Chapter 9
Arthropods of Cereal Crops in Canadian Grasslands

John Gavloski
Manitoba Agriculture, Food and Rural Initiatives, Crops Knowledge Centre,
65 3rd Ave. NE, Carman, Manitoba, Canada R0G 0J0

Scott Meers
Alberta Agriculture and Rural Development,
301 Horticultural Station Road East, S.S. #4, Brooks, Alberta, Canada T1R 1E6

Abstract. Cereal crops are a major aspect of the Canadian prairie landscape. This chapter focuses on insects of small grain cereals (wheat, oats, barley, and rye), but not on larger grains such as corn, which are less abundant on the Canadian prairies. Settlement of the Canadian prairies resulted in the replacement of vast amounts of native prairie plants with cereal crops. Many native insects adapted and flourished in this new habitat. Many alien insect species have also been accidentally introduced and are now pests of cereal crops. Other insects have been purposely introduced to regulate the populations of insect pests of cereal crops. Insect species are presented in feeding guilds in this chapter. Insects within a feeding guild feed on the same or a similar resource and may at times compete for this resource. Changes in cropping practices and varieties can also have an impact on the insect communities on cereal crops. Such interactions will also be described.

Résumé. Les cultures de céréales occupent une place très importante dans le paysage des prairies canadiennes. Le présent chapitre porte principalement sur les insectes qui s'attaquent aux petites céréales (blé, avoine, orge et seigle), et non sur ceux qui se nourrissent de céréales à graines plus grosses — par exemple, le maïs — moins abondantes dans les prairies canadiennes. La colonisation des prairies canadiennes a entraîné le remplacement de vastes superficies de prairies indigènes par des cultures céréalières. Beaucoup d'insectes indigènes se sont adapté à ces nouvelles conditions et ont prospéré. Plusieurs espèces exotiques d'insectes ont également été introduites accidentellement et sont aujourd'hui des ennemis des cultures de céréales. D'autres insectes on été introduits délibérément pour lutter contre les insectes indésirables. Le présent chapitre classe les espèces d'insectes par guildes alimentaires. Les insectes qui appartiennent à une guilde donnée dépendent de la même source d'aliments ou de sources semblables, et se livrent souvent une concurrence pour cette ressource. Les changements apportés aux pratiques culturales et aux variétés peuvent aussi influer sur les communautés d'insectes des cultures de céréales. Ces interactions seront également décrites.

Description of Habitat

The plant species bread wheat (*Triticum aestivum* L.), durum wheat (*Triticum turgidum* L. var. *durum*), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), and rye (*Secale cereale* L.) are sometimes referred to as small grains. Wheat, barley, oats, and rye are "bunch" grasses, and are grown for their edible seed. The bunch habit results from the development of basal buds on the main stem, which produce branches or stems called tillers (The University of Manitoba 1974). These are all cool-season, long-day, nitro-negative cereals. Nitro negative means that if they grow in soil that is rich in nitrogen, it tends to keep the carbon-nitrogen ratio low and delay flowering. Depending on the variety and the species, most small grains spend an equal amount of time in the vegetative period

Gavloski J. and S. Meers. 2011. Arthropods of Cereal Crops in Canadian Grasslands.
In *Arthropods of Canadian Grasslands (Volume 2): Inhabitants of a Changing Landscape.*
Edited by *K. D. Floate. Biological Survey of Canada. pp. 217-237.*
 ISBN 978-0-9689321-5-5
doi:10.3752/9780968932155.ch9

and in flowering and maturation (The University of Manitoba 1974).

Common wheat is derived from one or more species of wild grasses native to Asia (Vavilov 1951). Presently all wild species of wheat are distributed in the Mediterranean Basin and in southwest and central Asia, the centre of distribution being southeast Turkey (Kimber and Feldman 1987). These areas have short, mild, rainy winters and long, hot, dry summers. All *Triticum* species adapted to this climate are annuals that grow in the winter and pass the hot dry summer as seed (Kimber and Feldman 1987). Domesticated wheat was brought to North America in 1493 by Christopher Columbus and introduced to Canada in 1605 (Campbell and Shebeski 1986).

In Canada, 95% of spring wheat is produced in the three prairie provinces, Manitoba, Saskatchewan, and Alberta (Briggle and Curtis 1987). These provinces and the Northern Great Plains of the United States have long cold winters, short hot summers, and low rainfall (Briggle and Curtis 1987). Spring wheats are generally planted from May to June and harvested from August to October. Winter wheat is planted from September to November and harvested in July and August.

Oats are mostly grown in regions with generally cool temperatures and adequate moisture. For good kernel development, oats require more moisture than any other small grain (The University of Manitoba 1974). Oats are planted from May to June and harvested from August to October. Most oats are harvested for grain, but in Alberta and British Columbia, about 40% of oats are cut "green" and fed mainly to cattle as green chop, hay, or silage. In Manitoba and Saskatchewan, the area cut green is about 10 and 25%, respectively (USDA 2004*a*).

Barley can be grown under very diverse climatic conditions from the Yukon to the tropics. Some varieties mature in only 60 days (The University of Manitoba 1974). Barley is planted mostly from May to June and harvested from August to October. Most barley is harvested for grain, but in Alberta and British Columbia, about 15% is cut green and fed to cattle (USDA 2004*b*). Barley varieties are either two rowed or six rowed and both are used for malting or as livestock feed.

Most rye on the Canadian prairies is seeded in the fall rather than the spring. Rye does better than other cereals on relatively poor soils (The University of Manitoba 1974).

Cereal crops today constitute a large component of the Canadian prairie landscape, as indicated in Table 1.

Many insects can be found on cereal crops in the Canadian prairies. Each part of the plant can be considered a habitat, with its own assortment of herbivorous, predaceous, and parasitic insects. This chapter includes the more common insects encountered on cereal crops in the Canadian prairies. The insects have been organized into feeding guilds according to their food source (foliage, sap, other insects, etc.).

Feeding Guilds of Arthropods on Cereal Crops

Root and Surface Feeders

Wireworms (Coleoptera: Elateridae). In the Canadian prairies, a complex of wireworm species is found in cereal crops. Important species include the prairie grain wireworm (*Ctenicera aeripennis destructor* (Brown)), Great Basin wireworm (*Ctenicera pruinia* (Horn)), sugar beet wireworm (*Limonius californicus* (Mann.)), and western field wireworm (*Limonius infuscatus* Motschulsky) (Morrill 1995). *Aeolus mellilus* (Say), which has caused 20–30% thinning of wheat in Saskatchewan, *Hypolithus nocturnis* Esch., and *Hypolithus bicolor* Esch. (Beirne 1971) are also found.

Table 1. Average hectares per year for the period 1990–1999 for principal small grain cereal crops in the Canadian prairie provinces.*

Area (hectares) of Principal Crop by Province			
Crop	**Manitoba**	**Saskatchewan**	**Alberta**
All wheat	1,756,700	7,144,700	2,851,200
Winter wheat	12,700	29,400	31,500
Spring wheat (excluding durum)	1,673,100	5,455,300	2,516,200
Durum wheat	70,800	1,660,100	303,500
Oats	250,900	515,600	402,700
Barley	495,300	1,524,800	1,916,200
Rye	35,200	94,700	36,000

*Data from the *Canadian Grains Industry Statistical Handbook 2000*, Canada Grains Council (2000).

Wireworms generally have a multi-year life cycle, mostly spent as a larva (Fig. 1). Depending on species and food source availability, the life cycle may be from 3 to 12 years. Adults emerge in the fall but overwinter before mating and laying eggs in the spring. Females lay their eggs underground. Larvae feed on seeds and roots and may feed on the stem just above the seed (King 1928). Wireworms are generally found in land recently removed from perennial grasses (either native or seeded) but can also be in fields with a long history of only annual crops.

False wireworms (Coleoptera: Tenebrionidae). False wireworms occasionally become prevalent in cereal crops along field margins or on knolls, but seldom cause field-scale damage (Calkins and Kirk 1973). Adult false wireworms are larger than adult wireworms and are flightless, but the larval stage can easily be confused with true wireworms. False wireworm larvae generally have longer legs and antennae and a shorter life cycle than true wireworms.

In the treeless prairie areas of Saskatchewan, one species, *Blapstinus moestus* Melsh., has caused stem girdling of wheat seedlings at soil level and notching of wheat that is similar to grasshopper damage. Populations in Saskatchewan have been over a million per acre (Beirne 1971). Unspecified members of the genus *Eleodes* have cause thinning of wheat in Saskatchewan (Beirne 1971), and *E. hispilabris* and *E. tricostatus* feed on small grains in the Canadian prairie provinces (Campbell *et al.* 1989). False wireworms in Saskatchewan reach their greatest abundance in the more arid parts in the southwest of the province (King 1928).

Cutworms (Lepidoptera: Noctuidae). Outbreaks of cutworms are often localized or even field specific, depending on field conditions at egg laying. Many species feed on cereals, the redback cutworm, *Euxoa ochrogaster* (Guenée) (Fig. 2), being a more common species across the prairies, and the pale western cutworm, *Agrotis orthogonia* Morrison, and army

Fig. 1. Wireworms from wheat field. Photo by J. Gavloski.

Fig. 2. Redbacked cutworm, *Euxoa ochrogaster*, larva and pupae. Photo by J. Gavloski.

cutworm, *Euxoa auxiliaris* (Grote), being common in cereal crops in the western parts of the Canadian prairies (Byers and Struble 1987). All three species have univoltine life cycles, although they differ in specific life cycle details.

Redbacked cutworms generally lay eggs in weedy crop stubble. Larvae are frequently found with other cutworm species of *Euxoa* and *Feltia* (Ayre and Lamb 1990). The eggs are laid in July and August and larvae hatch the following spring (Ayre and Lamb 1990). The redbacked cutworm is the most important cutworm species in the parkland areas of the prairie provinces (Byers and Struble 1987).

Pale western cutworms prefer to lay their eggs in loose soil in the fall. The eggs overwinter and then hatch early in the spring. This species is the most important pest cutworm in the drier areas of the prairies. Larvae feed underground except when forced to the surface by rain (Cook 1930). Under extreme conditions, they may survive by cannibalism (Cook 1930).

Army cutworms tend to lay eggs in the fall in fields with some plant growth. The eggs hatch in the fall and the partially grown larvae overwinter (Byers and Yu 1993). This cutworm is often a problem in winter cereals because it prefers to lay eggs in fields with fall growth. The moths, upon emerging in early summer, migrate to foothills and mountains where they undergo a summer aestivation (Byers and Struble 1987). Grizzly bears are known to feed on aggregations of army cutworm moths (White *et al.* 1998). Moths return to the prairies in the fall to lay their eggs. Army cutworms are occasionally found in large numbers in Alberta, less often in Saskatchewan, and rarely in Manitoba (Beirne 1971).

Foliage and Seed Feeders

Grasshoppers (Acrididae). Several species of grasshoppers feed on cereal crops. The more abundant species include the clearwinged grasshopper, *Camnula pellucida* (Scudder); migratory grasshopper, *Melanoplus sanguinipes* (Fabricius); twostriped grasshopper, *Melanoplus bivittatus* (Say); and Packard grasshopper, *Melanoplus packardii* (Scudder).

These grasshopper species have different feeding preferences. *Camnula pellucida* prefers grasses, *M. bivittatus* prefers broad-leaved plants, and *M. sanguinipes* and *M. packardii* feed freely on either type of vegetation (Hinks and Olfert 1992).

Some species of grasshoppers also have feeding preferences among types of cereal crops. *Melanoplus sanguinipes* will feed more on wheat than on oats (Smith 1959; Hinks et. al. 1987, 1990, 1991). Differences in resistance to grasshoppers may occur between different cultivars (Clark 1936, reviewed by Hinks and Olfert 1992). Grasshoppers have also been noted to differentially clip the heads off of maturing bread wheat, durum wheat, and barley (Jones 1943; McBean and Platt 1951).

The change from native grasslands to crops with the advent of agriculture in the prairies has caused major changes in species composition and abundance among grasshoppers (Sanderson 1939; Riegert *et al.* 1965). Planting cereal crops adjacent to shortgrass prairie has enabled *C. pellucida* populations to far exceed those in shortgrass prairie alone (Riegert *et al.* 1965).

The club-horned grasshopper, *Aeropedellus clavatus* (Thom.), can occasionally occur in locally high numbers. In Saskatchewan in 1936, it was reported to have destroyed 300 acres of wheat (Beirne 1972). This species mostly occurs in areas with light soil and is one of the earliest grasshoppers to appear in the spring.

Cereal leaf beetle (*Oulema melanopus* L. (Chrysomelidae)). Cereal leaf beetle is not native to North America. It was first reported in North America from Michigan in 1962 (Helgesen and Haynes 1972; Haynes and Gage 1981). In the Canadian prairie provinces, it was first reported in Alberta in 2005 (Western Committee on Crop Pests (WCCP) 2005), in the southwest corner of Saskatchewan in 2008 (WCCP 2008), and in Manitoba in 2009 (WCCP 2009). It has been present in North Dakota since 2000.

Cereal leaf beetles feed on many members of the grass family. Small grains (oats, barley, wheat, spelt, and rye) are among the most favourable foods for cereal leaf beetles (Wilson and Shade 1966). Some forage grasses are also favourable, but larval development on them is usually slower than on small grains. The adults (Fig. 3) and larvae (Fig. 4) feed mainly on the upper surfaces of leaves and chew lengthwise between the leaf veins. Larvae feed only on parenchyma tissue between the veins in the leaves (Shade and Wilson 1967). Adults may chew completely through leaf tissue, causing leaves to split lengthwise and giving them a tattered appearance. Larvae have a slug-like appearance and are usually covered in a layer of moist fecal material.

Cereal leaf beetles are univoltine in North America and overwinter as adults in a wide variety of protected places, including under bark, forest litter, grass crowns, and grain stubble (Denton 1973). Larvae of cereal leaf beetle are commonly parasitized by an introduced parasitoid, *Tetrastichus julis* (Walker) (Hymenoptera: Eulophidae) (Stehr 1970; Evans *et al.* 2006). Small larvae and eggs may be eaten by lady beetles (Shade *et al.* 1970).

Billbugs (*Sphenophorus* spp. (Curculionidae)). Wheat and barley can be fed on by billbugs in the prairie provinces (Beirne 1971; Campbell *et al.* 1989). The weevil *Listronotus montanus* (Dietz) has damaged spring wheat in Montana and has been observed on grasses in the Cypress Hills of Alberta (Blodgett *et al.* 1997).

Larvae feed on roots and in the stems of small grains (Metcalf *et al.* 1951). Adults perforate the unfolding leaves and stems of the young plants (Beirne 1971). Feeding and egg-laying punctures, made while leaves are curled within the plant, appear as transverse rows of punctures or holes across the leaves after they expand (Metcalf *et al.* 1951). Adults

Fig. 3. Cereal leaf beetle, *Oulema melanopus*, adult. Photo by J. Gavloski.

Fig. 4. Cereal leaf beetle, *Oulema melanopus*, larva. Photo by J. Gavloski.

can also eat through the sheath above the upper node, severing the stems and turning the heads of wheat white (Beirne 1971). Billbugs usually overwinter as adults (Metcalf *et al.* 1951) and may be more common in low-lying, wet sites (Buntin *et al.* 2007).

Armyworm (*Mythimna* (formerly *Pseudaletia*) *unipuncta* Haworth (Noctuidae)). The armyworm is native to North America. It overwinters in tropical and subtropical regions of North America and migrates north in the spring. Armyworms probably do not overwinter on the Canadian prairies (Ayre 1985). They can travel at least 1,300 km during their northward migration (Hendrix and Showers 1992).

Armyworms feed on a variety of plants, although small grain crops are a common food source for larvae (Fig. 5). Larvae skeletonize the surface of the leaves or the inner surface of sheaths as early instars and later feed from the margins of the leaves. The inflorescence is seldom damaged unless leaf foliage is scarce, but in some grasses, notably timothy (*Phleum pratense* L.), green heads are often readily consumed by older larvae even when foliage is abundant (Guppy 1961).

Larvae typically pass through six instars and feed mainly at night. Early-instar larvae loop as they move and may drop from threads when disturbed (Breeland 1958; Guppy 1961). Studies in Ontario found that two and occasionally a partial third generation occur annually (Guppy 1961).

Wheat head armyworm (*Faronta diffusa* Walker (Noctuidae)). The wheat head armyworm is native to North America. It overwinters as a pupa (Beirne 1971). Adults emerge in the spring and lay eggs on many grass species. Adults fly at night and are attracted to light. Host plants include wheat, rye, oats, barley, and wild oats (Beirne 1971).

Fig. 5. Armyworm**,** *Mythimna unipuncta*, on oats. Photo by J. Gavloski.

Larvae are tan or green caterpillars with lateral white, gray, green, or brown stripes. Larvae feed on above-ground plant regions, causing some defoliation, and may also feed on maturing grain heads and chew directly into the developing kernels. They drop to the ground and pupate by harvest time (Buntin *et al.* 2007). High populations of this insect are infrequent (Beirne 1971).

Wheat midge (*Sitodiplosis mosellana* Géhin (Cecidomyiidae)). The wheat midge was introduced to North America from Europe and first reported in North America in 1819 near Quebec City (Sanderson 1915). In North America, the wheat midge is primarily a pest of wheat sown in spring rather than in autumn, as occurs in parts of Europe and China (Lamb *et al.* 2000*b*). Larvae (Fig. 6) are seed feeders that damage grain and cause it to shrivel. After feeding, larvae remain on the seeds until the head is dampened by rain. They then drop to the soil surface, tunnel into the soil, and form cells to overwinter. Larvae migrate to the soil surface in late May to mid-June and then pupate (Doane *et al.* 1987). Adults (Fig. 7) emerge from the end of June to the end of July most years, and the peak period for adult flight is mid-July. Males emerge one to three days ahead of females (Lamb *et al.* 1999).

The discovery of the *Sm 1* R-gene provides an opportunity to control the wheat midge with resistant wheat cultivars (Lamb *et al.* 2000*a*; McKenzie *et al.* 2002). They became commercially available in western Canada in 2010.

Stem Borers

Several species of Diptera, Lepidoptera, and Hymenoptera may occur in stems of small grain cereal crops.

Fig. 6. Wheat midge larvae, Cereal Research Centre, Winnipeg, Manitoba.

Fig. 7. Wheat midge adult, Cereal Research Centre, Winnipeg, Manitoba.

Hessian fly (*Mayetiola destructor* Say (Cecidomyiidae)). The Hessian fly is an introduced insect that is widespread in North America. The common name comes from the discovery of Hessian flies after the Revolutionary War near an encampment used by Hessian troops on Long Island (Morrill 1995). Genetic studies have shown that this insect was introduced to North America from at least three different locations in Europe (Ratcliff *et al.* 2000). In the southern United States, the insect may have several generations per year (Buntin and Chapin 1990), but they have only one or two generations on the Canadian prairies (Wise 2007*a*).

Hessian flies overwinter as puparia (resembling flax seeds) in stubble and adults emerge in the spring. Eggs are laid on upper leaf surfaces as single rows of eggs down the length of the leaf (Fig. 8). The larvae (Fig. 9) hatch and migrate down to the base of the leaf sheath. The larva secretes digestive juices that are toxic to the plant to aid in feeding. The resulting damage, which can include stem breakage, depends greatly on the stage of the plant when attacked. The larvae pupate at the feeding site at the base of the leaf sheath (Stokes 1956).

The early seeding of wheat relative to the emergence of second-generation adults and the presence of many beneficial insects that attack Hessian fly generally keep populations in check on the Canadian prairies (Wise 2007*b*). Six species of Hymenoptera were found as parasitoids of the Hessian fly in the Red River Valley of Manitoba in 2003–2005, with *Platygaster hiemalis* being the most abundant parasitoid of first-generation flies, and *P. eubius* of second-generation flies (Wise 2007*a*). Hessian flies can attack wheat, barley, and rye crops, as well as many perennial wheat grass and rye grass species (Stokes 1956; Morrill 1995).

Wheat stem maggot (*Meromyza americana* Fitch (Chloropidae)). Wheat stem maggot is native to North America and has a wide host range, including wheat, barley, rye, timothy (*Phleum pratense* L.), and many perennial wheat and rye grasses (*Agropyron* and *Elymus*) and *Bromus* species (Beirne 1971; Morrill 1995). There are two generations per year. Larvae overwinter in perennial grasses, generally along the headlands of annual crop fields. Adults emerge in June and eggs are laid on the flag leaf of crops. Larvae hatch approximately 10 days later, move down the leaf sheath, and burrow into the stem just above the top

Fig. 8. Hessian fly ovipositing, Cereal Research Centre, Winnipeg, Manitoba.

Fig. 9. Larvae of Hessian fly, Cereal Research Centre, Winnipeg, Manitoba.

node (Allen and Painter 1937). Feeding by larvae inside the stem after heads form severs conductive tissue. These heads die, turn white, and contain no kernels at a time when uninfested heads are still green; they can easily be slipped from the sheath of the upper leaf with a gentle pull (Keickhefer and Morrill 1970; Branson 1971). Careful dissection will reveal the larva just above the top node. A second type of damage can occur if young tillers are infested before the boot stage is reached. The upper portion of these infested tillers die and no head is produced (Branson 1971). Natural enemies keep populations at relatively low levels. Of six species of hymenopterous parasites of wheat stem maggot in South Dakota, *Bracon meromyzae* Gahan and *Coelinidea meromyzae* (Forbes) were the most important (Morrill and Kieckhefer 1971).

Frit flies (*Oscinella* spp. (Chloropidae)). Both the European frit fly, *Oscinella frit* L., and an indigenous species, *Oscinella soror* Macq., feed on cereal crops in the Canadian prairies. Larvae burrow into the base of young tillers and masticate plant tissues. Once the tissue begins to rot, it provides the food source for the maggot (Wise 2007*c*). This can distort or kill the infested tiller (Buntin *et al.* 2007; Wise 2007*c*). Feeding by frit flies is greatest in very wet years or in poorly drained areas (Beirne 1971; Wise 2007*c*).

Hylemya cerealis (Gill.) (Anthomyiidae). This wheat stem maggot caused severe local damage to cereals in southern Alberta in 1923 and in the 1930s (Beirne 1971). Levels were highest in sandy soils. Crested wheat grass is also a food plant. The flies are active and lay their eggs shortly after the plants appear above ground in the spring. Larvae burrow into the plants and feed mainly on the central shoots.

European corn borer (*Ostrinia nubilalis* (Hübner)). Larvae of the European corn borer can feed on seeds as they develop, but mainly damage wheat by feeding inside the stem. Larvae migrate to the uppermost node and exit by chewing a hole through the stem. Stems either break at the hole and remain attached, or remain standing (Wise 2007*c*).

Fig. 10. Wheat stem sawfly. Photo by H. Goulet.

Wheat stem sawfly (*Cephus cinctus* Norton (Cephidae)). The wheat stem sawfly is one of the most damaging pests of wheat in some parts of the Canadian prairies. It is thought to be a native insect (Criddle 1922), but there is an alternative theory of introduction from Asia (Ivie 2001). This species was first documented attacking wheat in Saskatchewan (then part of the Northwest Territories) in 1895 near Indian Head (Ainslie 1929). In the same year, sawfly larvae were found in wheat stems near Souris, Manitoba (Ainslie 1929). Small but severe outbreaks occurred across the prairies between 1906 and 1910. Significant outbreaks starting in 1921 continued until the late 1950s, with some persisting into the 1960s (Ainslie 1929; Holmes 1978). A more recent localized outbreak in 1998 in the Canadian prairies expanded to become a widespread problem through to 2005 (WCCP 1998–2005). In 2008, the outbreak had subsided, but pockets of concern remain in several areas of the prairies (WCCP 2008). The best control method for the wheat stem sawfly is the use of solid-stem varieties of wheat. The first solid-stem wheat variety, named Rescue, was released in 1948 (Platt *et al.* 1948). Higher yielding cultivars such as Lillian have subsequently been released.

The wheat stem sawfly is univoltine, overwintering as a larva inside the base of the stem of its host grass plant. Pupation occurs in late spring, with the adults (Fig. 10) emerging in late June or early July. Adults search for large-diameter grass stems and lay their eggs as quickly as possible. Adults generally live only 7–10 days. Eggs are inserted into stems and larvae feed inside the stem until the plants start to dry down in the fall. Larvae then migrate to the base of the stem and cut almost all the way through it. The notched stem usually beaks off in the wind. The sawfly overwinters in the resulting stub below the notch (Criddle 1922; Ainslie 1929; Morrill *et al.* 1992). Many predators and parasites attack this sawfly, but only two species are important in wheat (Morrill 1997). *Bracon cephi* is the only important parasitoid of wheat stem sawfly in Canada and is described elsewhere in this chapter.

Jointworms (Hymenoptera: Eurytomidae). Feeding by larvae of jointworms produces galls on the walls of cereal stems (Holmes and Blakeley 1971; Buntin *et al.* 2007). Jointworms weaken the stems and may cause lodging at the point of infestation.

Fig. 11. English grain aphid, *Sitobion avenae*, on oats. Photo by J. Gavloski.

Fig. 12. Oat-birdcherry aphid, *Rhopalosiphum padi,* on oats. Photo by J. Gavloski.

The rye jointworm, *Harmolita secale* (Fitch), caused economic damage to rye in Alberta in 1968, 1969, and 1970 (Holmes and Blakeley 1971). Infested stems reached an average of 21 galls, mainly in the second to fourth internodes.

The range of the wheat jointworm, *Tetramesa tritici* (Fitch), includes the Canadian prairie provinces (Buntin *et al.* 2007). Wheat, barley, rye, and other grasses may be hosts.

Sap and Fluid Feeders

Aphids (Aphididae). In western Canada, the English grain aphid, *Sitobion avenae* (Fabricius) (Fig. 11), and the oat-birdcherry aphid, *Rhopalosiphum padi* (L.) (Fig. 12), are common on cereal crops. The greenbug, *Schizaphis graminum* (Rondani), and the corn leaf aphid, *Rhopalosiphum maidis* (Fitch), occur sporadically (Robinson and Hsu 1963; Migui 1996). These aphids do not overwinter in western Canada (Robinson and Hsu 1963; Kieckhefer *et al.* 1974) but rather migrate into the area in early summer. Other species of aphids found on small grain cereals in the Canadian prairies include the quackgrass aphid, *Sipha agropyrella* Hille Ris Lambers; the rose grass aphid, *Metopolophium dirhodum* (Walker); and the rusty plum aphid, *Hysteroneura setariae* (Thomas) (Robinson and Hsu 1963; Malyk and Robinson 1971*a*).

Aphid species colonize cereals in distinct patterns (Dean 1974). The greenbug feeds in dense aggregations, whereas the oat-birdcherry aphid has substantially greater distance between feeding individuals (Messina *et al.* 2002). Oat-birdcherry aphids prefer feeding at the base of the stem and on the lower leaves of seedlings (Dean 1974; Gianoli 2000), whereas the greenbug feeds preferentially on the underside of lower leaves. Greenbugs induce distinctive lesions on wheat plants (Sandström *et al.* 2000), which are associated with chlorophyll loss (Doel *et al.* 2001). English grain aphids initially feed on leaves but move to spikes when they emerge (Bakker and Robinson 1975; Wratten and Redhead 1976).

Oat-birdcherry aphids feeding on wheat seedlings trigger the release of defensive chemicals in the plant. The nature of this induction depends on the tissue infested (Gianoli

and Niemeyer 1997, 1998). In contrast, greenbug feeding makes susceptible plants more nutritional for the aphids (Sandström *et al.* 2000). The growth of oat-birdcherry aphid colonies was reduced by 50% when reared on wheat previously infested by their conspecifics (Formusoh *et al.* 1992), but the growth of greenbugs is not reduced by previous feeding by greenbugs (Messina *et al.* 2002).

The English grain aphid is able to establish colonies on plants in many of the genera of grasses, but it occurs in much larger numbers on the cereal grains (Robinson and Hsu 1963). It is regarded as one of the most injurious aphids on cereals because of its preference for feeding on the heads (Bakker and Robinson 1975), and it is among the species of aphids capable of transmitting barley yellow dwarf virus, as can the oat-birdcherry aphid.

Barley is one of the preferred hosts of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch). Many thousands of acres of late-seeded barley were destroyed by *R. maidis* in western Canada in 1955 (Robinson and Hsu 1963).

The Russian wheat aphid, *Diuraphis noxia* (Mordvilko), has also been found on cereals in Alberta and southwest Saskatchewan (Jones *et al.* 1989). Leaves may show whitish or yellowish longitudinal streaking caused by a toxin that the aphids inject during feeding. Streaks that develop in cool weather are often reddish purple from the presence of anthocyanin pigments. The lengthwise rolling of leaves forms tubes that protect aphids that are feeding on the upper leaf surface.

Plant bugs (Miridae). The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvoir), feeds on at least 19 species of grasses, including wheat (Young 1986). Adults readily feed and can survive on wheat heads when seeds are developing. The immature stages have not been observed feeding on the heads; adults appear to use wheat as a temporary food source before overwintering. Feeding by adults causes bleached areas on wheat seeds (Wise *et al.* 2000). Symptoms of plant bug damage are probably caused by the proteolytic external digestion that is used to extract nutrients from the seed (Every *et al.* 1998).

The green grass bug (*Trigonotylus coelestialium* Kirkaldy (Miridae)) can be common on cereal crops in some years. Higher numbers seem to be associated with fields where the residue from a previous year's cereal crop has been left on the surface. High numbers can cause stunting of seedling barley (Byers *et al.* 1996), wheat (Byers *et al.* 1996), and oats (Wheeler and Henry 1985). In addition to stunting, feeding on oat seedlings in a greenhouse caused mottling, as well as browning of seedling tips and dark fecal spotting of blades at higher densities (Wheeler and Henry 1985).

Stink bugs (Pentatomidae). The Say stink bug, *Chlorochroa sayi* Stål, is an occasional pest of wheat in Saskatchewan and Alberta and has also been found in oats and barley (Beirne 1972). It sucks juices from the developing kernels in wheat, causing them to shrivel (Jacobson 1965). It also causes white heads by sucking the stems just below the heads. *Chlorochroa uhleri* Stål has also been found on wheat in the prairie provinces (Beirne 1972).

Leafhoppers (Cicadellidae). Various species of leafhoppers, including the aster or six-spotted leafhopper, *Macrosteles quadrilineatus* Forbes (formerly *M. fascifrons* Stål), and the painted leafhopper, *Endria inimica* Say, can be found on cereal crops in the Canadian prairies. Small grain seedlings are a preferred early-season food source and breeding environment for aster leafhoppers arriving from the southern United States (Westdal *et al.* 1961; Westdal and Richardson 1969). Aster leafhoppers can vector aster yellows in

small grains. Symptoms of aster yellows in wheat may range from chlorotic leaf blotches to complete plant collapse (Hollingsworth *et al.* 2008). Red to purplish blotches on leaves later become necrotic. Symptoms of aster yellows and barley yellow dwarf virus in wheat can be indistinguishable (Hollingsworth *et al.* 2008). Barley is moderately to highly susceptible to infection by aster yellows (Chiykowski 1965; Westdal and Richardson 1969). Infected plants are usually stunted and yellowed and produce "sterile" heads (Westdal and Richardson 1972).

Endria inimica is the only known vector of wheat striate mosaic virus in North America. It overwinters in the egg stage and has two generations per year. The life cycle and habits of *E. inimica* in Manitoba were studied by Westdal and Richardson (1966).

Thrips (Thysanoptera). Barley thrips (*Limothrips denticornis* Haliday (Thripidae)) are one of the more common thrips found on cereal crops in the Canadian prairies. They are native to northern Europe and were first reported in North America in 1923 (Herrick 1924) and in the northern Great Plains in 1946 (Buntin *et al.* 2007). Barley thrips are frequently found on wheat (*T. aestivum* L. and *T. durum* Desf.), rye (*S. cereale* L.), barley (*H. vulgare* L.), corn (*Zea mays* L.), and many common roadside grasses. Feeding reduces pigmentation in leaves, especially the flag leaf, which can lower grain yield and quality (Post 1955). Feeding on pollen by *L. denticornis* may reduce seed germination (Oakley 1980). Both immatures and adults feed by rasping the plant and sucking up the plant juices. This causes the plant to lose colour and eventually senesce (dry up), giving the plant a bleached appearance (Bates *et al.* 1991).

The predaceous thrips, *Aeolothrips fasciatus* L., and the grass thrips, *Anaphothrips obscurus* Muller, reportedly migrate from prairie grasses onto wheat in mid-summer as grasses ripen and then back onto the grasses when the grain is cut (Arnason 1941). Species of thrips found on the Canadian prairies that have been collected from cereal crops in the United States include the flower thrips, *Frankliniella tritici* (Fitch), and the western flower thrips, *F. occidentalis* (Pergande) (Buntin and Beshear 1995). *Frankliniella tritici* is reported to have injured oats in Alberta (Beirne 1972). More studies are needed on the abundance and diversity of thrips on cereal crops in the Canadian prairies.

Mites (Acari). Several species of mites occur on cereal plants in the Canadian prairies. Wheat curl mites, *Aceria tosichella* Keifer (Acari: Eriophyidae), are only 250 μm long and rely on wind currents to passively disperse to their summer hosts by using their caudal pad to regulate dispersal time. The size of the source population is the main factor in influencing the level of mite movement (Thomas and Hein 2003). They pass through egg, two nymphal, and adult stages within 7–10 days and are a vector of wheat streak mosaic virus (Slykhuis 1953). All stages of the mite, except the egg, can transmit the virus (Slykhuis 1955; del Rosario and Sill 1958), but only nymphs can acquire it. Several strains of the wheat curl mite are known (del Rosario and Sill 1965). Their primary hosts are wheat and various grasses (Somsen and Sill 1970). High humidity and frequent rains favour their survival and increase in number (Slykhuis 1955; Somsen and Sill 1970).

The brown wheat mite, *Petrobia latens* Müller (Acari: Tetranychidae), is a non-web-spinning spider mite that is generally believed to reproduce parthenogenetically. These mites have a broad host range that includes both monocots and dicots (Jeppson *et al.* 1975). High numbers can result in a very fine mottling of leaves, which from a distance appear bronzed or yellowed (Fenton 1951). Newly emerged larvae possess three pairs of legs and turn from bright red orange to a deep brownish colour upon feeding. Later stages have

four pairs of legs, the first pair being longest, and adults are about 0.7 mm long (Fenton 1951). Brown wheat mite is the only known vector of barley yellow streak mosaic virus (Smidansky and Carroll 1996).

The mite *Tetranychus sinhai* Baker (Acari: Tetranychidae) has been observed on barley, wheat, and rye in the prairie provinces of Canada (Sinha and Wallace 1963). This mite is greenish yellow to orange, with a large dark longitudinal band on each side of its dorsum (Wallace and Sinha 1961). Feeding can cause darkening, followed by yellowing and withering from the bend of the leaf to its tip and, occasionally, crinkling of the leaf edges from below.

Parasitoids and Predators

Bracon cephi Gahan (Braconidae). *Bracon cephi* (Fig. 13) is an idiobiont ectoparasitoid of the wheat stem sawfly (*Cephus cinctus*) (Runyon *et al.* 2001). It is the only parasitoid found in significant numbers with this sawfly in the Canadian prairies (Holmes *et al.* 1963). Many other parasitoids of wheat stem sawfly are either from perennial grasses or are not common in annual crops (Morrill 1997). *Bracon cephi* is bivoltine, overwintering as a larva in a cocoon inside the stem where it parasitizes the sawfly larva (Holmes *et al.* 1963). First-generation adults emerge in late June to early July at about the same time as the wheat stem sawfly, and oviposition generally starts three weeks later. The female wasp stings the sawfly larva, paralyzing it, and then lays an egg on the larva or nearby. The *Bracon cephi* larva then consumes the sawfly larva, spins a cocoon, and pupates. Second-generation adults usually appear in mid-August and immediately start to oviposit. Parasitism occurs until freezing temperatures kill the adults. The second generation is often reduced when harvest is early (Holmes *et al.* 1963). *Bracon cephi* are capable of terminating sawfly outbreaks in localized areas (Holmes *et al.* 1963). A related species, *Bracon lissogaster* Muesebeck, has not been reported from the Canadian prairies, although it is a common parasitoid of wheat stem sawfly in Montana (Morrill 1997).

Fig. 13. *Bracon cephi*. Photo by H. Goulet.

Fig. 14. *Macroglenes penetrans*. Photo by J. Doane.

Macroglenes penetrans Kirby (Pteromalidae). *Macroglenes penetrans* (Fig. 14) is an egg–larval endoparasitoid of the wheat midge (Doane *et al.* 1989). Eggs are laid into the egg of the midge and the larva develops to the first instar stage inside the developing midge larva before fall diapause. Development continues in the spring after the host emerges and moves to just below the soil surface to pupate. Adults emerge in early July and mate, and the females move into wheat fields to search for wheat midge eggs. This species parasitizes the wheat midge throughout the prairie provinces and is an important factor in regulating wheat midge populations (Doane *et al.* 1989).

Lady beetles (Coccinellidae). Worldwide over 90% of the approximately 2,400 coccinellid species are considered beneficial because they are predators on many insect pests, particularly aphids (Iperti 1999). There are 65 species of Coccinellidae recorded in Manitoba (Wise *et al.* 2001) and 75 species in Alberta (Acorn 2007). In most habitats, a complex of coccinellids attacks aphids. In cereal crops, the complex is often affected by surrounding vegetation and the region of the prairies. The sevenspotted lady beetle, *Coccinella septempunctata* L., invaded the prairies in Manitoba in 1988 and quickly became a dominant species (Turnock *et al.* 2003). In South Dakota, *Hippodamia convergens* Guérin-Méneville, *H. tredecimpunctata* (Say), and *H. parenthesis* (Say) are commonly found in cereal crops, with *H. convergens* being the dominant species prior to the appearance of *C. septempunctata* (Elliot *et al.* 1996). A new species of lady beetle has recently been reported in the Canadian prairies. *Harmonia axyridis* Pallas (commonly known as the multicoloured Asian lady beetle) has been reported from Manitoba and Alberta (Wise *et al.* 2001; Acorn 2007). What impact this invasive species will have on current lady beetle species is unknown.

Different species of lady beetles eat different amounts of different species of aphids. Adults of *Coccinella transversoguttata* Falderman ate an average of 180 third instars of *Rhopalosiphum maidis* in 24 hours, but only 125 *Macrosiphum avenae* in a 24-hour period (Malyk and Robinson 1971*b*). As well as showing how many aphids that adults eat, Malyk and Robinson (1971*b*) provide tables showing how many aphids, among five species found in cereal crops, that second-, third-, and fourth-instar larvae of four species of lady beetles eat. The number of aphids consumed increased with each coccinellid moult.

Lacewings (Neuroptera: Chrysopidae, Hemerobiidae). Species of both green (Chrysopidae) and brown (Hemerobiidae) lacewings may occur in cereal crops, with green lacewings being the most common (McEwan *et al.* 2001). Lacewing larvae are voracious predators of aphids and are often referred to as aphid lions.

Conclusions

More research is needed on the biodiversity and abundance of insects in cereal fields in the Canadian prairies. The biodiversity of Thysanoptera in cereal crops is not well studied, and little research has been done on groups such as frit flies (Chloropidae) and jointworms (Eurytomidae).

Insect-resistant varieties of cereals have been, and continue to be, developed, which can lead to future changes in insect populations in cereal crops. The adoption of reduced and zero tillage systems can also alter insect populations (reviewed by Stinner and House 1990). Changes in weed management practices may affect the biodiversity and behaviour of insects found in cereal fields. Army cutworms in a wheat field with tansy mustard, *Descurainia pinnata* (Walt) Britt., which these cutworms prefer to grain crops, did not

feed on the wheat crop unless the weeds were removed (Capinera 2005). Fewer and less abundant additional plant species may also result in decreased insect diversity in fields of cereal crops.

This chapter focused on insects that feed directly on cereal crops, but clearly the habitat in a cereal field is greater than just the crop and may be affected by many agronomic practices and future climate changes. Studies on the effects of such habitat alterations in isolation, as well as when combined, on populations of existing and potential pests and beneficial insects, are other avenues for future research.

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