Chapter

Insect Pest Complex of Wheat Crop

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Abstract

Wheat *Triticum aestivum* L. is grown on broad range of climatic conditions because of edible grains, cereal crop and stable food of about 2 Billion peoples worldwide. Additionally, it is the rich source of carbohydrates (55–60%), vegetable proteins and contributed 50–60% daily dietary requirement in Pakistan. Globally, wheat crops is grown over 90% area of total cultivated area; facing devastating biotic and abiotic factors. The estimated economic losses in wheat quantity and quality are about 4 thousands per tonne per year including physical crop losses and handling. Economic losses of about 80–90 million USD in Pakistan are recorded due to inadequate production and handling losses. Wheat agro-ecosystem of the world colonizes many herbivore insects which are abundant and causing significant losses. The feeding style of the insects made them dispersive from one habitat to another imposing significant crop loss. Areas of maximum wheat production are encountered with either insect which chew the vegetative as well as reproductive part or stem and root feeders. This chapter provides the pest's taxonomic rank, distribution across the globe, biology and damage of chewing and sucking insect pest of wheat. It is very important to study biology of the pest in accordance with crop cycle to forecast which insect stage is economically important, what the proper time to manage pest is and what type of control is necessary to manage crop pest. The chapter will provide management strategies well suited to pest stage and environment.

Keywords: Wheat crop, economic losses, biology, insect pests, management

1. Introduction

Wheat is undoubtedly one of the major cereal crop, staple food and rich portion of daily intake for much of world's population. With annual global production over 770 MT from 220 M hectares, it is a grain of life. The cultivation of wheat started about 10,000 years ago as part of the Neolithic revolution which state a transition from hunting and gathering of food to settle agriculture. Earlier cultivated forms of wheat were diploid (einkorn) and tetraploid (emmer) with known initial origin of the south-eastern part of Turkey. Hexaploid bread wheat that is currently widely adapted in about 95% area of world.

Though wheat was one of pesticide free crop in major areas of the world, however the things are not the same now. Today, all crop production practices are being highly challenged by biotic and abiotic stresses. Biotic stresses especially insect pests and diseases cause devastating damage in terms of yield and quality. On average pests cause 20–37% yield losses worldwide which is translating to approximately $70 billion annually.

Wheat is damaged by sucking and chewingtypes of pests. The list of insect pests damaging different stages of wheat crop varies from region to region, however the complete list of insect pests is around 100. It is therefore important to understand biology of insect pest simultaneously with the crop biology to understand when, where and what chemical should be used to control specific insect/pest more effectively. In this review, we have outlined major insects of wheat along with their biology and control strategies to minimize grain yield losses.

2. Chewing insects' pests of wheat

2.1 Wheat termite *Microtermes obesi* Holm. (Termitidae: Blattodea)

2.2 Taxonomy

Wheat termites belong to order (Earlier Isoptera) Blattodea consisting of 9 families exists worldwide. The families of termites were further classified as monogeneric families including Mastotermitidae (holotype *Masotermes darwinensis* in Australia), Indotermitidae (holotype *Indotermes* in India), Stylotermitidae (holotype *stylotermes* in India), Serrtermitidae (holotype *Serritermes serrifer*in Brazil). The family Termitidae comprises 145 Genera and have 4 subfamilies [1, 2] along with near about 3000 described species [3]. Termite fauna of the subcontinent comprised 337 described species and subspecies of 54 genera. Among these, 16 species found to be damaging to Wheat crops in Asia, of which dominant species are *Odentotermes obesus* and *Microtermes obesi* [4]. However, *Microtermes obesi* is known to be the most important pest of wheat. The taxonomic classification showed that *Microtermes obesi* belongs to order Blattodea and family Termitidae.

2.2.1 Distribution

Termites found all over the world except the Antarctic region. Termites distributed to Tropical, subtropical and temperate regions Worldwide. Termite's diversity is found to be very high in the South American region compared to North America and Europe. Out of 3000 known species of termites are extremely abundant if African region. In Asia the main distribution is restricted to China, India, Pakistan, Sri Lanka and Veitnam totaling 435 species. *Microtermes obesi* commonly known as Wheat termite is a very small species of genus *Microtermesobesi* is restricted to wheat habitats of south and Southeast Asian countries including India, Pakistan, Sri Lanka, Thailand and Vietnam [5, 6].

2.2.2 Biology

Termites undergo a developmental process as in case of other insect species known as incomplete metamorphosis with egg, nymph and adult stages [7]. Nymphs are small entities resembling adults, molts as they grow converted into adult stage. A nymph usually undergoes 3 molts [8]. During the summer months after monsoon, fertile reproductive caste of termites leaves its colony for nuptial flight. After successful fertilization the queen increased in size from 9 to 11 cm and laid around 70,000 kidney shaped eggs that will hatch in nearly 30–90 days. Usually in full reproductive colonies 80–90% individuals belong to the workers caste and 10% Soldier caste [9]. After sometimes they are produced into full adults with wings and reproductive or fertile females which can fly for nuptial flight to repeat cycle for new colony [10].

2.2.3 Damage

Under field conditions, the termites (*M.* obesi) are predominant insect pests causing severe losses in irrigated areas to about 20–40% [11]. In severe conditions, the yield losses might reach up to 40–80% due to this pest [4]. The termites infest wheat crop in Rabi season most of the time soon after sowing to maturity stages [12]. Young workers chew the young and tender part of the wheat plant resulting in dislodgment of seedlings. The mature stage of the wheat plant is also damaged by the workers of the termites causing the plant to dry and produce white ears at earhead stage [13].

2.3 Wheat armyworm *Mythimna separata* Walk. (Noctuidae: Lepidoptera)

2.3.1 Taxonomy

M. separate Walk. commonly known as Oriental armyworm is a minor insect pest of wheat crop. The name was first described by Francis Walker in the 19th century. The taxonomic classification showed that Wheat armyworm (*Mythimna separata* W.) belongs to order lepidoptera and family Noctuidae that noxiously feed on wheat.

Many synonyms of this name were used in the literature are *Pseudaletia separata* Walk. *Cirphis separate* and *Leucania separata.*

2.3.2 Distribution

The wheat armyworm is present in various wheat growing agro-ecosystems from Asia to Australian continent between 45 north and 45 south Latitude and 60 east to far 170 West Longitude. It is found in 27 countries including China, Japan, Pakistan, and India also in Pacific islands from tropics to temperate climatic regions [14].

2.3.3 Biology

The fertile females lay maximum eggs from 500 to 900, spherical and milky white in color to approximately 2000 eggs. The eggs are laid in clusters on or underside the young seedlings or in soil. The eggs will hatch in 2–7 days after that larva emerges and lasts long for 14–22 days. The mature larva possesses green to pink color having greenish to brownish black stripes on the entire body length [15]. Pupation is usually done in soil but can be done under dry leaves or fresh stubbles or fresh tillers as well. The pupae are shiny brownish yellow in color and last upto13 days. Thus, the whole span lasts in about 35–40 days which may repeat multiple times in each year.

2.3.4 Damage

M. separata Walk. damages the yield losses as this is influenced by the environmental conditions of the area and the stage of wheat crop. Innovations in farming systems such as introduction of high yielding cultivars, balanced fertilizer use and crop rotation of wheat increased the chances of high yield loss by this pest [16]. Severe attack must lead to decreased productivity by reduction of quantity as well as quality of grains [17]. Due to its polyphagous nature, it causes severe economic losses in crop production worldwide [18]. The young larvae feed on younger plants and due to its short life cycle results in heavy infestations with much heavier loss to young tillers [19]. In the past, loss due to *M. separata* Walk.was recorded as 10–30% in Wheat crop [20]. With every increase of 1% in leaves consumed by the armyworm decrease the yield by 0.07–0.88 g per plant from booting to panicle stage.

During the young vegetative stage of wheat plant, the damage is more prominent with extensive defoliation. Young larvae may feed at lemma and palea of young grain as well as male part anther of mature flowers. The larvae cut the young seedlings so often the damage is restricted to a single part of the field. During the grain formation stage, the larvae feed upon the panicles from the basal part of the plant causing it to bend downwards and sometimes the plant may fall down.

2.4 Wheat shoot fly *Atherigona naqvi* Steylskal (Muscidae: Diptera)

2.4.1 Taxonomy

The taxonomic classification was described by Steyskal in 1966. In Asia, it was first reported in wheat agro-ecosystem by [21]. However, in the subcontinent, 5 different species from genus *Atherigona* were reported by [22] too. The taxonomy of *A. naqvi* Seyskal. showed that it belongs to order Diptera and family Muscidae renowned for its damage to wheat crop.

2.4.2 Distribution

The Genus *Atherigona* predominantly comprises species of shoot fly which mostly affect maize crop only worldwide. However, this shoot fly species is responsible for serious threats to wheat agro-ecosystems across the globe. Species from genus *Atherigona* are mainly distributed in Pakistan [23], India [24], Thailand [25], and Africa both in East and West African regions [26, 27], and Egypt [28].

2.4.3 Biology

A. naqvi Steyskal adult shoot flies are grayish brown in color having relative smaller size ranging 4–5 mm than common house fly species. Fertile female flies lay eggs on the underside of the tender seedlings and near the base of the stem. Usually 15–25 elongated eggs, cylindrical like boat milky white along with projections with usual longitudinal ridges are laid. Eggs hatched in just 1–3 days after that tiny maggot emerged, starting to creep on to the leaf sheaths of the tillers. Larval period lasts for 7–10 days along with 3–4 larval instars. Pupation usually takes place inside the stem, making the barrel shape a darkish brown puparium. Adults who are free living usually live for approximately 4 days and ultimately complete their short life cycle in about 3–4 weeks.

2.4.4 Damage

The damage is usually done by the immature larvae of all instars. After the emergence of young seedlings, usually 3–4-week-old young seedlings are targeted by the maggots. After hatching, maggots feed the young growing tissues of the plant resulting in drying of central shoot by chewing the central phloem tube produce white dry seedling known as dead hearts. Dead hearts due to dryness can be pulled easily. Sever infestations resulted in bushy appearance of young tillers.

2.5 Surface grasshopper or cutworm *Chrotogonous trachypterus* Blanchard

2.5.1 Taxonomy

The name *Chrotogonous trachypterus* was given by Blanchard in 1836 to tribe *Chrotogonini* Bolivar (1904) and family Pyrgomorphidae. Surface grasshoppers are multivorous, stout, muddy in color, poly phagous insect feeding on almost all the foliage and green tender shoots belonging to order orthoptera and family Pyrgomorphhidae.

Infraspecies: *Chrotogonous (trachypterus) trachypterus.*

2.5.2 Distribution

C. trachypterus is distributed to many countries worldwide. However, Asian countries' including Pakistan, India, Bangladesh and Nepal are known for their maximum abundance. Iran and Afghanistan are also facing a serious problem regarding this pest. Locally it is present in all across Pakistan including Province Punjab, Balouchistan, Sindh, KPK and GB [29].

2.5.3 Biology

C. trachypterus deposits her eggs inside usually 4–5 cm deep in the soil with slight moisture inside. Female digs a hole with the help of an ovipositor and by means of collateral glands; eggs are deposited along with glutinous secretions in a waterproof egg pod. The female covers her tiny yellowish eggs of 7–8 mm by pushing the soil or sand by hind legs [30]. Eggs will hatch in 12–17 days and tiny nymphs of Pale-yellow color which later turned dark brown undergo 5–6 instars. Nymphs are wingless and smaller in size compared to adult. Nymphal period lasts for 13–17 days.

Adults are much larger than nymphs, have well developed mandibles and wings too. Sexual dimorphism is present as a female has four ovipositors to lay eggs and is usually bulky than males whereas males are smaller and rounded [31].

2.5.4 Damage

C. trachypterus is a polyphagous insect and usually present throughout the year. It damages the seedling stage of a variety of crops growing worldwide. Both nymph and adult feed on tillers of wheat plants. Severe attack results in repeated sowing of the crop. Wheat crop is one of its host plants worldwide [32]. The initial development of the seedling is the prime source of grain yield; so, seedling establishment is critical for better productivity. Nymphs and adults feed on young tillers so that in severe attacks the crop failed, and re-sowing had to be done [33]. Among different host plants, wheat seedlings are the most preferred one for *C. trachypterus* [34].

2.6 Pink stem borer *Sesamia inferens* Walker

2.6.1 Taxonomy and nomenclature

Francis Walker in 1856 described *Sesamia inferens* (Noctuidae: Lepidoptera) for the first time. Some common names of the Pink borer are Asian pink stem borer, Graminous stem borer, Pink borer of rice and purple stem borer. Literature has been reported on the synonymy of *S. inferens* and the synonyms are *Leucania inferens* Walker, 1856, *Leucania proscripta* Walker, 1856, Sesamia tranquilaris Butler, 1880, Nonagria innocens Butler, 1881, *Sesamia corticoides* Strand, 1920, *Sesamia kosempoana* Strand, 1920, *Sesamia sokutsuana* Strand, 1920, and *Sesamia hirayamae* Masturmura, 1929.

2.6.2 Worldwide distribution

According to CABI [35, 36], the current distribution of *S. Inferens*is **Asia**, Pakistan, China, India, Japan, Vietnam, Singapore, Korea, Indonesia, Sabah, Taiwan, Hong Kong, Ceylon, Burma and Thailand. Pink Stem Borer of wheat is also reported in **Australian** and **Pacific** islands.

2.6.3 Biology

Life span of *Sesamia inferens* lasts in 40–50 days under favorable conditions [37]. Adults lay globular and creamy white eggs at the base of the wheat plant [38] which may range from 120 to 348 [39]. Egg color changes from creamy white to brown before hatching [40]. Larvae emerge from the fertilized eggs within a week. The newly hatched larvae are pinkish in color with a reddish-brown head [41]. Six instars of larvae take 23–39 days for entering into pupal stage [42]. Full grown larvae measure 30 mm in length [37] and pupate in stem galleries. Adults have straw-colored forewings with a trivial dark brown streak. Males have Pectinate antennae while females have filiform [43]. Under tropical conditions *Sesamia inferens* completes 4–5 generations in a year.

2.6.4 Damage

Pink stem borer *Sesamia inferens* became a key pest in recent time in cereals and can-do considerable yield loss. Different crops of the family Graminae attacked by this polyphagous pest including rice [44], wheat, pearl millet, finger millet and sorghum [45]. Yield losses caused by *S. inferens* in maize may reach from 25.7 to 78.9% [39].

2.7 Shield bug *Eurygaster integriceps*

2.7.1 Taxonomy and nomenclature

Shield bug of wheat is also known as Sunn pest. A total of fourteen species has been reported so far, three of them are considered economically important; *E. integriceps* (Scutelleridae: Hemiptera), *E. mauru* (L.) and *E. austriaca* Schrk. [46].

2.7.2 Worldwide distribution

Sunn pest has a cosmopolitan distribution in **Asia**: Pakistan, India, Afghanistan, Armenia, Azerbaijan, Georgia, Iran, Israel, Jordan, Kazakhstan, Kyrgyzstan, Lebanon, Syria, Tajikistan, Turkey, Turkmenistan, Iraq, Uzbekistan. **Africa**; Algeria. **Europe**; Greece, Cyprus, Macedonia, Bulgaria, Moldova, Romania, Russia, Serbia, Ukraine [35, 36, 47–49].

2.7.3 Biology

The eggs of the *E. Integriceps* are spherical and measure about 1 mm of diameter [48]. At the time of oviposition, eggs look light green, which eventually turns dark as embryo matures [50]. *E. integriceps* has five nymphal instars [51–53]. First instars measure 1.5 mm in diameter and light in color. Nymphs look similar to adults except with 2–3 paired black dots in the midline between the lateral margins of the abdomen. The nymphs cannot be illustrious from closely related spp. and must be identified at adults [53].

Adults are elongated and elliptical, and their color varies from grayish to brown, to red or black [54]. In this concern, Color of the *E. Integriceps* is extremely uneven and has no worth for biosystematics identification [55]. Adult length and width measures 10–12 mm and 6.1–7.1 mm respectively. There is only one generation per year and an obligatory diapause in the adult stage [56–58].

2.7.4 Damage

E. integriceps is a destructive pest of wheat in the Middle East and Central Asia [59, 60]. They do considerable damage to wheat crop from 25% to as much as 100% [61]. Logothetis [62] have reported some severe outbreaks of this pest resulting in complete losses of the crops over large areas. They can destroy all parts of the cereal crops [63]. Nymphs preferably eat young leaves while adults are attracted toward kernels and ears [63]. Symptoms of the damage are shown as a 'deadheart' and withering of the leaves [46].

2.8 Loreyi Leafworm

2.8.1 Taxonomy and nomenclature

Current accepted scientific name ofLoreyi Leafworm *is Leucania loreyi* (Scutelleridae:Hemiptera) although many synonyms has been reported and these are; *Mythimna loreyi* Duponchel, 1827, *Noctua caricis* Treitschke, 1835, *Leucania curvula* Walker, 1856, *Leucania collecta* Walker, 1856, *Leucania exterior* Walker, 1856, *Leucania thoracica* Walker, 1856, *Leucania designata* Walker, 1856, *Leucania denotata* Walker, 1856, *Acantho leucania loreyi* Duponchel, *Cirphis loreyi* Duponchel, *Hyphilare loreyi* Duponchel.

2.8.2 Worldwide distribution

Leucania loreyi has been reported in various subcontinents of the world including **Asia**: Pakistan [64], Afghanistan [65], Lebanon, Azerbaijan [35, 36], Georgia, Iran, Israel [47], Jordan, Kazakhstan, Lebanon, Syria, Tajikistan, Turkey, Turkmenistan, Iraq, Uzbekistan [64]. **Africa**; Algeria. **Europe**; Greece, Cyprus, Macedonia, Bulgaria [66], Moldova, Romania, Russia, Western Siberia [67], and Ukraine [35, 36].

2.8.3 Biology

Leucania loreyi predominantly lay eggs in masses of 2–127 eggs but may lay singly at the last part of the oviposition time [68]. Eggs are laid on the leaf-sheath of the plants of Graminae. Eggs measure 0.5 mm diameter and are discoid in shape. Color of the freshly laid eggs is ashen-yellow or cream colored. Number of eggs laid decreases with increase in temperature above 30°C [69]. Mating starts after two days of emergence [69]. *L. loreyi* has six larval instars at 29' *C* and 70% relative humidity [68]. First instar larvae are transparent, light green and have elongated body. The color of the second and third instar larvae alters to pale green, dark-green respectively. Fourth and fifth instar larvae have the same colouration except having two lateral pale-brown lines. Newly pupated larvae are of yellowish-cream colored, which turns shiny brownish as pupae matures. Larvae pupate three inches below soil surface and measure 17-23 mm long and 5 mm wide [70]. Adults measure 17 mm in length 35-38 mm along their wingspan. Female moths are comparatively larger in size than males. Head and thorax covered with brownish-yellow scales. Forewings are of a rusty-brown color [68].

2.8.4 Damage

Loreyi leafwormis a major pest of graminous crops including wheat and maize [71]. Up till now, *L. loreyi* is not a major pest in Pakistan, but it has been reported to repeatedly cause rigorous damage in China [72] and other Asian countries. *L. loreyi* has been also known to cause damage in rice [73–78].

2.9 Black cutworm *Agrotis ipsilon*

2.9.1 Taxonomy and nomenclature

Ochsenheimer proposed the genus *Agrotis* in 1816. There are a number of synonyms proposed for *Agrotis ipsilon*, some of these are *Agrotis aureolum* Schaus, 1898, *Agrotis bipars* Walker, 1857, *Agrotis frivola* Wallengren, 1860, *Agrotis pepoli* Bertolini, 1974, *Agrotis suffusa* (Shiffermiller), *Agrotis telifera* Donzel, 1837, *Bombyx idonea* Cramer, 1780, *Bombyx spinula*Esper, 1786, *Noctua amenituma* Walker, 1865, *Noctua suffusa* Denis & Schffermuller, 1775, *Phalaena ipsilon* Hufnagel, 1766, *Phalaena ypsilon* (Cramer), *Phalaena ypsilon* Rottenberg, 1776, *Rhyacia pernigrata* Warren, 1912 and *Scotia ypsilon* (Hufnagel).

2.9.2 Worldwide distribution

Black cutworm is also scattered worldwide and causes a huge loss of crop yield. They are distributed in **Asia**; Pakistan, Afghanistan, Armenia, Azerbaijan, Bangladesh, Cambodia, China, India, Israel, Iran, Iraq, Japan, Jordan, Lebanon, Malaysia, Myanmar, North Korea, Philippines, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Turkey, Thailand, Taiwan, United Arab Emirates and Vietnam. **Africa**: Benin, Burkina Faso, Congo, Egypt, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Mauritius, Morocco, Reunion, Saint Helena, Senegal, South Africa, Sudan, Togo, Tunisia and Zimbabwe. **Europe**; Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Yugoslavia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Norway, Poland, Russia, Spain and the United Kingdom. **North America**; Canada, Dominican Republic, Honduras, Mexico and the United States. **South America**; Argentina, Bolivia, Brazil, Chile Colombia and Piru [35, 36, 79–81].

2.9.3 Biology

Agrotis ipsilon completes its life cycle in 50–77 days at 22’C-25’C temperature and 69–77% relative humidity [82]. Adult female moths lay 145–200 eggs. Egg laying goes on peak 5–6 days after mating [82]. They are 0.5 mm long and 0.45 mm high, semi-circular and have erect and parallel patterned terns. Recently laid eggs have milky color which turns grayish black at the time of hatching [83]. There are six instars of larvae of *A. ipsilon* [82]. Larvae color is grayish-black while ventral and sub-ventral abdominal sides are lighter in color.

Third to sixth instar larvae are 7 mm, 10-20 mm, 20–30 and 37–47 mm long [35, 36, 83]. Larvae of *A. ipsilon* can be distinguished from others with having these diagnostic characters; Stigerous D_2 tubercle large, dorsal anterior tubercle almost one third as long as posterior tubercle, pigmented black spiracles with convex granules [35, 36]. Papae are brownish in color which turns blackish at the time of adult emergence and measures 17–25 mm. Fifth and sixth abdominal tergites have distinct punctures on pleural sides; hook-like spines are present at the apex of the sixth abdominal segment [83]. Adults of the black cutworm are 16–23 mm long, spreaded wingspan measures 35–54-mm [35, 36]. There are three sections in the forewing internal transverse line, external transverse line and some distinct spots: clavate spot, reniform spot, ring spot and sword spot. Hindwings are grayish in color and do not have any markings. Males have feathers type antennae while females have filiform [35, 36].

2.9.4 Damage

Black cutworm has a broad has range and feeds on all crops and pasture plants. Newly emerged crop seedlings are attacked by the full-grown larvae migrated from summer and autumn weeds. Species of the *Agrotis* are the worst destroyers that they may attack on the whole fields of cereal crops. Early instars of larvae feed on the tender tissues of the foliage, but as they grow, they suppose their classic cutworm 'felling' activity [84].

3. Management of chewing insect pests of wheat

Seed is the basic building block of a crop. As seed is healthy insect and disease free more the yield is obtained. Insects are small creatures but are highly reproductive in nature so that they compete with humans for resources. Controlling of insects at appropriate time is the key point to obtained higher and healthy yields.

3.1 Seed treatment

Seed treatment is one of most important control measures which reduce the chances of insect's pests attack because eggs of some insects are glued to seeds and spores of different seed born diseases are attached so that seed treatment is necessary to control the insect's population at its initial stages. Different Insecticides were used to treat seeds against different insects' pests. Fall army worm *Spodoptera frugiperda*, green bug a, hessein fly often present in wheat crop in numbers so that they have a great impact to limit the yield of crop. In this case different measures can be used to limit these pests' infestations. Systemic seed treatment is which is an effective method to control these pests' infestations. Insecticides like imidacloprid treatment of seeds reduce infestation of Russian wheat aphid 27–85 days in wheat and barley crops [128, 139, 140].

3.2 Quarantine

A quarantine pest is "a pest of potential economic importance to that piece of land where it is present but not widely distributed and controlled or the endangered zone where pest does not presentyet. Chewing insect pests requires quarantine measures. Different chewing pests which were not reported or not widely distributed to wheat zone of Pakistan. Arecent exampleof it is fall armyworm that were 1st reported in Nigeria in west Africa in 2016 and within a short duration of time it was reported in 44 countries of Africa. In 2018 it was 1st reported in India [85, 86] that moved to Bangladesh, China, Sri lanka, Thailand, Myanmar [87]. Suitable and perfect environmental conditions for fall armyworm reproduction and wide range of host plants availability in Pakistan. corn and wheat zones are endangered, and several articles were published in newspapers. The international maize and wheat improvement center (CIMMYT) have cautioned Pakistan to make efforts against fall armyworm a potential threat to maize and wheat in Pakistan.

World Trade Organization agreement on the application of sanitary and phytosanitary measures and the international plant protection convention of the food and agriculture organization of united nations and convention for biological diversity all these organizations highly recommended that prevention is the most effective control of invasive species within a minimum cost. It shows better and cost-effective results where it is adopted. The IPCC released a summary of international standards and phytosanitary measureswhich includes all sanctions and guidelines for whole trade processes. Economically harmful species of plants and plants product are black-listed and banned from entering in the whole continent in Europe. The most cost-effective control against invasive species of insect pests is to inspect the incoming consignments with sanitary and phytosanitary inspections at borders this is the last weapon of defense which can be used against invasive species otherwise their control is very difficult.

3.3 Biological control

Biological control plays an important role in wheat crop pest management. Negligible use of insecticidesprovides conducive environment for biological agents to flourish and reproduce. Biological control is the most effective control method when using with other compatible controlling techniques for example in IPM we use biological control as an effective component of crop pest management with other controlling practiceslike cultural control and planting resistive varieties against insects' pests. On the other hand, we use selective insecticides against pests when other controlling method failsdue to some biotic or A-biotic factors to keep the population below ETL.

3.3.1 Biological control managers

Biological control managers of insects are divided intopredators, parasites and pathogens.

3.3.1.1 Predators

Predators are lions they kill and eat their host within few minutes for example Convergent lady beetles.

3.3.1.2 Parasites

Parasites are internal and external or attack to specific life stages of pests. The most important parasites belong to parasitic Hymenoptera puncture the parasites eggs with their sharp ovipositor and lay single egg eggs hatched in 6 to 7 days and larvae feeds on these eggs. Some parasitoids lay eggs directly larvae after hatching parasitoid larvae feed on internal parts of parasite and emerge dead larvae and their mummies left and found in the fields.

3.4 Physical control

physical control is also possible in some insects like larvae of some insects identified and picked from plants individually it is also done with modified method by **rope dragging** in wheat fields against different chewing insects' pests like army worm larvae feed on wheat fields and aphids and some other insects when.

3.5 MST and RIDL

Release of sterile male to reduce the population of an insect pest is a molecular approach and it is also practically performed against different pests like lepidopterans and dipterans. Male sterile techniques are used against chewing pests of wheat is a good approach to reduce the population without affecting our biological fauna.

RIDL is defined as release of insect with dominant lethal gene this technique was used against different pests like fruit flies and this control is also use against different dipterans. RIDL approaches as an insect having a dominant gene surviveand cause lethality in conditions when mating with a female. The survivors refer to a carrier of set of genes and strategies having bisex lethal, flightless females and non-sex specific late-acting lethal systems.

3.6 Legislative control

Wheat legislative control adds as timely sowing of wheat crop with good practices, recommended density of plants,

3.7 Push pull strategies

A behavior manipulation strategy known as Push Pull technique, which is widely used against different insect pests. The term Push pull coined by Australians to control the pests without use of hazardous insecticides. This strategy used against different pests to reduce their abundance. Australians use this strategy against different Helicoverpa species in cotton. Push pull technique combining with other control methods like natural enemies gives good results [88].

3.8 GMOs

Genetically modified organisms are used to kill insect pests and also genetically modified verities of different crops used to control the pests without using of any chemicals. Bt corn and Bt cotton is one of most popular strategies which are currently use against pests [89].

4. Sucking insect pests of wheat

4.1 Chinch bug *Blissus leucopterus*

4.1.1 Taxonomy

Chinch word in Spanish means Pest. The family lygaeidae genus Blissus which contain chinch bug species, yet the taxonomy of the genus is poorly understood. Chinch bug, though native of tropical America but extended its range to the world. It subdivided into two species *Blissus leucopterus* and subspecies *B. leucopterus leucopterus* which are known as Chinch bug and hairy chinch bug respectively. Before and in 1831, the original species combination was Lygaeus leucopterus Say [90] The genus name was replaced in 1835 burmeister. The species name combination of two word leuco which means lack of color and pterus means wings [91]. However, it belongs to order hemiptera (suborder: Heteroptera) and family Lygaeidae. Sub species are *B. leucopterus leucopterus (*Say*), B. leucopterus hirtus* (montandan).

4.1.2 Distribution

Chinch bug, *B. leucopterus* (say) native to the new world, found throughout Americas south as well as the North America region. Chinch bug spread Virginia to Georgia extending to south Dakota and Texas in east and west respectively [92].

4.1.3 Biology

B. leucopterus passes two generations per year, a complete life cycle occurs in 30–60 days. Eggs are elongate-oval and rounded at one end, truncate shape at the other end. The eggs are whitish on the first days, turn yellowish after a few days and become red at time of hatching. Female of chinch bug lays eggs in short rows on root, stem, leaf sheath or on soil near the plant [92]. Eggs rate laying by females are 15–20 per day over 2–3 week, producing upto 500 eggs a single female. Eggs are hatching 16 days at 27°C and 8 days at 31°C [93].

There are five nymphal instars with 5, 6, 5, 4, and 6 intervals during each instar when reared at 29°C, under field conditions, the development time may be extended. The normal development time is 30–40 days in normal and may be extended in 60 days. Identification of nymph in early stages, head and thorax are brown, legs are yellowish. These colors are darker as the mature nymph, so the mature nymphs are blackish in color. There are yellowish and whitish colors on the first two segments of abdomen. Wing pads become visible in 3rd instars. Nymphs prefer sheltered locations to feed and aggregate on the stem near the main stem of the plant [92].

Adults are blackish in color; wings nearly attain the end of abdomen and are white in color with blackish spots found near the center. Measurements of adults are 3.5 to 4.5 mm in length.

4.1.4 Damage

Host of chinch bugs consist solely of family gramineae, but also include other grasses and plants. Chinch bug is a plant feeding insect, causing reddish color at the site of feeding and death of the plant. Plant growth can be stunted, or dead by a large number fed on plants. The losses by chinch bug were estimated at 19 million dollars in 1989 [94].

4.2 Wheat aphid

4.2.1 Taxonomy

Aphids evolved in Carboniferous period about 280–300 million year ago [95, 96] Many species of aphid attack on wheat crop, three major aphids pest are *Myzus persicae* (Sulz.), *Sitobion avenae* (F.) and *Schizaphis graminum* (Rondani). Sulzer was the first who described *Myzus persicae* in 1776 as *Aphis persicae.* Species have many synonyms which are listed by Borner [97]. The Aphid genus of Myzus belongs to the largest tribe of aphid Macrosiphini [98], which contains fifty five species. *M. persicae* make a species complex which describes as a separate species *M. nicotanae*.

Order: Hemiptera. Suborder: Sternorrhyncha, Family: Aphididae, Genus: Myzus, Sitobion and Schizaphis, Species: *M. persicae, S. avenae and S. graminum.*

4.2.2 Distribution

Myzus persicae (Sulzer), green peach aphid is found throughout the world. The green peach aphid probably belongs to Asian origin, *Myzus persicae* growth is not acceptable when temperature and humidity are not bearable for aphids [99].

4.2.3 Biology

Aphids biology is quite complicated than other insects. In single colony, aphid adults are present in wing form or wingless form. Aphids characters in life cycle is continuous asexual production and of larvae by live birth, parthenogenesis and viviparity respectively. In parthenogenesis, embryos arise from cells without reduction of chromosomal and individuals, so all females are genetically identical to their parents. Sexual reproduction occurs in autumn, female of autumn season oviparous results in the production of overwintering eggs. In the following growth season of plant eggs hatch and produce a series of parthenogenetic generations [100, 101].

4.2.4 Damage

Aphids damage in stages of adults and nymphs. Nymph and adult suck the cell sap of the plant part [102]. Aphids can attain very high populations on young plant tissue, wilting and reducing the growth rate of plants. Losses due to aphid upto one third crops yield [103].

4.3 Green stink bug

4.3.1 Taxonomy

The genus *Nezara* proposed by Amyot and Serville in a group 'Rhaphigastrides' with other spices in 1843. In the family Pentatomidae, Kirkaldy (1909) recognized six subgenera in *Nezara*, now all of which are considered as genera. *Nezara viridula* have color variability and wide distribution in the world, resulting in the form of synonyms [104]. Most existing forms of species are two G-type and O-type, *Nezara viridula var. Smaragdula* is G-type with complete green color and *Nezara viridula* var. *torquata* is O-type with green body and anterior yellowish coloration [105]. It belongs to Order: Hemiptera, Suborder: Hetroptera and Family: Pentatomidae.

4.3.2 Distribution

*Nezara viridula*is referred to as worldwide or cosmopolitan distributed as the species and occurs throughout regions (Tropical, Subtropical and Temperate) Also in Australia [106, 107]. The species *Nezara viridula* expands its range constantly, both in Northern and Southern spheres, by natural dispersal and human translocation [108].

4.3.3 Biology

The development of life stages of this species has been described by Jones in 1918. Females lay eggs in clusters; each cluster contains 60–90 eggs [109]. Fresh eggs are cream in color, and become dark after one day, eggs hatch in 3 days [110]. First instars of *Nezara viridula* are red in color and turn dark by the stadium on the second day [111]. Second to fourth instars are green in color, fourth and fifth instars may be green/dark [112]. Development of insect adults from eggs is approximately 30 days but varies on time period. Female adults start mating in 5 days and male take 6 days for mating. Female deposited the egg within 7 to 8 days after mating. The diapausing of species occurs in adult form and insect diapauses before mating.

4.3.4 Damage

Nezara viridula species is a highly polyphagous insect, attacking both monocot and dicots. Range of plants is 145 plant species which belong to 32 families as host plants [113]. Different generations of species breed utilize and feed different plant species during vegetative stages of host plant in a season. Damage come from feeding of nymphs on podm fruits and seed which results in yield reductions and other aspects like quality and germination of seeds.

4.4 Haplothrips

4.4.1 Taxonomy and nomenclature

Haplothrips was first described by Amyot & Serville in 1843. Synonyms of the *Haplothrips ganglbaueri* Schmutz, 19136 are *Haplothrips ganglbaueri* Schmutz, 1913, *Haplothrips angustus* Hood, 1919, *Haplothrips vernoniae* Priesner, 1921, *Zygothrips andhra* Ramakrishna, 1928, *Haplothrips priesnerianus* Bagnall, 1933, *Haplothrips themedae* Priesner, 1933 and *Haplothrips tolerabilis* Priesner, 1936 [114]. Order: Thysanoptera and Family: Phlaeothripidae.

4.4.2 Distribution

Haplothrips is widely distributed in **Old world**, Pakistan, China, Iran, Japan, Sri Lanka, India, Indonesia, Egypt. **New world**; Central and South America, Australia and New Zealand [115–117].

4.4.3 Biology

Eggs of Haplothrips are cylindrical, rounded from posterior, tapered anterior end, which looks like a knoblike process. Eggs measure 433-500 μ length and 137-150 μ width. Nymphs at the time of egg hatching are microscopic, transparent and amber in color. Color changes from amber to pink after considerable feeding. The length of the first instar before eclosion measures 1100 μ in length. The color of the second instar nymph is glowing red except for the appendages which are dark brownish to black. Second instar mature nymph measures about the same length as that of the adult. The pre pupal stage of the *Haplothrips ganglbaueri* ischaracterized by small antennal sheath, the glassy colored appendages and the lack of wing sheaths. Overall pre-pupal stage is pale red. Adult color is pale red. They have a transparent head, with a dorsal blotch. An occasional adult in the field may be dark red. Length of the adult's measure 1415-2268 μ. Morphology of abdomen is compressed and pointed toward its apex, fringed with setae. Head, thorax, and abdomen lack bristles. Seven to nine accessory cilia present on the wings [118].

4.4.4 Damage

Polyphagous pest *Haplothrips ganglbaueri* severely damage graminous crops such as *Oryza sativa*, wheat *Triticum vulgare*, and *Sorghum vulgare*. It has been known for doing damage to fruiting parts such as inflorescence. Both adults and nymphs preferably feed on inflorescence. Uneven oval and subtle brown patches on the lemma, palea and ovarian tissues of rice were found by Ananthakrishnan and Thangavelu [115].

5. Management of sucking insect pest of wheat

5.1 Cultural methods

Cultural control comprises the modification of regular farm operations that destroy the insects or prevent them from causing injury. This control is to adjust the time of sowing, plowing, irrigation, harvesting and improved farm management. The opinion regarding aphids shows that it damages the wheat badly that is sown earlier and if the cool weather remains until March [119]. Tabasum et al. [120] reported that the crop sown earlier was least affected and the wheat crop can be set aside by doing modification in sowing dates. The early sowing of the wheat crop is the best way to minimize the risk of aphid attack [121]. The abundance of *Coccinella septempunctata* was greater on late-planted wheat than the crop sown earlier [122]. Preferably wheat in Multan should be planted in the last week of November to avoid heavy aphid attack [122].

Intercropping with different crops can increase the natural enemy population in a wheat field for many reasons. The intercrop plants may release chemicals to attract natural enemies and their early establishment in the field. Intercropping with non-host plants seemed to be favorable for the parasitoid's population [123]. The rye-grass strips in wheat fields and wheat– oilseed rape intercropping is used to enhance the number of natural enemies. The population density of ladybeetle and ratio of ladybeetle to *S. avenae* was greater than in the wheat-oilseed rape intercropping field. It is recommended that *Bactris campestris* intercropping with wheat should be encouraged among farmers to maximize the wheat crop profit by reducing the aphid population [124].

5.2 Seed treatment

Seed treatment is environment friendly and economical with excellent control. The systematic and relatively low rate of the application makes it user-friendly for seed dressing and it protects from sucking insect pests by eliminating the repeated needs for sprays. Seed treatment by using neonicotinoid insecticides against piercing-sucking insects, such as aphids is very effective. Ahmed et al. [125] reported that when imidacloprid in combination with tebuconazole is used as seed treatment against *Schizaphis graminum* can control aphids for 8 weeks. The mixture of imidacloprid + Tebuconazle with a relatively low rate of application can make it environment friendly and an effective option for seed dressing against *Schizaphis graminum* [126]. It can be concluded that Actara® and Hombre® as seed treatment could be efficiently utilized for controlling *Sitobion avenae* [127].

5.3 Biological control methods

Natural Biological control is the action of predators, parasitoids, pathogens and plant extracts in maintaining pest density. The natural enemies may help to reduce the sucking pest population from reaching the economic injury level in the Wheat. The aphid parasitoids in Pakistan have been reported by [128, 129]. In Pakistan, *Aphidius* sp. has been recorded parasitizing *S. graminum* attacking wheat crop [130].

A. ervi and *A. colemani* are reported by against wheat aphid [131], while *Diaeretiella rapae* reported by [126]. On wheat aphid parasitism rates started low, as the season progressed, the mean rate of parasitism increased [132].

In wheat, sucking pest populations are effectively restricted by adults and larvae of ladybird beetles, lacewing larvae and larvae of hoverflies. Predators are the parasitoids due to their broader host range and can feed on both egg and larvae stage of pests and also [129]. Coccinellids are the most abundant predator on wheat and cotton for the controlling of the aphid population [133]. *Coccinella septempunctata* is one of the most efficient predators of immature and adult aphids on wheat [134]. As the biological control agents, syrphid flies against *S. graminum* may provide a complementary management method [135]. One of the voracious predators of all the aphids exposed eggs and small nymphs are *Chrysoperla carnea* [136].

There are several botanicals derived from plant oils extracted from leaf and seeds have been used to control aphids in Pakistan. *Moringa oleifera* and *Eucalyptus oblique* leaves showed higher mortality of *S. avenae* [137]. *Azadirachta indica* seed kernel extracts to control *S. avenae* are effective as imidacloprid [138]. Abid [139] concluded that tobacco caused maximum mortality against all instars of *S. graminum* and *S. avenae* followed by neem, dhatura and onion. Iqbal et al. [140] treated the aphid by different botanicals, Orange Peel extract exhibited the maximum mortality of aphid followed by Garlic and Tobacco. *Azadirachta indica* and the entomopathogenic fungi *Beauveria bassiana* or *M. anisopliae* exhibited efficacy against *S. avenae* [126].

5.4 Host plant resistance

Plants can resist invading insects and diseases. The plants with this ability can be attributed to their morphological and chemical characteristics. Moreover, resistant plants can change their physiology in case of invasion and compensate for the damage caused by the pests. Planting resistant cultivars is a simple and effective method to reduce its damage. Shahzad et al. [121] proved that Galaxy 2013 gives higher yield and can tolerate aphid damage. Wheat genotypes can play a vital role to suppress the aphid population, Sarsabz, Kiran-96 and Khirman varieties were shown to be resistant [141]. Results proved that 6309–2103 shows resistance among other varieties and has the lowest Aphids population density [142]. Shafaq-06 is more susceptible and 9114 is relatively more resistant wheat varieties lines against the aphid population [134].

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