Omkar *Editor*

Sucking Pests of Crops

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Preface

The increase in human population in the twentieth century at a pace much beyond that in any of the previous centuries is attributed to multiple factors including more scientific breakthroughs, rapid industrialization, better health care, better understanding of hygiene, and increased food availability. The increased food availability can be attributed to both the increase in agricultural land and the development of high yielding seeds and more efficient means of pest management.

But while the overall agricultural yield has managed to keep pace with the rapidly increasing human population, it has also led to a rapid increase in yet another population of organisms, the insect pests. Pests reduce crop productivity in various ways. Without preventive measures using pesticides, natural enemies, host plant resistance, and other nonchemical controls, 70% of crops could have been lost to pests. Weeds produce the highest potential loss (30%), compared to animal pests (23%) and pathogens (17%). However, the control measures for pathogens and animal pests show efficacy of 32 and 39%, respectively, compared to almost 74 % for weed control.

Herbivorous insects are known to cause damage up to 20% of the crop yield despite massive global inputs in pest control measures. Globally, arthropods destroy an estimated 18–20% of annual crop production worldwide, at a value of more than US$ 470 billion. The greater proportion of these losses (13–16%) occurs in the fields, before harvest, and losses have been heaviest in developing countries. An overview of recent studies on global food loss and waste magnitudes shows a range from 27 to 32% of all food produced in the world. In fact, multiple studies have shown that the global crop losses due to insect pests have increased considerably in the post-green revolution era, in almost all the crops except cotton and rice.

Of these pests, sucking pests, viz. aphids, scale insects, mealy bugs, thrips, whiteflies, leafhoppers, and mites, form one of the major concerns for agricultural crop yield as they inflict both quantitative and qualitative losses. Sucking pests pierce plant parts with slender, sharp-pointed mouthparts and suck the plant sap. Withdrawal of the sap results in minute white, brown, or red spotting on the leaves, fruits, or stems of the plant. It may also cause curling leaves, deformed fruit, general wilting, browning, and drying of the entire plant. Many sucking pests promote fungal growth due to their exudates. Many of these pests are also resistant to pesticides. Some of these are important virus vectors, transmitting a range of plant viruses.

Because of the multipronged attack of sucking pests, as well as their cosmopolitan distribution and polyphagous nature of many of them such as aphids and whiteflies, sucking pests have turned into a serious affliction of numerous agricultural and horticultural crops. It is also predicted that the increase in temperatures accompanied with higher humidity owing to global warming-induced climate change is likely to increase the incidence of sucking pests. Thus, an understanding of the biology of sucking pests, their damaging stages, nature of damage, and control measures is essential for furthering agricultural yield.

Keeping these facts in mind, the present book *Sucking Pests of Crops* was proposed. The present form of the book contains 16 chapters under two sections: (1) Agricultural Pests and (2) Horticultural Pests. It is hoped that it will cater to the needs of PG students of Agricultural Zoology, Entomology, and Zoology with specialization in Entomology along with faculty members and also the researchers of this field. In addition, it is also likely to be more useful to the policy planners involved in agriculture and plant protection.

Lucknow, India Omkar
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Omkar has over three decades of teaching experience and has been actively involved in research for nearly four decades. He is currently a Professor and Former Head of the Department of Zoology, University of Lucknow, Lucknow 226007, India. He is a fellow of the National Academy of Sciences, India, and several other professional bodies. He was also a recipient of the Young Indian Zoologist of 20th Century Gold Medal (2000) by the Zoological Society of India; Prof. T. N. Ananthakrishnan Foundation Award (2012); Rescholar Award of Excellence in Agricultural Entomology by the Association of Entomologists, Patiala (2014); Prof. G. S. Shukla Gold Medal by the Academy of Environmental Biology, India (2014); and the Prestigious Saraswati Samman by Govt. of Uttar Pradesh (2017). His research focuses on identifying and harnessing the potential of beneficial insects, in particular ladybird beetles, for which he is globally recognized. He has completed ten research projects funded by state and central government agencies. He is author of several books and journal articles on this theme.

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Part I

Agricultural Crops

Sucking Pests of Cereals

1

Omkar and Arun Kumar Tripathi

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Abstract

Cereal crops are grasses belonging to monocot plants under the family Poaceae. They are grown primarily for the harvesting of mature grains which are used or processed into staple food and animal feed. They are also processed into various products, such as starch, malt, biofuel (alcohol), and sweetener (i.e., high fructose corn syrup). They are also a rich source of carbohydrates. The top five cereals in the world ranked on the basis of production tonnage are maize (corn), rice (paddy), wheat, barley, and sorghum.

The global losses due to various categories of pests vary with the crop and agroclimatic conditions. Total yield losses from different pests of all crops have been estimated to be US$ 500 billion worldwide. Animal pests account for 15.6% loss of production, pathogen 13.3%, and weeds 13.2%. The insects also cause indirect loss as a vector of various plant pathogens.

The present chapter describes about major sucking insect-pests of cereal crops like barley, finger millet, maize, oat, rice, sorghum, and wheat. Common name, scientific name, host range, life cycle, and nature of damage are given for each insects covered under different cereal crops along with economic importance of

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the concerned crop. Integrated pest management approach for sucking insect-pests is given separately in the last section of this chapter.

1.1 Introduction

The cereals are members of the grass family (a monocot family Poaceae, also known as Gramineae), which usually have long, thin stalks, such as wheat, rice, maize, sorghum, millet, barley, and rye. Their starchy grains are used as food. The term cereal is not limited to these grains, but, also refers to foodstuff prepared from the starchy grains of cereals like flours, breads, and pasta.

On a worldwide basis, wheat, and rice are the most important crops, accounting for over 50% of the world's cereal production. All of the cereals share some structural similarities and consist of an embryo (or germ), which contains the genetic material for a new plant, and an endosperm, which is packed with starch grains. Cereals are staple foods, and are important sources of nutrients in both developed and developing countries. Cereals and cereal products are an important source of energy, carbohydrate, protein, and fibre, as well as containing a range of micronutrients such as vitamin E, some of the B vitamins, magnesium, and zinc.

Crop losses are usually defined as the reduction in either quantity or quality of yield (Zadoks and Schein 1979) and these may be caused by abiotic and biotic factors, leading to the reduction in crop productivity. Losses can occur at any stage of crop production in the field (preharvest) or even during storage (postharvest) (Oerke 2006). Direct yield losses caused by pathogens, animals, and weeds are altogether responsible for 20–40% loss of global agricultural productivity (Sharma et al. 2017; Kalsa et al. 2019).

The limited data available indicate that arthropods may be destroying an estimated 18–20% of the annual crop production worldwide. Further, the losses are considerably higher in the developing tropics of Asia and Africa, where most of the future increase in world population is expected during the next 50 years. There is an urgent need to precisely estimate the extent of food loss and waste at different stages from the agricultural fields to human consumption with emphasis on the developing countries. This is the necessary first step towards development of safe, economical, and sustainable methods of pest management, as well as food security for the future (Sharma et al. 2017).

The present chapter deals with sucking insect-pests of some economically important cereals like barley, finger millet maize, oat, rice, sorghum, and wheat in detail covering crop importance, list of major sucking insects attacking each crop along with their respective systematics, life histories, and their economic impacts on the cereal crops. Systematics of insects recorded on selected cereal crops has been tabulated at one place (Table 1.1) and detailed descriptions of major pests are given in detail for each crop.

Table 1.1 Systematic of major sucking insect-pests attacking cereals

Plant name	Damaging insects				
	Common name	Scientific name	Order	Family	Pest status (major/minor)
4.1. *Hordeum vulgare*	4.1.1. Russian wheat aphid	*Diuraphis noxia* (Mordvilko)	Hemiptera	Aphididae	Major
	4.1.2. English grain aphid	*Macrosiphum avenae* (F.)	Hemiptera	Aphididae	Major
	4.1.3. Green bug	*Schizaphis graminum* (Rondani)	Hemiptera	Aphididae	Major
	4.1.4. Rose grass aphid	*Metopolophium dirhodum* (Walker)	Hemiptera	Aphididae	Major
	4.1.5. Corn leaf aphid	*Rhopalosiphum maidis* (Fitch)	Hemiptera	Aphididae	Major
	4.1.6. The bird cherry-oat aphid	*Rhopalosiphum padi* (L.)	Hemiptera	Aphididae	Major
	4.1.7. Barley mealybug	*Trionymus haancheni* (Mc Kenzie)	Hemiptera	Pseudococcidae	Major
	4.1.8. Barley thrips	*Limothrips cerealium* (Haliday)	Thysanoptera	Thripidae	Major
4.2. *Eleusine coracana*	4.2.1. Rusty plum aphid	*Hysteroneura setariae* (Thomas)	Hemiptera	Aphididae	Major
	4.2.2. Root aphid	*Tetraneura nigriabdominalis* (Sasaki)	Hemiptera	Pemphigidae	Major
	4.2.3. Ragi jassid	*Cicadulina bipunctella bipunctella* (Melichar)	Hemiptera	Cicadellidae	Major
4.3. *Zea mays*	4.3.1. Corn leaf aphid	*Rhopalosiphum maidis* (Fitch)	Hemiptera	Aphididae	Major
	4.3.2. Black bean aphid	*Aphis fabae* (Scopoli)	Hemiptera	Aphididae	Major
4.4. *Avena sativa*	4.4.1. The bird cherry-oat aphid	*Rhopalosiphum padi* (L.)	Hemiptera	Aphididae	Major
	4.4.2. Russian wheat aphid	*Diuraphis noxia* (Mordvilko)	Hemiptera	Aphididae	Major

(continued)

Table 1.1 (continued)

Plant name	Damaging insects				
	Common name	Scientific name	Order	Family	Pest status (major/minor)
	4.4.3. Green bug	*Schizaphis graminum* (Rondani)	Hemiptera	Aphididae	Major
	4.4.4. Barley thrips	*Limothrips cerealium* (Haliday)	Thysanoptera	Thripidae	Major
4.5. *Oryza sativa*	4.5.1. Rice stink bug	*Oebalus pugnax* (F.)	Hemiptera	Pentatomidae	Major
	4.5.2. Chinch bug	*Blissus leucopterus* (Say)	Hemiptera	Blissidae	Major
	4.5.3.1. White rice leaf hopper	*Cofana spectra* (Distant)	Hemiptera	Cicadellidae	Major
	4.5.3.2. Sugarcane leaf hopper	*Pyrilla perpusilla* (Walker)	Hemiptera	Lophopidae	Major
	4.5.3.3. Brown plant hopper	*Nilaparvata lugens* (Stal)	Hemiptera	Delphacidae	Major
	4.5.3.4. White backed plant hopper	*Sogatella frucifera* (Horvath)	Hemiptera	Delphacidae	Major
	4.5.3.5. Green leafhopper	*Nephotettix virescens* (Distant)	Hemiptera	Cicadellidae	Major
	4.5.4. Rice delphacid	*Tagosodes orizicolus* (Muir)	Hemiptera	Delphacidae	Major
	4.5.5. Rice black bug	*Scotinophora lurida* (Burmeister)	Hemiptera	Podopidae	Major
	4.5.6. Earhead bug	*Leptocorisa oratorius* (F.)	Hemiptera	Alydidae	Major
4.6. *Sorghum*	4.6.1. Green bug	*Schizaphis graminum*	Hemiptera	Aphididae	Major
	4.6.2. Corn leaf aphid	*Rhopalosiphum maidis*	Hemiptera	Aphididae	Major
	4.6.3. Chinch bug	*Blissus leucopterus*	Hemiptera	Blissidae	Major
	4.6.4. Yellow sugarcane aphid	*Sipha flava*	Hemiptera	Aphididae	Major

(continued)

Table 1.1 (continued)

Plant name	Damaging insects				
	Common name	Scientific name	Order	Family	Pest status (major/ minor)
4.7. *Triticum*	4.7.1. Russian wheat aphid	*Diuraphis noxia*	Hemiptera	Aphididae	Major
	4.7.2. English grain aphid	*Macrosiphum avenae*	Hemiptera	Aphididae	Major
	4.7.3. Green bug	*Schizaphis graminum*	Hemiptera	Aphididae	Major
	4.7.4. Corn leaf aphid	*Rhopalosiphum maidis*	Hemiptera	Aphididae	Major
	4.7.5. The bird cherry-oat aphid	*Rhopalosiphum padi*	Hemiptera	Aphididae	Major

1.2 Systematics of Major Insect-Pests Attacking Cereal Crops

1.3 Major Insect Pests of Cereal Crops

1.3.1 *Hordeum vulgare* L. (Barley)

Crop Importance

Barley is an edible grain cereal, which is the fourth largest grain crop globally after wheat, rice, and corn. Barley is grown for many purposes, but the majority of all barley is used for animal feed, human consumption, or malting (Kling 2004). High protein barleys are generally valued for food and feeding, and starchy barley for malting. The major sucking insect-pests recorded on this plant are described below.

1.3.1.1 Common Name: Russian Wheat Aphid (RWA)

Scientific name: Diuraphis noxia Mordvilko (Hemiptera: Aphididae)

Host Plants

Russian wheat aphid affects cereal crops throughout the world, primarily barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*) (Miller et al. 2001). RWA attacks most of the cereals including wheat, barley, triticale, rye, and oat. Other primary hosts include durum wheat (*Triticum durum*), field brome grass (*Bromus arvensis*), *Elymus* sp., and jointed goat grass (*Triticum cylindricum*).

Fig. 1.1 Wingless adult of *Diuraphis noxia*, showing the presence of a "double tail"

Fig. 1.2 Winged (alate) adult *Diuraphis noxia*

Primary hosts for RWA support the entire life cycle and allow for reproduction to occur. All instars and adults can feed on these plants. Secondary hosts are plants that only support adults and final instars. They allow the aphid to survive but not reproduce. Secondary hosts include cereal rye (*Secale cereale*), triticale (*Triticum aestivum* x *Secale cereale*), and various grasses in the Poaceae family, such as oats (*Avena sativa*), tall wheat grass (*Agropyron elongatum*), and Indian ricegrass (*Oryzopsis hymenoides*).

Life Cycle

RWA is a small insect, 1.5–1.8 mm in length. The body is light green in colour, and an elongated spindle-shaped. They have short antennae (about one-quarter of body length), and a distinctive double-tailed (cauda) appearance when viewed from the side (Fig. 1.1). They also lack the visible siphunculi (special tubes or pores in the abdomen of aphids for extruding waxy defensive fluids), which are present on other cereal aphids. This characteristic distinguishes RWA from other cereal aphids. Instars look similar to apterous adults but do not develop the characteristic caudal features until the fourth and fifth instars. This species also has alate (winged) adult morphs (Aalbersberg et al. 1987) (Fig. 1.2).

Fig. 1.3 Colony of *Diuraphis noxia* Damage: yellow and white streaks along the leaf surface

RWA spend their entire life on cereals and grasses, and have the ability to reproduce both sexually and asexually. Yet, RWA is only known to reproduce sexually in Russia and central Asia, and male aphids have not been observed in many parts of the world (Tolmay 2006). Sexual reproduction allows the aphids to overwinter as eggs, in contrast to areas where asexual reproduction occurs that requires the aphid to continue to feed over the winter period.

All invasive populations of RWA outside of its natural range are parthenogenetic (i.e., reproduce asexually).

Asexual Reproduction of RWA

Asexually reproducing populations of RWA are all female and adults give birth to live nymphs. After the fourth moult, aphids develop into either wingless (apterous) or winged (alate) adults. Wingless adults have a higher reproductive capacity and can produce 4–5 nymphs per day for 3–4 weeks. Reproduction rates increase as the temperature increases with generation times becoming shorter and more young produced by each female. In general, maturation is completed within 7–10 days.

Sexual Reproduction of RWA

RWA are holocyclic, and, therefore, they can reproduce both sexually (usually for overwintering as eggs) and asexually (mostly during the warmer months). After mating, females lay 8–10 eggs on young cereal plants and die a few days afterwards. The eggs hatch in early spring and aphid population increases rapidly by parthenogenetic reproduction.

Nature of Damage

Russian wheat aphid feeding produces strong plant symptoms due to the injection of saliva into the plant during feeding (Kazemi et al. 2001). Symptoms include rolled leaves, chlorotic spots, leaf streaking, trapped awns giving a hooked appearance and a stunted appearance under heavy infestation (Kazemi et al. 2001). Heavily infested plants may typically look stunted with yellow or whitish streaks on leaves (Fig.1.3). These streaks, basically, are formed due to the saliva injected by the RWA. RWA can act as a vector for viruses, including Barley yellow dwarf virus and Barley stripe mosaic virus (Elsidaig and Zwer 1992; Kazemi et al. 2001).

1.3.1.2 Common Name: English Grain Aphid

Scientific name: *Macrosiphum (Sitobion) avenae* F. (Hemiptera: Aphididae)

Host Range

English grain aphid is widespread throughout Europe, Asia, West Africa, America, and Japan. It prefers both cultivated and wild cereal grasses. Among the wild cereal grasses, it prefers *Phleum pratense* L., *Avena fatua* L., *Agropyrum repens* P.B., *Dactylis glomerata* L., *Bromus mallis* L., *Bromus secalinus* L., and *Festuca pratensis* Huds., etc.

Life Cycle

English grain aphids are pale green in colour with black antennae and black cornicles. They are up to 2.5 mm in length. Apterous female have green or yellow-brown

Fig. 1.4 *Macrosiphum avenae* wingless adult

Fig. 1.5 *Macrosiphum avenae* winged adult

fusiform body and long legs (Fig. 1.4). Antenna is longer than body. Siphunculi are black (1.5 times as long as light green tail). Winged female has red-brown thorax and green abdominal segments (Fig. 1.5). The female produces 6–12 eggs, which are oval and black. Overwintering takes place during the egg phase on winter cereals, and also on cereal weeds. Larval period lasts 8–12 days. Life span of apterous parthenogenetic females is about 30–60 days and they produce 20–40 larvae.

Most populations are anholocyclic giving birth parthenogenetically only to asexual morphs. A female produces 20–40 nymphs which overwinter; sometimes already as apterous adults. Their life span takes about 4–10 weeks. A small part of the population is holocyclic. Some of these individuals give birth to males and females that mate, producing about a dozen eggs which overwinter and hatch during next spring. There are 15–20 annual generations (Gaur and Mogalapu 2018).

Nature of Damage

They usually prefer the upper parts of the plant and are commonly found in wheat heads where the accumulation of honeydew and sooty mould are sometimes observed. The pest causes much damage to wheat, barley, rye, oats, sorghum, and maize, resulting in great yield reductions. This aphid excretes honeydew which is colonized by sooty mould fungi. It is also a vector of the barley yellow dwarf virus (BYDV) and affects crops worldwide (Leybourne et al. 2020).

1.3.1.3 Common Name: Green Bug

Scientific name: *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae)

Host Range

Greenbug was first reported on oats during early twentieth century and also has colonized successfully in sorghum during 1960 (Harvey and Hackerott 1969). Greenbug is known to be originated from Virginia, North America (Hunter 1909) with a contradictory report that it might have originated from Italy. There are more than 80 grass species, including several cultivated cereals, millets, and turfgrasses, that support the survival of *S. graminum*.

Fig. 1.6 *Schizaphis graminum* wingless adult

Fig. 1.7 *Schizaphis graminum* winged adult

Life Cycle

Greenbugs are small (1.3–2.1 mm), elongate oval-shaped aphids with head and first part of thorax straw to pale green and with light to medium green abdomen (Fig. 1.6). A darker green stripe down the middle of the top surface of the abdomen is most visible on last instar nymphs and adults. The antennae are uniformly dusky. The cornicles or siphunculi are pale with slightly flared and darkened tips.

It is facultatively holocyclic, i.e., in cold climates. It may reproduce sexually in the cool season and lay eggs that are able to withstand low temperatures, but where winters are mild, it will propagate parthenogenetically throughout the whole year.

After mating, the winged female (Fig. 1.7) lays eggs into leaf sheaths of winter cereals or other grasses: 10–12 in groups of 2–4 over a period of 4–5 weeks. In contrast to other aphids, *S. graminum* has no change of host. In the spring, wingless females hatch from the eggs. After 1–3 weeks, they give birth to live young and asexual reproduction starts again (Shehata et al. 2018). There are several biotypes of greenbug that differ greatly in terms of host preference, temperature tolerance, and their ability to overcome plant resistance. Several biotypes (C, E, I, and K) have been identified of which biotype I is the most predominant and severe (Punnuri et al. 2013). There are eleven documented *S. graminum* biotypes, designated by letters from A to K, although only eight have any relation to HPR varieties (Porter et al. 1997). The term ‘biotype’ here will be used to designate strains of insects differing in their capability of infesting certain Host Plant of Resistant varieties (Diehl and Bush 1984). *S. graminum* has a bacterial endosymbiont (*Buchnera aphidicola*) that plays an important role in the insect’s amino acid metabolism.

Fig. 1.8 *Schizaphis graminum* damage on barley

Nature of Damage

Greenbug ingests phloem sap with its piercing-sucking mouthparts. This weakens the plant due to loss of nutrients and water. The necrotic lesions appear as small yellow or reddish spots around the punctures. As feeding continues, these soon coalesce into larger patches. Eventually, the whole leaf will wilt and the plant may be killed off completely.

High densities of greenbugs significantly lower the plant's photosynthetic activity, resulting in stunting and reduced yield. Infestation is particularly dangerous during stem elongation. The aphid prefers to settle on the undersides of older, lower leaves, which their colonies may cover completely in severe cases. On expanding, the colonies gradually move upwards on the plant. Greenbug saliva has enzymatic activity that breaks down cell walls and chloroplasts in susceptible plants (Al-Mousawi et al. 1983). Greenbug damage is often apparent in the field as circular patches that slowly grow in size (Fig. 1.8). The greenbug is the vector of several plant viruses including barley yellow dwarf virus, sugarcane mosaic virus, maize dwarf mosaic virus, and millet red leaf virus (Harvey et al. 2005; van Emden et al. 2007).

1.3.1.4 Common Name*:* Rose Grass Aphid

Scientific name: *Metopolophium dirhodum* Walker (Hemiptera: Aphididae)

Host Range

M. dirhodum is of palaearctic origin, but is nowadays found in almost all grain-producing regions of the world. The rose grass aphid host alternates from rose as the primary host in spring and early summer to cereals and grasses especially wheat, barley, and maize as the secondary hosts (Honek et al. 2018).

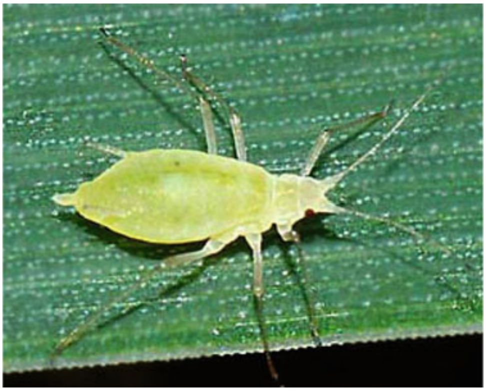

Fig. 1.9 *Metopolophium dirhodum* wingless adult

Fig. 1.10 *Metopolophium dirhodum* winged adult

Life Cycle

Rose grass aphid has a spindle-shaped body and is green, with a noticeably lighter stripe along the back (Fig. 1.9). The apterae are up to 3 mm in length, the oviparous females less than 2 mm. The length of the antennae is about three-fourths that of the whole body.

It usually undergoes an alternation of generations and hosts. The summer generation (virginoparae), which lives on the secondary host, is parthenogenetic, and consists solely of females. Only in the autumn morphs (sexuales) of both sexes appear, mate, and produce eggs, which are laid on the primary host (*Rosa* spp.). The colony founders (fundatrices) hatch in the spring, and adults of the subsequent second or third generations migrate to the summer host (Poaceae). However, in regions with mild, temperate climates, this aphid can be anholocyclic, i.e., without a sexual generation and with aphids overwintering on the secondary host as well. Mild autumns and winters, an early rise in temperatures in spring, and warm, dry weather in summer are conditions favourable for rapid population increase. Peak densities tend to more or less coincide with the milky stage of cereal development.

As the plant grows, the aphid colonies climb from ageing to younger parts. When the host becomes overcrowded, winged morphs (alatae) (Fig. 1.10) develop and then spread to other plants.

Nature of Damage

The preferred feeding sites are the undersides of leaves, and less often, the ears. *M. dirhodum* feeds on plant sap, which it obtains by puncturing phloem vessels. Its saliva does not contain substances that are toxic to the plant, but the drain of nutrients and water can lead to yield losses, if the aphid occurs in large numbers. Plants that are already under water stress may start to yellow and become stunted. It is also a vector of several plant viruses, most importantly barley yellow dwarf virus, maize mosaic virus, and potato viruses.

1.3.1.5 Common Name: Corn Leaf Aphid

Scientific name: *Rhopalosiphum maidis* Fitch (Hemiptera: Aphididae)

Host Range

The corn leaf aphid is a serious pest of maize and barley with Asiatic origin but it is now distributed throughout the tropics and temperate regions of the world (Blackman and Eastop 2000; Kuo et al. 2006). Host plants include many common grass weeds (barnyard grass, crabgrass, and foxtail) and most cereal crops (corn, barley, rye, oats, wheat, sorghum, and millet).

Life Cycle

Corn leaf aphids are oval-shaped, with soft bodies and a pair of cornicles protruding from end of their abdomen (Fig. 1.11). This aphid is bluish-green or black, with black legs and short antennae. Corn leaf aphids overwinter as females on the host plant. Their average body length is 2.56 mm. Both wingless and winged forms occur. They are polymorphic in nature. No males or egg stages occur. Females give birth to live youngs via parthenogenesis. Offsprings develop through four nymphal instars, each instar lasts for 2 days. Total life cycle is completed in 7–8 days (Kuo

Fig. 1.11 Adult and nymph of *Rhopalosiphum maidis*

et al. 2006). There are up to nine generation per year. These aphids are usually found in the whorls and on the tops of newly emerged leaves of the plants.

Nature of Damage

This aphid is a polyphagous pest and can cause damage to many host plant species and weeds from Poaceae and occasionally Cyperaceae and Typhaceae. *R. maidis* damages its host plants by feeding, viral disease transmission, and honeydew production. Aphid infestation occurs on seedlings, leaves, inside the whorl, the covers inflorescence of plants and produces plentiful honeydew (Blackman and Eastop 2000), which may result in deformed leaves as well as the sterilization of inflorescences (Hill 1987). In addition, *R. maidis* is a vector of plant viruses and may transmit ten viral diseases to cereals (Blackman and Eastop 2000).

It interferes with pollen production and fertilization, resulting in poor kernel fill of the ears. Infestation also can cause a delay in plant maturity and reduced plant size (Bing and Guthrie 1991). Honeydew secreted by the aphids supports growth of sooty mould fungus, causing an unsightly appearance of the ears.

1.3.1.6 Common Name: *The Bird Cherry-Oat Aphid*

Scientific name: *Rhopalosiphum padi* Linnaeus (Hemiptera: Aphididae)

Host Range

The bird cherry-oat aphid is found almost worldwide (except the subtropical and tropical regions). It attacks almost all cereal crops. The primary hosts are *Prunus* spp., and the secondary hosts are many species of Poaceae, Cyperaceae, and Typhaceae.

Life Cycle

The body of the apterous females is about 2.5 mm long (Fig. 1.12) and green-brown in colour. The head, siphunculi (which are swollen) and cauda are brown-black. The alate females (Fig. 1.13) are mostly green, siphunculi brown, body length about

Fig. 1.12 *Rhopalosiphum padi* showing siphunculi (darker brown parts protruding from abdomen) and single tail

Fig. 1.13 *Rhopalosiphum padi* winged adult

2.4 mm. Female lays egg in the narrow gap between the axillary buds and the stem. After egg hatch, the newly emerged nymphs move to bird cherry leaves, where they feed and develop. Nymphs develop rapidly into very large light green fundatrices. The fundatrix is pale green and 2.5–3.0 mm in length. These fundatrices give rise to a second, wax covered, generation. The bird cherry-oat aphid often reproduces exclusively by parthenogenesis from spring to late summer. All individuals are females, and they give birth to live young, which are also female. Most of them remain wingless. Each female is able to produce 60–80 larvae during its reproductive period of 3–4 weeks.

Under stress conditions, winged forms appear and start to colonize other plants. In warm weather, the generation cycle can be completed in about a week. Each female is able to produce 60–80 larvae during its reproductive period of 3–4 weeks. Accordingly, population growth can be very rapid. In climates with mild winters, parthenogenesis remains the only mode of reproduction throughout the year (Luo et al. 2019).

In colder regions, however, sexual forms appear in the autumn, which then migrate to the primary (winter) host (e.g., the bird cherry), mate, and produce eggs, which are laid near the buds. The overwintering eggs are very frost-resistant. In the spring, female founders (the so-called fundatrices) hatch and start to produce offspring. After several generations (usually three) on winter hosts, migration to the summer host starts. The summer (secondary) hosts are grasses, including most cereal crops.

Nature of Damage

R. padi uses its piercing-sucking mouthparts to penetrate plant tissues in order to reach a vascular bundle and ingest phloem sap. Strong infestations can sometimes lead to contortion of leaves. The insect causes most damage by transmitting a number of viruses, especially barley yellow dwarf virus (BYDV), the cereal yellow dwarf virus-RPV, filaree red leaf virus, maize leaf fleck virus, and rice giallume virus, oat yellow leaf disease, and the onion yellow dwarf virus. Infection with BYDV causes barley and wheat to turn yellow, whereas oat becomes reddish in colour. Affected plants are generally severely stunted and non-productive (Stern 1967). During severe infestation, honeydew produced, can create a sticky film on plant surfaces that can reduce photosynthesis and promote the growth of sooty mould.

1.3.1.7 Common Name: Barley Mealybug

Scientific name: *Trionymus haancheni* McKenzie (Hemiptera: Pseudococcidae)

Host Range

The Haanchen barley mealybug was discovered for the first time on barley in Idaho in June 2003 (Alvarez 2004).

Life Cycle

Mealybugs are named for the waxy secretions that cover the soft bodies of these insects. They are pink, oval-shaped females with body length up to 5 mm. They have well-developed legs and are covered with a distinctive white, waxy secretion (Fig. 1.14). Egg masses are laid in a sac under a leaf sheath at the base of the plant and covered with cottony wax. A single female can lay up to 256 eggs. After hatching, the immature crawlers disperse to protected feeding sites under the leaf sheath. Crawlers moult into successive instars, each resembling small adults, becoming less mobile with each instar (McKenzie 1967).

The Haanchen mealybug is apparently able to survive winter where it is protected by soil and plant material. Although winged male forms occur, they are rarely detected and do not appear to feed or damage plants. The number of generations is not known, but all stages have been found coexisting on infested plants.

Fig. 1.14 *Trionymus haancheni*

Nature of Damage

Both immatures and females damage crops. The first signs of mealybug presence are ovisacs (cottony clusters of eggs) at the base of the plants. They feed with sucking mouthparts and reduce the amount of chlorophyll in the leaves, causing extensive yellowing and browning of the foliage. In addition to direct feeding injury to barley plants, the Haanchen barley mealybug can indirectly damage the crop by producing honeydew, which has the potential to reduce grain quality. Mealybug infestations cause yellowing of the foliage, reduced vigour, and root damage.

1.3.1.8 Common Name: Barley Thrips

Scientific name: *Limothrips cerealium* (Haliday) (Thysanoptera:Thripidae)

Host Range

Barley thrips cause damage to cereal crops like barley, maize, oats, and wheat.

Life Cycle

Their bodies range from a pale yellow to darker brown and they have slender wings fringed with fine hairs (setae). The life cycle consists of five stages: egg, larva, prepupa, pupa, and adult. Adults are straw-coloured, yellowish-brown, and elongated measuring 1mm in length. Antennae have seven segments with the first segment paler and the second is usually dark. A brown band marks anterior edge of the abdominal tergites. There is a single pair of pores on tergite nine (Fig. 1.15).

Females deposit eggs directly in the host tissue. Eggs are minute, kidney shaped laid in slits in leaf tissues. Nymphs are creamy to pale yellow in colour, resemble adults but wingless.

Nymphs hatch from eggs after 5 days and begin to feed on the plants. Occasionally, wing buds are visible during pre-pupal stages. After two moults, the nymphs

Fig. 1.15 *Limothrips cerealium*