Cultural Control:** Row covers, repellent mulches, and soil mulching with yellow polyethylene sheet could be helpful to lower the population of whitefly (Cohen and Melamed-Madjar 1978).
- **Host Plant Resistance:** It has a lot of potential to suppress the population of whitefly and is considered a very important component of integrated pest management against whitefly (Berlinger 1986).

(c) **Biological Control.**

- **Parasites:** (1) Species belonging to genus *Encarsia* (Polaszek et al. 1992).
- **Predators:** The following predators attack whiteflies:

  – *Coccinella undecimpunctata* (Cock 1993).
  – *Coccinella septempunctata* (Cock 1993).
  – *Orius albidipennis* (Cock 1993).
  – *Cardiastethus assimilis* (Dean 1996).
  – *Orius insidiosus* (Dean 1996).
  – *Chrysoperla carnea* (Cock 1993).

11.2.3 Cotton Aphid

1. **Scientific Name:** *Aphis gossypii* Glover.
2. **Common Names:** Melon aphid, cotton aphid (Takalloozadeh, 2010).
3. **Family:** Aphididae **Order:** Homoptera.
4. **Identification.**

   (a) **Eggs:** Eggs are laid singly in the form of loose masses. Each egg is covered with wax secreted by female. Newly laid eggs are elongated in shape with a flat surface and are bright; these eggs are yellow and change into black with the passage of time.

   (b) **Nymph:** Nymphal stage consists of four instars.

   - First instar nymph is yellowish in color and translucent and changes into grayish with elongated shape after 1 day. On that stage, red noticeable compound eyes can be seen, but legs are not well developed. Two clear antennae can also be observed in first instar with four antennal segments. In first instar, abdomen is small and nine segmented.
   - Second instar nymph is similar to first instar, but second instar has five antennal segments; through this characteristic, we can differentiate first instar and second instar.
   - Third instar nymph is yellow in color, but the ventral side is pale. Clear red eyes and antennae can be observed easily. Prominent wing pads are also present in third nymphal instar.
   - Fourth nymphal instar is dark in color, and red dark eyes are present. Abdomen is more elongated than thorax. Third instar has no setae on genital plate, while fourth instar has setae on genital plate. That is the distinguishing characteristic of third and fourth instars (Begum et al. 2018; Wool and Hales 1996).

   (c) **Adult:** Adults are 1–1.5 mm long, and the color is yellow to dark green depending on temperature and winter and summer season. Cornicles are present at the end of the abdomen (Bethke and Paine 1991; Setokuchi 1981; Wall 1933). We can separate *Aphis gossypii* through these cornicles which are equally sclerotized from tip to base and darkly pigmented. They are longer than cauda which gradually tapers toward the apex with a small opening (Blackman and Eastop 2000).

5. **Biology.**

   (a) **Eggs:** On cotton plant, 1–4 nymphs/day are reported in previous studies, and incubation period is 15–19 h as reported in the laboratory (Begum et al. 2018; Saha et al. 2016).

   (b) **Nymph:** Nymphal duration is reported 5–6 days on cotton plant in earlier studies (Saha et al. 2016).

   (c) **Adult:** Adult longevity of 9–11 days is reported in earlier studies (Saha et al. 2016).

6. **Number of Generations:** 15.
7. **Hosts:** *Aphis gossypii* attacks 912 plant species belonging to 166 families. Cotton, okra, potato, chili pepper, sweet pepper, eggplant, melon, and watermelon are the major plant hosts (Ebert and Cartwright 1997; Inaizumi 1980).
8. **Damage:** Aphids attack their host plants through direct and indirect ways. Aphids are phloem feeders; they consume all nutrients which are essential for plant growth. When aphids feed on different parts of the host plant, they inject saliva which is highly toxic for plants (Dedryver et al. 2010; Nault 1997). Aphids transmit almost 275 plant diseases as a vector in their host, while *Aphis gossypii* vectored 60 diseases in their hosts (Dedryver et al. 2010; Kersting et al. 1999). Aphids secrete honeydew which helps black sooty mold to grow on it, and this inhibits photosynthesis in host plants (Michaud and Sloderbeck 2005). Formation of sticky fiber in open bolls of cotton is due to honeydew secretion by cotton aphid (Dedryver et al. 2010). Direct damage caused by cotton aphid in cotton induced plant deformation (Kersting et al. 1999). Curling of leaves downward, wrinkled leaves, stunted growth of young plants, and death of young plants are the major damage symptoms of cotton aphid (Ebert and Cartwright 1997; Matthews 1989).
9. **ETL:** 10–15 nymphs or adults per leaf.
10. **Control.**

(a) **Chemical Control:** (1) Acetamiprid 50g/l of water, (2) carbosulfan 330 ml/acre, (3) pymetrozine 80 g/l of water, (4) imidacloprid 250 ml/acre.

(b) **Nonchemical Control.**

- **Cultural Control:** Topping (remove the top portion or leaves) of plants is considered a cultural control in cotton against cotton aphid (Deguine et al. 2000).
- **Host Plant Resistance:** Host plant resistance is a very vital component of integrated pest management against aphids (Dedryver et al. 2010). In previous studies, some resistant cotton cultivars are very effective against *Aphis gossypii* (Du et al. 2004).

(c) **Biological Control.**

- **Parasitoids:** (1) *Lysiphlebus testaceipes*, (2) *Aphidius colemani*, (3) *Aphidius matricariae* (van Steenis 1995; Zamani et al. 2007).
- **Predators:** Predators attack all stages except the egg of *Aphis gossypii*, and these predators belong to the following families: Coccinellidae, Syrphidae, Chrysopidae, and Hemerobiidae (Ebert and Cartwright 1997).

  Some important predators of cotton aphid are (1) *Adalia bipunctata*, (2) *Coleomegilla maculata*, (3) *Cycloneda sanguinea*, and (4) *Chrysoperla carnea* (van Steenis 1992).

11.2.4 Onion Thrips

1. **Scientific Name:** *Thrips tabaci* Lindeman.
2. **Common Names:** Onion thrips, thrips.
3. **Family:** Thripidae **Order:** Thysanoptera.
4. **Identification and Biology.**
   (a) **Eggs:** Female lays white- or yellow-color kidney-shaped eggs and puts them on the lower or upper surface of the leaves (Abdel-Gawaad and El-Shazli 1971). Eggs are approximately 0.26 mm in length (Ghabn 1948).
   (b) **Nymph:** Nymphs are white to pale yellow in color and have short micro setae with three segmented antennae. Abdomen has ten segments with a pair of spiracles on second and eighth abdominal segments (Vierbergen et al. 2010).
   (c) **Pre-pupa and Pupa:** Pre-pupal and pupal stages have wing sheath. We differentiate these stages through development and orientation of antennae, length of antennae, and wing sheath (Ghabn 1948).
   (d) **Adult:** Adults are pale yellow to dark brown in color; however, they change their color as the temperature changes (Morison 1957; Murai et al. 2002; Nakahara 1991; Sakimura 1937; Tripplehorn and Johnson 2005). Adults have seven segmented antennae and four setae on front wing (Diaz-Montano et al. 2011; Mound and Walker 1982). Males are smaller than females; the length of male is approximately 0.7 mm (Pergande 1895), and of female is 1 to 1.3 mm (Morison 1957) (Fig. 11.22).
5. **Number of Generations:** 5–8 per year.
6. **Hosts:** There are 141 plant species belonging to 41 families that are reported as hosts of *tabaci* in previous studies (Ghabn 1948). Onion, beans, cabbage, beets, cauliflower, cotton, cucumber, tomato, melon, chilies, tobacco, potato, clover,

Fig. 11.22 Adult of thrips

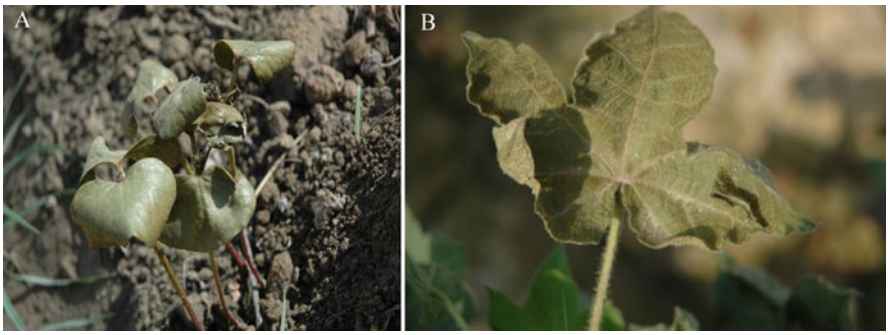

Fig. 11.23 (**a**) Damages caused by thrips

and squash are the major hosts of *tabaci* (Attique and Ahmad 1990; Doederlein and Sites 1993).

7. **Damage:** Due to sap sucking from the leaves of cotton, the following symptoms can be observed in cotton: stunted plant growth; delay in fruiting, maturity, and harvesting; faded leaf tips; and damage of the lower parts which leads to plant death (Ananthakrishnan 1993; Hawkins et al. 1966) (Fig. 11.23a, b).
8. **ETL:** 8–10 adults/leaf.
9. **Control.**

   (a) **Chemical Control.**

   (1) Acetamiprid 125 g/acre, (2) spinetoram 50–60 ml/acre, (3) chlorfenapyr 100 ml/acre, (4) acephate 300–400 g/acre, (5) profenofos 800 ml/acre

   (b) **Biological Control:** (1) *Coccinella septempunctata* is the best control agent in controlled environment (Deligeorgidis et al. 2005).

11.2.5 Red Cotton Bug

1. **Scientific Name:** *Dysdercus koenigii* (Fabricius).
2. **Common Names:** Cotton stainer.
3. **Family:** Pyrrhocoridae **Order:** Hemiptera.
4. **Identification and Biology.**

   (a) **Eggs:** Eggs are creamy white and change into yellowish orange with the passage of time. Incubation period varies from 4 to 9 days at different temperature (Fig. 11.24).

   (b) **Nymphs:** Nymphal period of red cotton bug consists of five instars.

   (c) **First Nymphal Instar: First** instar nymphs are light orange and change into blood red within one day. The duration of first instar is 2–3 days in previous studies. The average body length is 1.58 mm, and width is 0.94 mm. In first

Fig. 11.24 Eggs of red cotton bug

instar, antennae are shorter than the body length of red cotton bug. No wing pads are present in first instar.

(d) **Second Nymphal Instar:** First and second instars are similar in appearance, but second instar is larger in size than first instar. The average duration of second instar is 3–4 days. The average length of second instar is 3.02 mm, and width is 1.25 mm.

(e) **Third Nymphal Instar:** Third instar nymphs are red in color and change into reddish within 1 day. Wing pads are clear on thorax in third instar. The duration of third instar is 4–5 days. The average length is 5.52 mm, and width is 2.36 mm.

(f) **Fourth Nymphal Instar:** Fourth instar is tubular in shape and crimson red in color. Wing pads are developed from metathorax. White transverse bands can be seen on third to seventh abdominal segments. The duration of fourth instar is 5–6 days. The length of fourth instar is 9–9.5 mm, while average width is 3.64 mm.

(g) **Fifth Nymphal Instar:** Fifth nymphal is crimson red in color and cylindrical in shape. Wing pads are well developed. Legs and antennae are black in color, while antennae are five segmented. The average duration of fifth instar is 6.12 days. The average length of fifth nymphal instar is 12.22 mm, and width is 4.98 mm (Fig. 11.25a–c).

Fig. 11.25 (**a–c**) Nymphs of red cotton bug

(h) **Adult:** Adult of red cotton bug is also crimson red in color. Hind wings are membranous and broader than forewings. Black spots can be observed in the center of forewings. The average duration of male adult is 16.18 days, while for female adult, it is 20.85 days. Female is larger (15.30 mm length and 8.44 mm width) than male (14 mm length and 7.32 mm width) (Fig. 11.26).

5. **Hosts:** The following are the major host plants of red cotton bug: cotton, okra, and hollyhock.
6. **Damage:** Red cotton bug feeds on emerging bolls and mature seed and transmits the fungi *Nematospora gossypii* which develop on immature lint and seed (Jaleel et al. 2013) (Fig. 11.27a, b).
7. **Control.**

(a) **Chemical Control:** In Pakistan, red cotton bug is considered a minor pest. That is why no research-based chemical recommendations are available for red cotton.

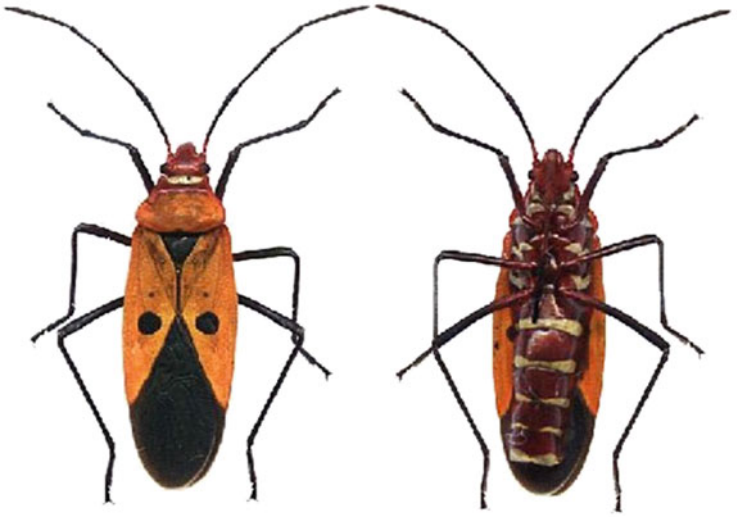

Fig. 11.26 Adults of red cotton bug

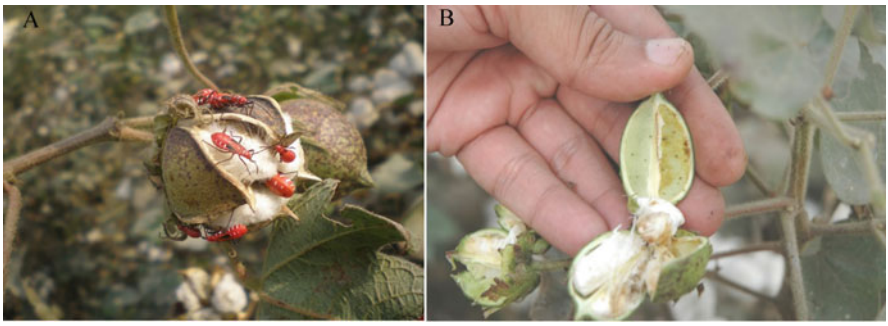

Fig. 11.27 (**a**) Damages caused by red cotton bug

11.2.6 Dusky Cotton Bug

1. **Scientific Name:** *Oxycarenus hyalinipennis* Costa.
2. **Common Names**: Cotton seed bug.
3. **Family:** Lygaeidae **Order:** Hemiptera.
4. **Biology and Identification.**

   (a) **Eggs:** Eggs laid by females are single or in patches form, and the color of eggs is yellow and becomes red near hatching.
   (b) **Nymph:** The nymphs are red in color, and abdomen of nymphs is orange in color (Smith and Brambila 2008).
   (c) **Adults:** Adults of dusky cotton bug are black and white translucent in color; thorax of adults is black, and wings are in white translucent color. Life span of

Fig. 11.28 Adults of dusky cotton bug

males is 33–49 days, and for females, it is 35–51 days. Single female can lay up to 110 eggs (Fig. 11.28).

5. **Number of Generations**: 6–7 per year (Srinivas and Patil 2010).
6. **Hosts:** The following plants are considered major host plants of dusky cotton bug: cotton, lemon, chilies, guava, mango, moringa, and okra (Shah et al. 2016).
7. **Damage:** Nymph and adults of dusky cotton bug suck the sap from tender parts and oil from seed which reduced the quality and quantity of cotton (Ijaz and Shad 2018). Due to sap and oil sucking, up to 32% yield losses and 88% germination losses were recorded in previous studies (Ahmed et al. 2015) (Figs. 11.29 and 11.30).
8. **Control.**

   (a) **Chemical Control:** No official recommendations against dusky cotton bug are available, but according to my personal observations, fipronil and matrine are very effective against dusky cotton bug.

11.2.7 Cotton Mealybug

1. **Scientific Name:** *Phenacoccus solenopsis* Tinsley.
2. **Family:** Pseudococcidae **Order:** Hemiptera.
3. **Biology and Identification.**

Fig. 11.29 Damage of dusky cotton bug

Fig. 11.30 Damage of cotton stainers

(a) **Eggs:** Females of cotton mealybug are ovoviviparous, and a single female lays 150–600 eggs which are covered in waxy ovisac (Lu et al. 2008).
(b) **Nymphs:** Nymphs of cotton mealybug are known as crawlers. Nymphal period of cotton mealybug consists of three nymphal instars for female and four instars for male. First instar nymph has six segmented antennae and quinquelocular openings on head, thorax, and abdomen. The second instar

Fig. 11.31 Nymphs of cotton mealybug

nymphs are distinguished by having 18 pairs of distinct cerarii around the margin of the body, lack of quinquelocular pores on the body, and claw having a distinct denticle. The third instar nymph differs by having seven segmented antennae and a circulus. Nymphal period consists of 25–30 days depending on temperature, and cotton mealybug can survive from 0 °C to 45 °C (Hodgson et al. 2008; Sharma 2007) (Fig. 11.31).

(c) **Adults:** Cotton mealybug can be distinguished through the morphology of adult female. Adult females of cotton mealybug are covered with waxy and powdery secretion, and six pairs of dark transverse bands are present on pro- to meta-thoracic segments. The length of adult females is 2–5 mm, and width is 2–4 mm (Kosztarab 1996; McKenzie 1967) (Fig. 11.32).

4. **Hosts:** According to a survey report, cotton mealybug is considered a serious pest, and 202 plants of different categories are reported as hosts of cotton mealybug. Some major host plants are cotton, brinjal, okra, sesame, China rose, tomato, and sunflower (Arif et al. 2009; Sharma 2007).
5. **Number of Generations:** Several.
6. **Damage:** Nymphs of cotton mealybug suck cell sap from plants and their leaves. Due to sucking of the sap, leaves become yellow and whitish and drop from the plant. As a result, the following symptoms can be observed: small fruits, crinkled

Fig. 11.32 Adults of cotton mealybug

Fig. 11.33 Damage of cotton mealybug

fruits, malformed fruits, loss of plant vigor, damaged foliage, fruit drop, and potential plant death (Culik and Gullan 2005; Dhawan and Saini 2009) (Fig. 11.33).

Cotton mealybug also feeds on phloem which leads to stunted growth of plants (Culik and Gullan 2005; Dhawan and Saini 2009). Cotton mealybug produces honeydew which creates problem in photosynthesis and also vectors some plant diseases like cocoa swollen shoot virus, cocoa mottle leaf virus, and cotton leaf curl virus (Cudjoe et al. 1993; Culik and Gullan 2005; Saeed et al. 2007).

7. **ETL:** On appearance.
8. **Control.**

(a) **Chemical Control:** (1) Profenofos 500 EC 800 ml/acre.

(b) **Biological Control:** Biological control which includes predators and parasitoids is considered the most effective control against cotton mealybug. Some important biocontrol agents are (1) *Aprostocetus minutus*, (2) *Cheiloneurus* sp., (3) *Chalcaspis arizonensis*, (4) *Aenasius* sp., and (5) *Aenasius bambawalei* (Fuchs et al. 1991; Hayat 2009; Sharma 2007).

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