Chapter

Pest Insects and Their Biological Control

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Abstract

Cotton is an industrial plant with a high commercial value. It is used in various fields such as textile, food (cotton oil), gunpowder industry, paper, and furniture production. One of the most important problems encountered during cotton production is insects that feed on cotton and cause economic loss. The intensive amount of pesticides is used by the producers for the control of pest insects. As insects gain resistance to pesticides over time, the amount of chemical pesticides applied is gradually increasing. Chemical products are quite harmful to both living things and the environment. For this reason, there is a need to popularize biological control methods instead of using pesticides to control pests. In this chapter, detailed information about insect species causing damage to cotton and biological control methods is given.

Keywords: cotton pests, damage, biological control, pesticide

1. Introduction

Cotton, *Gossypium hirsutum* (Linnaeus) is an important cultivated plant in the mallow family (Malvaceae), originated from India [1, 2]. Cotton is one of the oldest and most common agricultural products in the world. The fiber of cotton is used in the textile industry, cottonseed is used in the oil industry, and the pulp obtained after oil extraction is used in the feed industry [3]. The use of cotton in various commercial areas contributes to the economy of many countries and has an important place in both exports and employment [4]. It is an agricultural product that employs millions of people and earns money in the production, processing, and marketing, which is grown in temperate and subtropical regions of more than 60 countries. In addition, cotton is a very important economic base in developing and underdeveloped countries, and it is a product that provides foreign exchange income for these countries [1, 4]. Especially in recent years, organic cotton and organic textile products have become preferred by consumers [5]. However, factors affecting the economic importance of cotton in the field of plant protection are pests, diseases, and weeds. These factors reduce cotton yield by about 30% [6]. The use of plenty of water and fertilizer in the cultivation of cotton, which is a plant with abundant green parts, makes the plant attractive to harmful insects [3]. In cotton production, harmful insects are encountered in every period from sowing to the end of harvest. In cases where the pest population exceeds the economic damage threshold, the yield loss in cotton is 15–20% [7]. There are 96 insect and mite species known as the main pest and other pests in cotton [8]. While chemical control should be the last method to be applied in the control against these pests, it is frequently referred to by the producers [9]. Since the fiber obtained from cotton is not a direct nutrient, the absence of pesticide residue problem allows the use of pesticides more widely than other herbal products in the fight against pests [10]. For many years, the most common method used by manufacturers to prevent product loss has been chemical control [11]. Although chemical control is seen as an easy-to-apply and successful method of controlling pests in the short term, it causes crucial problems in a long time. Chemical pesticides cause the insects to gain resistance over time, and the beneficial insects in nature die because they are not specific to the target organism [12, 13]. In addition, after application, it accumulates in the soil and mixes with the air and water, harming both plants and other vertebrates. Over time, it accumulates in the human body and causes many diseases. This situation causes the deterioration of the ecological balance and also harms the health of living things. In addition, chemical residues remaining on products, prepared for export, cause rejection of products by many countries. Thus, the need to develop biological control methods to be used as an alternative to chemical products in the control of agricultural pests has arisen.

Biological control is the use of predators, parasitoids, or pathogens to control the population of the target organism. In biological control, predators and parasitoids are methods based on the use of beneficial insects against the target organism, while pathogens consist of microorganisms that cause disease or death of the target organism. These microorganisms originate from fungi, nematodes, bacteria, protozoa, and viruses and are bioinsecticides that can reduce harmful insect populations below the economic damage threshold in a short time [14]. Studies on widespread use of these pathogens have gained importance because, unlike chemical substances, they are specific to the host, do not cause harm to nontarget organisms, do not leave residues in nature, and are environmentally friendly and reliable [15]. For this reason, as in other products, cultural measures and biological control should be the first preferred control methods in cotton [3]. Chemical control should be used as the last alternative. It is more important in terms of biological control to protect the natural enemies present in the grown cotton [16]. In order to keep pests below the economic damage threshold, natural enemies and friendly microorganisms should be given an opportunity.

In this chapter, harmful insects that feed on cotton plants and cause economic loss and biological control methods applied against them are given.

2. Cotton pest insects

The pest insects' variety and density vary according to the development stage of the cotton plant and the geography where it grows. In this section, insects that cause economic loss by feeding on cotton are classified under two headings as main pests and other pests.

2.1 Main pest insects

Insects that are the main pests of cotton are: cotton aphid (*Aphis gossypii*), cotton jassid (*Amrasca bigutulla*), tobacco thrips (*Thrips tabaci*), cotton leafhoppers (*Empoasca* *decipiens* and *Asymmetrasca decedens*), two-spotted spider mite (*Tetranychus urticae*), and white tobacco fly (*Bemisia tabaci*) [9]. These insects cause great economic losses in cotton by invading cotton planted areas, especially in summer [17].

2.1.1 Cotton aphid, A. gossypii glover (Hemiptera: Aphididae)

Adult individuals of the pest, which have an average maturity of 7 days, have the ability to procreate offspring immediately. Since aphids reproduce by parthenogenetic reproduction, they have the ability to form large colonies in a short time [9]. This insect damages cotton in several different ways. Plant sap of cotton is rich in sugar, yet low in protein. For this reason, aphids need to take large amounts of sap to obtain sufficient protein. Excess sugar is secreted in the form of honeydew and makes the crop and fruit sticky. Black mold fungi (*Cladosporium* spp.) thrive in this plant sap, contaminating fruit and ornamental plants while making them unsuitable for the market. At the same time, photosynthesis in leaves decreases, which affects the production of cotton [18]. However, nymphs and adults take nutrients from the plant and disrupt the balance of growth hormones. As a result, plant growth is slowed by deformed leaves or pest infestation. In addition, being a vector of plant viruses, it causes different diseases to be transmitted to cotton [19]. This aphid species can transmit more than 70 different viruses, including the cucumber mosaic virus [18]. *A. gossypii* has many natural enemies and these are very effective in reducing the population of the pest. In the basic development period, it is very important for biological control that a large number of useful insects such as Coccinellid (bride beetles) pass to cotton after the wheat harvest. However, in order to preserve this existing natural enemy balance and to be effective, the field should be controlled very well during this period and care should be taken not to disturb the natural balance by avoiding unnecessary spraying. The most effective natural enemies of cotton aphids are especially *Chrysoperla carnea* and Coccinellid larvae. In addition, *Fusarium subglutinosa*, which is an entomopathogenic fungus, is effective in reducing the aphid population from time to time [9, 20].

2.1.2 Cotton jassid, Amrasca bigutulla *Ishida (Hemiptera: Cicadellidae)*

Amrasca bigutulla is one of the most damaging species to the cotton plant. It feeds on cotton in both nymph and adult stages by sucking the sap of the cotton plant due to its absorbent and piercing mouth structure. They cause damage to the plant with the poisonous saliva it leaves on the plant during feeding [21–25]. Intense infestation of *A. bigutulla* on cotton causes leaves to turn yellow, curl up, and fall off. In addition, the secretions that insects leave on cotton cause mold formation on the plant. In this case, it restricts the amount of light reaching the photosynthetic surfaces of the plant and reduces the yield [25]. These harmful species cause an epidemic in cotton plants almost every year [26]. Natural enemies (ladybugs, predatory lygaeid insects, and various mantises) and neem oil are widely used as a method of control [27].

2.1.3 Tobacco thrips, T. tabaci *Lindeman (Thysanoptera: Thripidae)*

T. tabaci grow in dry environments rather than moist environments, and in the years when the spring is dry, their density is quite high and the damage increases. It feeds on the underside of the leaves. Adults and nymphs tear the epidermis of the leaves and stems of cotton and tobacco plants with their mouthparts and suck the sap, while also destroying the chlorophyll-bearing cells [28]. The places where the pest feeds on the plant take a silvery color after a while. In heavy contamination, the leaves of cotton seedlings curl, turn brown, and fall off. If the growth point of the plant is damaged, a forked plant occurs [29]. Reduction in fruit branches in the lower parts of the damaged plant causes a decrease in yield. In addition, delays in harvesting occur in heavy damage [30]. Tobacco thrips have many effective natural enemies. Natural enemies are effective in reducing the population of the pest. The *Orius* species (*Orius albidipennis*, *Orius niger*, *Orius horvathi*) are among the most effective natural enemies [9].

2.1.4 Cotton leafhoppers, Empoasca decipiens *Paoli and* Asymmetrasca decedens *Paoli (Hemiptera: Cicadellidae)*

Cotton leafhoppers, which are seen in dense populations in the early period in cotton fields, feed on the vegetative and generative parts of the cotton plant by sucking, affect the development of the plant negatively, and cause shedding especially in the generative organs [31]. It is known that hairless and broad-leaved cotton varieties are more adversely affected by the population growth of leafhoppers [32, 33]. In addition to the sucking damage, it gives to the plant, cotton leafhoppers are also harmful because of toxic secretions into the plant body. The toxic substances cause hypertrophy in the phloem tissue cells of the leaf and blockages in sap transport. Biological control of cotton leafhoppers is done with the use of natural enemies. Among these natural enemies, the most successful are: *C. carnea*, *Deraeocoris* spp., *Geocoris* spp., *Nabis* spp., and *Paederus kalalovae* [9].

2.1.5 Two-spotted spider mite, Tetranychus urticae *Koch (Acarina: Tetranychidae)*

Tetrancyhus urticae Koch (Acari: Tetranychidae), also called the two-spotted red spider, is an important polyphagous pest species that are frequently found in agricultural areas where crop production is carried out in the world [34, 35]. The two-spotted spider mite is found in all parts of the plant. However, it especially prefers fresh and strong leaves and lives under these leaves. It is densely located on the underside of the leaves, especially where the petiole and leaf blade meet, and passes from there to other parts of the cotton plant. As a result of the feeding of the pest, yellow spots interspersed on the upper surface of the leaves, which are its characteristics. Later, the yellow spots turn red due to the damage of the chlorophyll substance, which gives the leaf its green color. This redness increases and covers the entire leaf surface or a part of the leaf homogeneously, and the leaves dry out before time [36, 37]. Another feature of the pest is the nets they form due to the substances they secrete during their feeding. The abundance of the nets also indicates that the pest population is dense [9]. The economic loss caused by mites in the plant can reach significant dimensions depending on the population, and these mites can hardly be controlled even with the use of intensive pesticides. Although success can be achieved with biological control elements in the control of these mites in greenhouse cultivation in the world, producers in many places prefer chemical pesticides in the control of this pest. The extensive use of these chemical drugs has caused this mite to develop resistance primarily to organophosphorus, mitochondrial electron transport inhibitors, growth regulators, and many specific acaricides [34, 38]. In the biological control of *Tetrancyhus urticae*, ethanol extracts obtained from sage, rosemary, yarrow, and cumin plants are used to remove the harmful species from the plant [39]. In addition, the two-spotted spider mite has many effective natural enemies. Of these species, *Scolothrips longicornis* and *Stethorus* spp. are specialized predators of the pest. For this reason, if pest control is required, specific acaricides should be used to protect beneficial species [9].

2.1.6 White tobacco fly, B. tabaci *Gennadius (Hemiptera: Aleyrodidae)*

B. tabaci has become one of the most important cotton pests due to its high reproduction rate and resistance to many chemical pesticides [40]. Whitefly larvae need a lot of protein to grow, so they consume large amounts of plant sap. Since the sap contains a large amount of sugar, the excess sugar is excreted as honeydew. As the larva grows, the amount of freshwater excreted also increases. The damages caused by whiteflies to cotton plants are as follows [41]:

- Since whiteflies feed by sucking the sap of the cotton plant during periods of high population density, plant leaves are greatly damaged. This damage to the leaves can affect fruit development and lead to a decrease in yield.

- Fruits become sticky due to the sweet juice left on them. Dirt sticks to the fruit, and the development of dark mold (Cladosporium spp.) accelerates, so the fruit becomes unsaleable. In severe cases, the fruit rots.

However, dark mold can also develop on the leaves, as a result of which the amount of photosynthesis and transpiration is reduced in cotton plants [41, 42]. The consumption of plant sap by whiteflies and the secretion of fresh juice also reduces the esthetic value of the crop. This is a very important problem, especially in ornamental plants. Besides, larvae inject enzymes into the plant, altering the plant's normal physiological processes [43, 44]. Many effective natural enemies are used in the control of *B. tabaci*. Natural enemies of this species include the predators such as *Amblyseius* spp., *Euseius rubini* (Acarina: Phytoseiidae), *C. carnea* (Neuroptera: Chrysopidae), and *Serangium parcecetosum* (Coleoptera: Coccinellidae); parasitoids such as *Encarsia fomosa*, *Encarsia lutea*, and *Eretmocerus mundus* (Hymenoptera: Aphelinidae); as well as entomopathogens such as *Aschersonia* spp., *Beauveria bassiana*, *Paecilomyces* spp., and *Verticillium lecanidae* [45–49]. In different studies conducted around the world, potential entomopathogenic bacterial species that can be used in pest control have also been determined. Among them, *Enterobacter cloacae*, *Acinetobacter radioresistens*, and *Erwinia persicinus* are promising bacteria for biocontrol of *B. tabaci* [50–52]. However, today there is no entomopathogenic bacterial species that is effective on whiteflies and can be converted into commercial form.

2.2 Other pest insects

Under this section of "other pest insects," information is given about the insects that cause significant damage to the cotton plant by causing epidemics in some years. These insects are cotton bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*), Egyptian bollworm (*Earias insulana*), cutworms (*Agrotis ipsilon* and *Agrotis segetum*), beet armyworm (*Spodoptera exigua*), cotton leafworm, (*Spodoptera littoralis*), flower thrips (*Frankliniella intonsa* and *Frankliniella occidentalis*), and plant bedbugs (*Creontiades pallidus, Lygus gemellatus, Lygus pratensis,* and *Lygus italicus*).

2.2.1 Cotton bollworm, Helicoverpa armigera *Hübner (Lepidoptera: Noctuidae)*

Helicoverpa armigera is an important group that causes millions of dollars of damage every year in the world [53]. Since the adults usually lay their eggs on fresh leaves, the damage starts on the leaves first. The larvae cause product loss by eating only the veins of the leaves and even eating some of the veins. In the following period, the larvae turn to the upper part of the plant and begin to feed on the flower bud, seed, and capsule. Since edible flowers generally cannot form seed capsules, crop yield is directly affected. After the seed capsules are formed, damage occurs as a result of the larvae feeding by piercing the capsules [54, 55]. In areas with high populations, they can cause significant damage, requiring replanting. *H. armigera* has a number of natural enemies found in the orders Hymenoptera, Diptera, Coleoptera, Hemiptera, and Neuroptera. Although parasitoids and predators have the ability to keep their hosts under pressure, they are not sufficient for the control of pests due to their insufficient number in nature [56]. There are 2 commercial preparations that are widely used in the world for the microbial control of *H. armigera*: *Bacillus thrungiensis* [57] and nucleopolyhedrovirus (NPV). These belong to the baculovirus group. However, it was reported that *H. armigera* developed resistance against *B. thrungiensis* [58, 59]. For this reason, studies on the development of baculovirus-derived products have been focused on the control of *H. armigera* [60–68].

2.2.2 Pink bollworm, Pectinophora gossypiella *Saund (Lepidoptera: Gelechiidae)*

The larvae of *Pectinophora gossypiella* feed on the comb, flower, and cocoon parts of the cotton plant, and the larvae eat pollen and anther, especially in the flower, preventing fertilization of the plant [69]. In addition, the larvae feeding on cotton seeds secrete a substance during feeding and this substance creates twin seeds by sticking 2 seeds together. In years when the pest density in the cocoon is high, blind cocoon formation is observed and the damage rate can reach up to 80% [70]. The small size of *P. gossypiella* eggs allows the pest to be easily suppressed by natural enemies. The most well-known natural enemies are: *Pyemotes ventricosus*, (Acarina: Pyemotidae), *Exeristes roborator* (Hymenoptera: Ichnoumonidae), Chrysocharis sp. (Hymenoptera: Eulophidae), Habrocytus sp. (Hymenoptera: Pteromalidae), and *Pediculoides ventricosus*. (Acarina: Piemotidae) [71, 72].

2.2.3 Egyptian bollworm, E. insulana *Boisduval (Lepidoptera: Noctuidae)*

E. insulana, which is an important pest in cotton, directly affects the yield and quality of a cotton plant. This pest causes damage to shoots, combs, flowers, and cocoons. The larva that emerges from the egg while the cotton plant is in its development period is fed by eating the bud. Then it pierces the shoot and enters the stem and continues to feed in the stem [9]. In the comb area of the cotton, the larvae generally penetrate the top of the comb and enter and cause damage. Larvae in more advanced stages can do their damage by piercing the comb from the side. Damaged combs are poured. *E. insulana* does its main damage in the cotton boll. The newly hatched larvae usually enter the lower half of the cocoon and expel the dung. The larva also feeds on undeveloped fiber and grains. More than one larva can be found in a cocoon. Cocoons damaged by prickly worms usually do not open, and the damaged bolls create a suitable environment for the growth of bacteria that cause angular leaf spot disease (*Xanthomonas malvacearum*). When there is no control during the epidemic years, it can cause up to 90% damage [73]. Natural enemies are mainly used in the biological control of the *E. insulana*. Predatory insects, especially in the *Orius* genus, are quite successful in controlling the population density of *E. insulana* [9].

2.2.4 Cutworms, A. ipsilon *Hufnagel,* Agrotis segetum *Schiffer (Lepidoptera: Noctuidae)*

Cutworms larvae damage cotton seedlings by cutting them. It damages cotton plants by cutting from the two-leaf period, which is the basic development period, to the 6-8-leaf period, and cuts the young plants from the soil surface. However, they can also cut underground under conditions where the soil is soft and the soil moisture is low. Especially large larvae pull the cut plants under the ground and eat their leaves. They do damage by taking turns. Damage is greater in late planting areas and rainy spring months. Damage may occur to a degree that requires replanting [9]. Biological control agents, including fly and wasp parasites, disease organisms, and predatory beetles, continually reduce cutworm populations [74]. However, entomopathogenic nematodes are used successfully in the control of cutworms living under the ground [75, 76].

2.2.5 Beet armyworm, S. exigua *Hübner (Lepidoptera: Noctuidae)*

S. exigua larvae are mostly seen in cotton in the early period. Especially after the first hoe, it passes from weeds to cotton plants and its damage is important in this period. They are seen more intensely after the rainy spring months. The first instar larvae that have just hatched from the egg coexist collectively at first. Then, larvae consume the epidermis of the leaf, making it like a membrane. It prevents the growth of the plant by damaging the leaves and tip shoots of small cotton plants. The damage in the leaf is in the form of large holes with regular edges. If the plant is in the combing period, it will also be harmful to leaves, shoots, and combs. However, they do not eat the combs completely, and they gnaw them out from the outside, although they rarely get inside the comb. In addition, it can be damaged in the flower and cocoon of the cotton plant. However, this damage to the pest is not significant. During the epidemic years, it causes significant damage to the median by eating the top shoots and leaves of the cotton in a way that the middle vein remains or completely [9]. In its biological control, formulations originating from entomopathogenic bacteria *Bacillus thrungiensis* isolate, and toxin proteins produced by this isolation are used successfully [77–80]. However, baculovirus has been used successfully in commercial products [81, 82].

2.2.6 Cotton leafworm, Spodoptera littoralis *Boisduval (Lepidoptera: Noctuidae)*

Spodoptera littoralis larvae mostly damage the leaf part of the cotton plant. The newly hatched *S. littoralis* larvae feed in such a way that only the large veins of the leaf remain. They gnaw the lower surface of the leaf and eat the epidermis, making it like a membrane. In this case, the leaf takes on a sieve-like appearance. As it grows, it feeds on other leaves and punctures the leaves. In the following periods, they feed on buds and cocoons and cause these parts to shed or dry. Inside the cocoons, the insect's excrement and the holes they create can be seen. Predators (*C. carnea*, *Nabis pseudoferus*) and parasitoids (*Microplitis rufiventris*) are used successfully in biological control [83]. In addition, the use of the bacterial endochitinase enzyme from *Bacillus thuringiensis* has recently been used to control many bacteria-resistant *S. littoralis* larvae [84]. However, Azadirachtin obtained from the neem tree is an effective herbal solution for the control of *S. littoralis* larvae [85].

2.2.7 Flower thrips, F. intonsa *Trybom,* F. occidentalis *Pergande Thysanoptera: Thripidae*

Flower thrips, especially in late planting cotton fields, in case the population is very high, adults feed on flowers and larvae feed mostly on the cocoons, causing shedding of flowers and newly formed bolls and early opening of mature bolls. However, no economic damage is caused in the cotton fields of our country. Species belonging to this genus are harmful, especially by sucking on the flowers and flower buds of the cotton plant. In addition, large and mature cocoons cause the formation of cocoons that do not fully open and are called "Crispy cocoons" as a result of the suction damage that occurs in dense populations [9]. In the biological control of flower thrips, predatory insects of the genus *Dicyphus* and *Orius* and the fungus *Metarhizium anisopliae* have been used successfully [86, 87].

2.2.8 Plant bedbugs, Creontiades pallidus *Rumb,* Lygus gemellatus *Herrich-Schaffer,* L. pratensis *Linnaeus,* Lygus italicus *Wagner (Hemiptera: Miridae)*

Plant bedbugs feed by sucking all the organs of the cotton plant due to their stinging and sucking mouth structures. The absorbed place deformed as a result of the toxic substance secreted and then turns black. If the damage occurs on the leaves, the leaf tissue dies over time in the place where it is absorbed. The leaves become perforated or segmented. These pest larvae do their main damage by feeding on generative organs [88]. Most of the scallops, flowers, and small bolls that are damaged by the suction are shed. As a result of casting, a decrease in the product occurs, as well as a delay in maturation. In sucked cocoons, the seed weight decreases. This reduces the seed yield [89]. In addition to generative organ casting, they also cause deformities such as abnormal comb formation, elongation of plant height, and an increase in the number of nodes on the branches. Predators (*C. carnea*, *Nabis pseudoferus*) and parasitoids (*Leiophron deciphiens*) are used in the biological control of plant bedbugs [9].

3. Conclusions

With the increasing importance of cotton plants both in commercial and domestic use, harmful insect species found in cotton fields and their damage to the product have started to gain more importance. Both the suitability of the leaf surface (especially the hairless cotton leaf) and the high irrigation rate of cotton attract harmful insects. For this reason, there are at least 20 agricultural pest insect species on the cotton plant. When cotton producers see the presence of harmful insects on the product, they prefer the use of chemical pesticides in terms of ease of application in a short time. However, the use of chemical products has long-term negative effects on natural enemies (predators and parasites), other nontarget invertebrates and vertebrates, the environment, nature, and human health. Besides, unnecessary and excessive use of chemical pesticides causes harmful species to resistance. Therefore, the use of chemical drugs should be reduced as much as possible, and biological control agents should be preferred instead. Predator and parasitoid species are used quite successfully for the biological control of cotton pests. In addition, studies on the preparation and marketing of commercial formulations of entomopathogenic microorganisms continue all over the world. In recent years, consumers have started to prefer organic products for all products. In the food and clothing sectors, products containing organic cotton (especially baby clothes) are preferred. For this reason, the development of biological control agents and the cultivation of natural enemies should be supported, and producers should be encouraged to apply them in nature. In particular, the licensing procedures required for placing organic biopesticides on the market involve a very difficult process in some countries. Facilitation of this process by the relevant ministries of agriculture is one of the most important factors that will increase large-scale biopesticide production.

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