Chapter 8
Insects of Canola, Mustard, and Flax in Canadian Grasslands

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Abstract. Oilseed crops, particularly canola, *Brassica napus* L., and *B. rapa* L., are now a major part of the prairie landscape in Canada. A diverse assemblage of arthropods can be found in areas devoted to oilseed crop production, either feeding on a resource provided by the crop, or feeding on other insects that have been attracted to these areas. Some insects prefer to feed on other plants that are growing in fields of oilseed crops and will feed more readily on the oilseed crop only when the more preferred host diminishes or is destroyed. The principal orders of insects found in fields of oilseed crops include Orthoptera, Thysanoptera, Hemiptera, Coleoptera, Lepidoptera, Diptera, and Hymenoptera. Several species of spiders and mites also comprise a substantial component of the arthropod biodiversity of oilseed crops. Many other species of insects that are not discussed in this chapter include species that feed on crop residue, seeds on the soil surface from various plants, or soil invertebrates. More research is needed to fully understand the diversity of the insect community associated with oilseed crops in the Canadian prairies.

Résumé. Les cultures d'oléagineux — notamment le canola, le *Brassica napus* L. et le *B. rapa* L. — constituent aujourd'hui un élément majeur du paysage des prairies canadiennes. On trouve dans les zones consacrées ces cultures une grande variété d'arthropodes qui dépendent des ressources qu'elles produisent, ou d'autres insectes attirés par ces ressources. Certains insectes préfèrent se nourrir d'autres plantes présentes dans les champs d'oléagineux et ne s'attaquent aux oléagineux que lorsque leur hôte préféré se raréfie ou est détruit. Les ordres principaux d'insectes que l'on trouve dans les champs d'oléagineux sont les orthoptères, les thysanoptères, les hémiptères, les coléoptères, les lépidoptères, les diptères et les hyménoptères. Plusieurs espèces d'araignées et d'acariens forment également une part appréciable de la biodiversité des arthropodes des cultures d'oléagineux. Beaucoup d'autres insectes sont passés sous silence dans le présent chapitre, notamment ceux qui se nourrissent de résidus de culture, de graines laissées à la surface du sol par diverses espèces de plantes, ou d'invertébrés du sol. De plus amples recherches seront requises pour parfaire nos connaissances de la diversité des communautés d'insectes vivant dans les cultures d'oléagineux des prairies canadiennes.

Description of Habitat

In the early years of agricultural development on the Canadian prairies, oilseed crops were not a major part of the prairie landscape. However, with the development of canola, the production of oilseed *Brassica* (Brassicaceae) crops has now expanded to become a major

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component of the prairie landscape (Table 1). Canola is the name applied to oilseed rapes (*Brassica napus* L. and *B. rapa* L.) that have been bred to produce seed that is low in erucic acid and glucosinolate. The canola cultivars were developed because erucic acid was a suspected health hazard for humans and glucosinolates caused the meal to be unpalatable or toxic to farm animals.

Oilseed *Brassica* crops grow best in cool, short-season climates (Thomas 2002). This makes them very suitable for production on the Canadian prairies. Currently, annual forms of *B. napus* and *B. rapa* are sown in the spring in the Canadian prairies. Winter-dormant, biennial forms are sown in the late summer in some regions such as central and southern Europe. If winter-dormant varieties are adopted in Canada, their earlier development will result in insects encountering canola at more advanced stages of development and may alter the interactions between the insect and host (Dosdall and Stevenson 2005).

Reduced and zero tillage methods of growing crops have become more common in Canada, with the resulting differences in habitat affecting insect–*Brassica* interactions (Dosdall *et al*. 1999*b*). In zero-tillage systems, organic residues accumulate from the previous crop, which can cause temperature reductions at or near the soil surface early in the growing season (Kasper *et al*. 1990). Zero-till systems also have less evaporation and higher soil moisture levels than occur in conventional systems (Lafond *et al*. 1992; Borstlap and Entz 1994). In addition to tillage systems, adoption of new cultivars, different seeding rates, and weed management practices can all affect the insect communities found on oilseed *Brassica* crops. Additional information on the production of canola in Canada is available through the Canola Council of Canada (see http://www.canola-council.org/).

Mustards currently constitute a minor component of the oilseed brassicaceous crops grown in Canada. Yellow mustard (*Sinapis alba* L.), oriental mustard (*Brassica juncea* (L.) Czern and Coss), and brown mustard (*Brassica juncea* (L.) Czern.) are the three main types grown in the country. Oriental mustard seed is often used to produce spicy cooking oils, whereas brown mustard is used to prepare specialty mustards, such as Dijon. Yellow mustard is used in traditional hot dog mustards. Mustard is produced primarily in the semi-arid regions of western Canada (Johnston *et al*. 2002). In recent years, cultivars of *B. juncea* with canola-like qualities have been grown in the Canadian prairies. *Brassica juncea* is more tolerant than canola of drought, heat, and frost. Additional information on growing mustard and its uses is available from the Saskatchewan Mustard Development

Table 1. Hectares seeded to canola and rapeseed (*Brassica napus* and *B. rapa*) in western Canada from 1945 to 2005 (Statistics Canada 2009).

Year	Hectares seeded to canola in western Canada
1945	5,000
1955	55,800
1965	580,700
1975	1,800,900
1985	2,712,000
1995	5,261,000
2005	5,301,300

Commission (see http://www.saskmustard.ca/) and Agriculture and Agri-Food Canada (http://sea.agr.gc.ca/supply/3311_e.htm).

Flax, *Linum usitatissimum* L. (Linaceae), is grown either for seed (oilseed flax) or for fibre (linen flax) (Johnston *et al*. 2002). The cultivars grown and the production practices used differ depending on the intended use of the flax crop. In the Canadian prairies, oilseed flax cultivars are grown almost solely, although flax fibre from these oilseed varieties can be processed at plants in Winkler, Manitoba or Canora, Saskatchewan. No differences in insect diversity are known to occur between flax grown for seed or for fibre (Wise and Soroka 2003). In the Canadian prairies, flax is seeded in the spring. Additional information on growing flax and its uses is available from the Flax Council of Canada (see http://www.flaxcouncil.ca/english/index.jsp?p=home).

Oilseed crops other than canola, mustard, flax, and sunflowers (the latter being described in Chapter 7) are much less widely grown and are a minor part of the prairie landscape. Safflower (*Carthamus tinctorius* L. (Asteraceae)) is a thistle-like annual herbaceous plant with long, sharp thorns that has been grown commercially in the Great Plains since the late 1950s (Knowles 1958). Feeding by grasshoppers (Johnson and Mundel 1987; Mundel and Johnson 1987) and the seasonal distribution of flower thrips (*Frankliniella tritici* (Fitch)) and onion thrips (*Thrips tabaci* Linderman) each have been studied in relation to this crop (Weiss and Beshear 1987). Little information is available on the insect fauna of other minor oilseed crops, for example, camelina (*Camelina sativa* (L.)) (Brassicaceae).

Some of the insects that are now common on oilseed crops in Canada are indigenous species that were originally restricted to feeding on native species of plants. However, many other insects on these crops are species that have been accidently introduced into North America.

This chapter provides an account of the more common insects encountered in canola, mustard, and flax crops in the Canadian prairies. Insects have been organized into feeding guilds to demonstrate and compare those insects that compete for a given food source (e.g., foliage, sap, or other insects). For purposes of this publication, a guild is defined as a group of species that feed on the same plant resource in a similar way.

Insects on Canola and Mustard

The roots, foliage, and sap of canola and mustard plants all have a variety of both native and introduced insects that feed on them (Table 2). Root and foliage feeding guilds are composed of insects that feed on many families of plants (generalists) and those that feed only on plants in the family Brassicaceae (specialists). Sap feeders on canola and mustard are primarily generalists, except for some species of aphids.

Root Feeders

A complex of insect herbivores attacks below-ground portions of canola and mustard crops. The principal species that feed on root tissue include root maggots (Diptera: Anthomyiidae), flea beetles (Coleoptera: Chrysomelidae), and cutworms (Lepidoptera: Noctuidae). For each of these root-feeding insect complexes, it is the larval stage that consumes root tissue.

Root maggot complex (Diptera: Anthomyiidae). Five species of root maggots in the genus *Delia* occur in canola in the grasslands (Liu and Butts 1982). The turnip maggot, *Delia floralis* (Fallén), is often dominant in northern regions of Alberta and Saskatchewan

Table 2. Most common insect species, their origins, and host specificities for each feeding guild associated with canola and mustard.

Species	Family	Stage Feeding on Plant[1]	Origin	Host Specificity
		Root Feeders		
Delia radicum	Anthomyiidae	Larvae	Introduced	Specialist
Delia floralis		Larvae	Native	Specialist
Delia platura		Larvae	Native	Generalist
Delia planipalpus		Larvae	Native	Specialist
Delia florilega		Larvae	Introduced	Generalist
Phyllotreta cruciferae	Chrysomelidae	Larvae	Introduced	Specialist
Phyllotreta striolata		Larvae	Introduced	Specialist
Euxoa ochrogaster	Noctuidae	Larvae	Native	Generalist
Euxoa messoria		Larvae	Native	Generalist
Feltia jaculifera		Larvae	Native	Generalist
Agrotis orthogonia		Larvae	Native	Generalist
		Foliage and Seed Feeders		
Melanoplus bivittatus	Acrididae	Nymphs and adults	Native	Generalist
Melanoplus sanguinipes		Nymphs and adults	Native	Generalist
Phyllotreta cruciferae	Chrysomelidae	Adults	Introduced	Specialist
Phyllotreta striolata		Adults	Introduced	Specialist
Entomoscelis americana	Chrysomelidae	Larvae and adults	Native	Specialist

Lytta nuttalli	Meloidae	Adults	Native	Generalist
Epicauta ferruginea		Adults	Native	Generalist
Ceutorhynchus obstrictus	Curculionidae	Larvae and adults	Introduced	Specialist
Plutella xylostella	Plutellidae	Larvae	Introduced	Specialist
Mamestra configurata	Noctuidae	Larvae	Native	Generalist
Discestra trifolii	Noctuidae	Larvae	Native	Generalist
Autographa californica	Noctuidae	Larvae	Native	Generalist
Loxostege sticticalis	Crambidae	Larvae	Native	Generalist
		Sap Feeders		
Lygus lineolaris	Miridae	Nymphs and adults	Native	Generalist
Lygus elisus		Nymphs and adults	Native	Generalist
Lygus borealis		Nymphs and adults	Native	Generalist
Lygus keltoni		Nymphs and adults	Native	Generalist
Lipaphis pseudobrassicae	Aphidae	Nymphs and adults	Introduced	Specialist
Brevicoryne brassicae	Aphidae	Nymphs and adults	Introduced	Specialist
Myzus persicae	Aphidae	Nymphs and adults	Introduced	Generalist
Macrosteles quadrilineatus	Cicadellidae	Adults	Introduced	Generalist
Frankliniella tritici	Thripidae	Nymphs and adults	Native	Generalist

[1] Stage that feeds on the plant resource defining the feeding guild (root feeders, foliage and seed feeders, or sap feeders).

(Broatch 1993; Soroka *et al*. 2004), and the cabbage maggot, *Delia radicum* (L.), has a more southerly distribution (Griffiths 1986*a*, 1986*b*, 1991; Turnock *et al*. 1992). *Delia planipalpus* (Stein) usually occurs in low densities across western Canada (Griffiths 1991), but the seedcorn maggot, *D. platura* (Meigen), and the bean seed maggot, *Delia florilega* (Zetterstedt), can be relatively abundant (Soroka *et al*. 2004; Broatch *et al*. 2006; Hummel *et al*. 2009). *Delia radicum*, *D. floralis*, and *D. planipalpus* are primary feeders on roots, consuming cells of the taproot phloem, periderm, and xylem parenchyma. *Delia platura* and *D. florilega* are considered secondary feeders that attack damaged roots (Read 1958; McDonald and Sears 1992; Griffiths 1993; Soroka *et al*. 2004). Root maggot (Fig. 1) infestations can be associated with leaf and stem wilting, poor seed set, and in severe infestations, killed plants that have completely severed roots (Griffiths 1986*a*; McDonald and Sears 1992).

Herbivory by root maggots appears to have increased substantially in recent years. The percentage of canola plants with evidence of larval feeding damage increased from 12% in Manitoba, 19% in Saskatchewan, and 91% in Alberta in the 1980s (Liu 1984; Burgess and Weeger 1988*a*; Turnock *et al*. 1992) to 96%, 96%, and 100%, respectively, in the late 1990s (Soroka *et al*. 2004).

Infestation levels of root maggots are related to oilseed crop species, geographical region, and environmental variables. Plants of *B. rapa* are more susceptible to root maggot oviposition and are damaged to a greater degree than are *B. napus* and *B. juncea* plants, and plants of *S. alba* are resistant to root maggots (Dosdall *et al*. 1994, 2000). Greatest root maggot herbivory and damage over the largest geographical area has been found in western and northwestern Alberta, although localized areas with severely damaged roots can occur in Saskatchewan and Manitoba (Soroka *et al*. 2004). High mean temperatures in July and August often result

Fig. 1. Root maggot larva in canola root. Photo by J. Gavloski.

in reduced root maggot infestations in the following year (Soroka *et al*. 2004). In addition, root maggot infestations are usually greatest in years of relatively high precipitation (Griffiths 1986*b*; Turnock *et al*. 1992). However, the relationship between increased root maggot herbivory and high precipitation is not always evident (Soroka *et al*. 2004).

Flea beetle larvae (Coleoptera: Chrysomelidae). Several species of flea beetles are associated with oilseed *Brassica* crops in the Canadian grasslands, including the crucifer flea beetle, *Phyllotreta cruciferae* (Goeze); the striped flea beetle, *P. striolata* (Fabricius); the cabbage flea beetle, *P. albionica* (LeConte); the western black flea beetle, *P. pusilla* Horn; the horseradish flea beetle, *P. armoraciae* (Koch); *P. bipustulata* (F.); *P. robusta* LeConte; *P. oregonensis* (Crotch); *Chaetocnema protensa* LeConte; the threespotted flea beetle, *Disonycha triangularis* (Say); and the hop flea beetle, *Psylliodes punctulata* Melsheimer (Burgess 1977, 1980*a*; Bok Cho *et al*. 1994). Among these species, *P. cruciferae* and *P. striolata* are most abundant and damaging to crops of canola and brown mustard (*B. juncea*) (Burgess 1982*a*; Lamb 1989), although white mustard (*S. alba*) is resistant to flea beetle infestation (Bodnaryk and Lamb 1991). *Phyllotreta striolata* feeds on a wider range of host plants than does *P. cruciferae* (Hicks and Tahvanainen 1974), and larvae of both species feed on root hairs of canola (Westdal and Romanow 1972).

Cutworms (Lepidoptera: Noctuidae). A number of subterranean and surface-feeding cutworm species attack oilseed crops in the Canadian grasslands. The redbacked cutworm, *Euxoa ochrogaster* (Guenée); the darksided cutworm, *E. messoria* (Harris); the dingy cutworm, *Feltia jaculifera* (Guenée); and the pale western cutworm, *Agrotis orthogonia* Morrison, are considered to be most damaging (Turnock *et al*. 1993; Thomas 2002). Several additional cutworm species can be associated with oilseeds in densities that are not considered to be economically significant. The true species diversity of this group has not been conclusively determined. *Feltia jaculifera* is a complex of several morphologically indistinguishable sibling species (Byers *et al*. 1990); about 15 species have been identified from canola crops in southern Manitoba with abundance patterns that varied considerably among years (Turnock *et al*. 1993). Reproduction for some species, such as redbacked cutworms, may be enhanced by high temperatures and low precipitation in late summer (Alberta Agriculture and Rural Development 2010).

Subterranean cutworm species consume root tissue, but larvae may also consume foliage. Most species overwinter as eggs that hatch in spring, with greatest plant damage inflicted in the rosette stage of development (Philip and Mengersen 1989).

Foliage and Seed Feeders

From the time canola plants emerge until mature plants are harvested, many defoliating insects may feed on leaf tissue or on tissues of the buds, flowers, pods, and seeds. Those that are most common and most studied in this feeding guild generally belong to the orders Coleoptera and Lepidoptera (Lamb 1989). Species in other insect orders, such as Orthoptera, may also occasionally be prevalent on canola but have not been well studied in this habitat.

Flea beetles - *Phyllotreta* spp. (Coleoptera: Chrysomelidae). Of the species of flea beetles that feed on oilseed *Brassica* crops, only *P. cruciferae* and *P. striolata* (Fig. 2) are economic pests. Both of these flea beetles are alien, invasive species in North America. *Phyllotreta cruciferae* was first recorded in Canada in 1923 at Agassiz, British Columbia (Burgess 1977), and within 20 years became a serious pest of cultivated crucifers on the prairies. *Phyllotreta striolata* apparently was introduced to North America prior to 1700 and was present in Canada from the Atlantic provinces to British Columbia by the early 1900s (Burgess 1977; Bain and LeSage 1998).

Both of the economically important species of flea beetles overwinter as adults, usually beneath hedges or groves of trees, but *P. cruciferae* can overwinter in the soil in fields if green food plants are available there until cool fall weather sets in (Burgess 1977). These species become active with the arrival of warm sunny weather in the spring (Burgess 1977; Lamb 1983; Ulmer and Dosdall 2006*a*). They feed most actively when the weather is sunny, warm, and dry; cool, damp weather reduces the intensity of attack and aids plant growth (Burgess 1977). Adults feed on the cotyledons and slender stems of seedling cruciferous plants and continue to feed on the leaves as the plant develops (Feeny *et al*. 1970). Feeding by flea beetles typically consists of small holes or pits in the epidermis of leaves. Although the initial feeding does not penetrate the leaf completely, tissues below the injury eventually dry up and break or fall out, giving a shot-hole appearance (Westdal and Romanow 1972; Brandt and Lamb 1993).

Red turnip beetle - *Entomoscelis americana* Brown (Coleoptera: Chrysomelidae). The red turnip beetle (Fig. 3) is native to North America, with most of its range occurring between latitudes 45° N and 68° N (Gerber 1989). Larvae and adults feed on the foliage of plants in the family Brassicaceae. This northern species undergoes most of its growth and development in spring. They overwinter as eggs and hatch in April and early May, shortly after the snow has melted (Gerber and Lamb 1982). Larval development is normally completed by the end of May.

Fig. 2. Striped flea beetle, *Phyllotreta striolata*, on canola. Photo by J. Gavloski.

Larvae grow and develop rapidly in the spring, even though the temperature threshold for development is near 10 °C and mean daily temperatures are <10 °C during most of the development period (Lamb and Gerber 1985). Two adaptations likely account for this rapid larval development under cool conditions. Larvae apparently elevate body temperature by behavioural thermoregulation. During cool periods of the day, they usually bask singly or in aggregations in fully exposed areas on the soil surface, host plant, or plant litter. The elevation of body temperature was estimated as equivalent to adding 5–6 °C to the maximum daily air temperature (Lamb and Gerber 1985). In addition, larvae are black with no metallic sheen, which maximizes the absorption of radiant heat.

Adults emerge during the first three weeks of June and may feed on rapeseed, canola, and mustard seedlings (Gerber 1976). At the end of June, adults enter the soil to aestivate for about one month. They reappear in late July and August, and mate and lay eggs until late October (Gerber 1987).

Blister beetles (Coleoptera: Meloidae). Both the Nuttall blister beetle, *Lytta nuttalli* Say, and *Epicauta ferruginea* Say (Meloidae) feed on canola in the Canadian prairies (Burgess 1983). *Lytta nuttalli* feeds on all above-ground parts of canola plants, whereas *E. ferruginea* may feed exclusively on the blossoms.

Lytta nuttalli commonly feeds on caragana (*Caragana arborescens* Lam.) on the Canadian prairies, and larger populations in fields of canola often occur near caragana hedges. These beetles are gregarious and may assemble in clusters on their food plants (Church and Gerber 1977).

Fig. 3. Red turnip beetles, *Entomoscelis americana*. Photo by J. Gavloski.

In addition to being observed feeding on canola, *E. ferruginea* has been collected from plots of commercial mustard in the Canadian prairies (Burgess 1983). Larvae of the genus *Epicauta* feed on grasshopper eggs, and populations of *Epicauta* tend to fluctuate with those of their grasshopper hosts (Church and Gerber 1976).

Cabbage seedpod weevil - *Ceutorhynchus obstrictus* Marsham = *Ceutorhynchus assimilis* Paykull (Coleoptera: Curculionidae). The cabbage seedpod weevil (Fig. 4) is native to Europe and was first recorded in the United States in the state of Washington in 1936 (Baker 1936). This species was not reported from the Prairie Ecozone of western Canada until 1995, when it was first detected in southern Alberta (Butts and Byers 1996). It is now established in Alberta and Saskatchewan (Dosdall *et al*. 2002) and was also found in Quebec in 2000 (Brodeur *et al*. 2001) and Ontario in 2001 (Mason *et al*. 2004).

Adults overwinter in debris in protected areas such as shelterbelts and ditches. They emerge in April and May, when air temperature reaches 15–18 °C, to feed on buds and flowers of early flowering brassicaceous hosts such as wild mustard, *Sinapis arvensis* L.; flixweed, *Descurainia sophia* L.; and hoary cress, *Lepidium draba* L. (Fox and Dosdall 2003; Ulmer and Dosdall 2006*b*). In early to mid-June, they migrate to canola fields at the bud to early flower stage. There is significant clustering of adults along field edges in the early stages of movement into canola, followed by more homogeneous distribution as canola reaches the mid- to late flowering and pod enlargement stages (Dosdall *et al*. 2006). Adults feed on buds and flowers and can destroy the vascular tissue of buds, causing “bud blasting” (Dosdall *et al*. 2001). Mated females lay single eggs in immature pods (i.e., <50 mm long) through punctures they make with their mouthparts (Fox and Dosdall 2003; Dosdall and

Fig. 4. Cabbage seedpod weevil, *Ceutorhynchus obstrictus*. Photo by L. Dosdall.

Moisey 2004). The three larval instars usually consume three to six seeds before chewing an exit hole through the pod and dropping to the ground to pupate in the soil.

Oilseed *Brassica* crops differ in susceptibilities to cabbage seedpod weevil. *Brassica rapa* and *B. napus* are more susceptible than *B. juncea*, whereas *S. alba* is virtually immune to attack (Kalischuk and Dosdall 2004; Cárcamo *et al*. 2007).

Ceutorhynchus neglectus Blatchley also feeds on canola in western Canada, although leaves and pods of flixweed, *D. sophia*, are preferred by adults as feeding sites (Dosdall *et al*. 1999*a*). Adults will feed on canola seedlings, including the cotyledons, particularly when flixweed is unavailable.

Diamondback moth - *Plutella xylostella* L. (Lepidoptera: Plutellidae). Larvae of diamondback moth (Fig. 5) feed only on Brassicaceae in North America (Talekar and Shelton 1993), although a localized population developed on sugar snap pea (*Pisum sativum* L.) in Kenya (Löhr 2001). Newly hatched larvae crawl to the lower surface of the leaf and bore through the epidermis (Harcourt 1957) to tunnel within or "mine" the leaf tissue. Typical mines are shallow and appear as numerous white markings on the leaf. Late first-instar larvae emerge from the mines, spin a few protective threads, and moult beneath them, selecting a sheltered site such as a depression on the leaf or near an edge that is slightly curled. Older larvae feed on the lower leaf surface and usually consume all tissue except the wax layer on the upper surface to create a "window" in the leaf (Talekar and Shelton 1993). Late in the season when the leaves become senescent, larvae may feed on pods. There are four larval instars. Adults feed on water drops or dew and are short lived (Talekar and Shelton 1993).

Fig. 5. Larva (right) and pupa (left) of diamondback moth, *Plutella xylostella,* on canola. Photo by J. Gavloski.

Increased temperatures can lead to the production of more generations per season, and increased rainfall can lead to increased incidence of fungal disease (Talekar and Shelton 1993), direct mortality of small larvae (Beirne 1971), or possibly disruption of mating (Tabashnik and Mau 1986). The activity of the moths is reduced by cool and cloudy weather, and if such weather persists, the females may die before they have finished egg laying (Beirne 1971). Successful overwintering of diamondback moth is rare in western Canada (Dosdall 1994). Populations observed in Canada probably migrate from the south of the United States (Dosdall *et al*. 2004).

Bertha armyworm - *Mamestra configurata* Walker (Lepidoptera: Noctuidae). Larvae of this indigenous species (Figs. 6 and 7) climb and feed on a variety of native broad-leaved plants. Since European settlement, it has expanded its host range to include sweet clover, alfalfa, flax, rape, and canola (Mason *et al*. 1998*a*). Larvae are most active at night. The first four larval instars feed mainly on foliage, whereas the final two instars prefer leaf material, but will also feed on developing pods of maturing canola and flax plants (Bracken 1984). Most (70–80%) of the food eaten by larvae occurs in the final instar (Bailey 1976).

Moth flight occurs from early June to early August (Turnock 1987). Females oviposit at night, laying clusters of eggs on the underside of host plant leaves. Females strongly prefer to lay eggs on leaves that have eggs of a different female than on leaves without eggs (Ulmer *et al*. 2003).

Clover cutworm - *Discestra trifolii* Hufnagel (Lepidoptera: Noctuidae). Clover cutworm is a climbing species and is widely distributed throughout the northern hemisphere (Struble and Swailes 1975). It is bivoltine in the Canadian prairies (Ayre and Lamb 1990). Larvae feed on numerous species of plants, including field crops such as sunflowers, canola, and flax. Several types of vegetables and some species of deciduous trees are also hosts of *D. trifolii* (Tietz 1972).

Other Lepidoptera on canola and mustard. Beet webworm, *Loxostege sticticalis* (L.), will feed on canola and mustard (Beirne 1971). In addition, larvae of alfalfa looper (*Autographa californica* Speyer (Noctuidae)), thistle caterpillar (*Vanessa cardui* L. (Nymphalidae)), armyworm (*Mythimna unipuncta* Haworth (Noctuidae)), and variegated cutworm (*Peridroma saucia* Hübner (Noctuidae)) have all been observed feeding on canola (Gavloski 2001). These caterpillars have broad host ranges and only occasionally are observed feeding on canola.

Sap Feeders

***Lygus* spp. (Heteroptera: Miridae)**. The assemblage of lygus bugs in oilseed crops on the prairies includes four common species, depending on the region: *Lygus lineolaris* (Palisot de Beauvois), *L. elisus* Van Duzee, *L. borealis* (Kelton), and *L. keltoni* (Schwartz). Two incidental species also occur: *L. rubrosignatus* Knight and *L. solidaginis* (Kelton) (Schwartz and Foottit 1992*a*, 1992*b*, 1998). *Lygus lineolaris* (Fig. 8) has a wide geographical range, from Alaska to El Salvador (Schwartz and Foottit 1998). It is the dominant species in the more humid regions of the prairies (Manitoba and the Peace River region of Alberta and British Columbia), although *L. elisus* and *L. borealis* can also be common in these regions. In drier areas of Saskatchewan, *L. elisus* is more dominant (Schwartz and Foottit 1992*b*). In southern Alberta, *L. keltoni* or *L. elisus* can be dominant, with *L. borealis* less common and *L. lineolaris* rare (Cárcamo *et al*. 2002). No studies have been done that compare the species composition on canola with that on various mustards, such as *S. alba*.

Fig. 6. Larva of bertha armyworm, *Mamestra configurata*, on canola pod. Photo by J. Gavloski.

Fig. 7. Larvae of the bertha armyworm, *Mamestra configurata*. Photo by J. Gavloski.

Lygus bugs can reach pest status in canola and have been the subject of several applied studies (e.g., Butts and Lamb 1991). In northern regions, lygus bugs will feed on dicotyledonous weeds and then disperse to canola fields, where they complete one generation. In southern regions, the first generation completes development on weeds or alfalfa. The new generation of adults will disperse to canola, where they can complete a second generation that can potentially damage late-maturing canola before they move to other hosts (any late-maturing dictotyledonous species) to feed prior to dispersing to tree shelters or road margins to overwinter.

Lygus bugs feed on the growing tip of seedlings and reproductive structures (buds, flowers, and developing seeds) of mature plants. On canola, they cause seed shrinkage that reduces weight and oil content. Feeding during the early pod stage can reduce yields at thresholds of one to two adults per sweep with a 38-cm-diameter sweep net (Wise and Lamb 1998). However, plants at earlier stages of development can compensate for feeding damage, particularly when growing under ideal conditions.

Aphids (Homoptera: Aphidae). The cabbage aphid (*Brevicoryne brassicae* (L.)), the turnip aphid (*Lipaphis pseudobrassicae* (Davis) = *Lipaphis erysimi* (Kaltenbach)), and the green peach aphid (*Myzus persicae* (Sulzer)) are components of the cosmopolitan assemblage of aphids found in *Brassica* crops in many parts of the world and are expected to occur in canola in Canada. *Brevicoryne brassicae* has been reported in cabbage (Robinson and Bradley 1965), and *Brassica* crops are listed within its host range in Foottit's (1992) entry as an insect of the Canadian fauna. They overwinter as eggs in the stems of wild or weedy brassicaceous plants and annually recolonize canola fields. The cabbage aphid

Fig. 8. *Lygus lineolaris*. Photo by H. Goulet.

prefers to congregate on flowers, whereas the green peach aphid prefers seedlings and the lower leaves of older plants. Several overlapping generations can be produced during the season, with winged individuals produced when overcrowding occurs. Aphids do not often reach pest populations in canola in Canada because peak populations and feeding occur in August when pod formation is complete. However, populations of *L. pseudobrassicae* have occasionally resulted in insecticide applications in canola (Gavloski 2003). Some localized plant stunting and discoloration can occur at the site of feeding.

Leafhoppers (Homoptera: Cicadellidae). There are over 1,200 species of leafhoppers in Canada (Maw 2000), but information on their diversity and abundance in prairie agroecosystems is limited. The few published reports have focused on species of economic importance that can transmit diseases. Olivier *et al*. (2007) found 35 species by sweeping canola fields in Saskatchewan from 2001 to 2005, including the aster leafhopper, *Macrosteles quadrilineatus* (Forbes); *Neokolla hieroglyphica* (Say); *Scaphytopius acutus* (Say); *Balclutha* sp. (Kirkaldy); *Gyponana* sp. (Germar); *Psammotettix* sp. (Haupt); *Euscelis maculipennis* (DeLong and Davidson); *Diplocolenus configuratus* (Uhler); *Sorhoanus ulheri* (Oman); *Ceratagalia humilis* (Kirkaldy); and *Amplicephalus inimicus* (Say). These species were highlighted because of their potential to vector diseases and, except for *Balclutha* sp. and *M. quadrilineatus*, occurred in low numbers. Most abundant species of leafhoppers are thought to increase their populations by passive dispersal on wind currents that originate in the southern United States. *Macrosteles quadrilineatus* (Fig. 9) has been studied in greater detail (Westdal *et al*. 1961) because of its extensive host range (over 300 species of plants) and potential to transmit aster yellows in many crops, including canola,

Fig. 9. *Macrosteles quadrilineatus*. Photo by C. Olivier.

flax, carrots, and others. This species is also known to overwinter to some extent in Canada in the egg and adult stage (Westdal *et al*. 1961; Olfert *et al*. 2004).

Thrips (Thysanoptera): Nine species of thrips have been collected from canola fields in Saskatchewan (Burgess and Weegar 1988*b*). Of these, the flower thrips, *Frankliniella tritici* (Fitch); the onion thrips, *Thrips tabaci* Linderman; and *T. vulgatissimus* were collected in largest numbers, constituting 70%, 15%, and 13% of the total thrips examined, respectively. One of the nine species, *Aeolothrips fasciatus* L., is facultatively predaceous and also feeds on pollen (Heming 1985).

Frankliniella tritici occurred mainly in fields of flowering canola and quickly disappeared from individual canola plants once the last flowers disappeared (Burgess and Weegar 1988*b*). Flower thrips probably do not overwinter in the Northern Great Plains (Weiss and Beshear 1987). Populations likely establish anew each year by migrants carried on air trajectories from the south (Burgess and Weegar 1988*b*).

Insects on Flax

Most of the insects of greatest abundance and concern on flax are native species (Table 3). The majority are also generalist feeders. Although larvae of Lepidoptera represent the most diverse group of insects commonly associated with flax, they only occasionally occur at densities that are of economical concern.

Root Feeders

The principal subterranean species of arthropod herbivores on flax include cutworms (Lepidoptera: Noctuidae) and wireworms (Coleoptera: Elateridae). For each of these root-feeding insect complexes, it is the larval stage that consumes root tissue.

Cutworms. Several species of root and surface feeding cutworm larvae can occur, and sometimes become abundant, in flax. The most common species in flax in the Canadian grasslands include the pale western cutworm, *Agrotis orthogonia*; the redbacked cutworm, *Euxoa ochrogaster*; and the early cutworm, *Euxoa tristicula* Morrison (Parker *et al*. 1921; King 1926; Philip 1977; Flax Council of Canada 2008). Outbreaks of cutworm larvae in flax are generally localized and consist of a single species (Wise and Soroka 2003).

Most species of cutworms in flax overwinter as eggs laid in loose soil in the late summer to autumn (Wise and Soroka 2003). Eggs hatch in spring and the polyphagous cutworm larvae feed on weeds before flax seedlings emerge (Wise and Soroka 2003).

Wireworms. Wireworms, or click beetles, are a diverse family in western Canada. Although many native species occur in grasslands, three introduced species are often of greatest economic importance: the lined click beetle, *Agriotes lineatus* (L.); the dusky wireworm, *Agriotes obscurus* (L.); and the common click beetle, *Agriotes sputator* L. (MacKenzie *et al*. 2008). Wireworms have a short-lived adult phase that seldom causes substantial crop damage. However, larvae are more damaging and can often persist in the soil for several years, feeding on the roots of host plants and causing significant reductions in yield and quality.

Foliage and Seed Feeders

Grasshoppers and larvae of several species of Lepidoptera are the main insects that feed on foliage and seeds of flax.

Grasshoppers (Orthoptera: Acrididae). Species of grasshopper that feed on flax typically are highly migratory and feed on flax only after other food sources become scarce (Wise and Soroka 2003). The twostriped grasshopper, *Melanoplus bivittatus* Say, is the most common species that periodically damages flax by feeding on flowers and buds or by severing the capsules (Shotwell 1941).

Variegated fritillary - *Euptoieta claudia* Cramer (Lepidoptera: Nymphalidae). Adults of the variegated fritillary (Fig. 10) are migratory, and populations in the Canadian prairies consist of new southern immigrants every spring (Klassen *et al*. 1989). Larvae (Fig. 11) can appear sporadically in flax. Preferred host plants in the Canadian prairies include violets,

Table 3. Most common insect species, their origins, and host specificities for each feeding guild associated with flax.

Species	Family	Feeding Stage on Plant[1]	Origin	Host Specificity
		Root Feeders		
Euxoa ochrogaster	Noctuidae	Larvae	Native	Generalist
Euxoa tristicula		Larvae	Native	Generalist
Agrotis orthogonia		Larvae	Native	Generalist
		Foliage and Seed Feeders		
Melanoplus bivittatus	Acrididae	Nymphs and adults	Native	Generalist
Euptoieta claudia	Nymphalidae	Larvae	Native	Generalist
Mamestra configurata	Noctuidae	Larvae	Native	Generalist
Discestra trifolii	Noctuidae	Larvae	Native	Generalist
Heliothis ononis	Noctuidae	Larvae	Native	Specialist
Loxostege sticticalis	Crambidae	Larvae	Native	Generalist
		Sap Feeders		
Lygus lineolaris	Miridae	Nymphs and adults	Native	Generalist
Macrosiphum euphorbiae	Aphididae	Nymphs and adults	Native	Generalist
Macrosteles quadrilineatus	Cicadellidae	Nymphs and adults	Introduced	Generalist

[1] Stage that feeds on the plant resource defining the feeding guild (root feeders, foliage and seed feeders, or sap feeders).

Fig. 10. Adult of variegated fritillary, *Euptoieta claudia*. Photo by J. Gavloski.

Fig. 11. Larva of variegated fritillary, *Euptoieta claudia*. Photo by J. Gavloski.

pansies, and cultivated flax (Klassen *et al*. 1989). In flax, larvae feed on foliage, but later may clip off the bolls (Gavloski 2001).

Bertha armyworm. This species was first observed doing substantial feeding on flax near Moose Jaw, Saskatchewan, in 1922 (King 1928). Until about 1960, concern over crop feeding by bertha armyworm was restricted mainly to flax, alfalfa, and sweet clover, but thereafter *B*. *napus* and *B*. *rapa* were the main crops attacked (Turnock 1988). Feeding on flax can be damaging when late-instar larvae feed on the flowers and immature capsules (Wise and Soroka 2003).

Clover cutworm. Although the clover cutworm occurs only sporadically at densities that cause damage in crops (Ayre *et al*. 1982), occasionally populations can reach outbreak levels. In 1980 in Manitoba, a 64-ha field of flax was destroyed by as many as 160 fifth- and sixth-instar clover cutworm larvae per square metre (Ayre and Lamb 1990).

Flax bollworm - *Heliothis ononis* Denis and Schiffermüller (Lepidoptera: Noctuidae). Females of the flax bollworm lay their eggs in open flax flowers. Young larvae eat the developing seeds within the flax boll, and older larvae leave the boll from which they emerged and feed on the seeds in surrounding bolls. High populations are sporadic, and populations are usually kept low by parasites and diseases (Wise and Soroka 2003).

Beet webworm - *Loxostege sticticalis* L. (Lepidoptera: Crambidae). Larvae of the beet webworm occasionally do extensive feeding on flax in localized areas of western Canada (Strickland and Criddle 1920). Larvae of the second generation may feed on leaves, flowers, and stems of flax in July to August, often consuming many different dicotyledonous weeds before feeding on flax (Wise and Soroka 2003). Larvae are highly migratory and may travel over 1 km in search of new food sources after they have destroyed the local food supply (Esterberg 1932). The larvae migrate to nearby crops when the weeds are defoliated, dry up because of drought, or are destroyed by weeding or the use of herbicides (Beirne 1971).

Sap Feeders

Lygus bugs. *Lygus lineolaris* is the dominant plant bug in flax crops in Manitoba and likely throughout the Parkland Ecoregion, but *L. elisus* and *L. borealis* also occur at lower densities (Wise and Lamb 2000). The species complex is likely to vary depending on the region because *L. lineolaris* is replaced by *L. elisus* or *L. keltoni* as the dominant species in drier areas of the prairies. The biology of plant bugs in flax is similar to canola, as discussed earlier, but flax appears to incur less damage from lygus feeding compared with canola (Wise and Lamb 2000).

Potato aphid - *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae). This North American native is polyphagous and feeds on over 200 dicotyledonous host plant species, including flax. It overwinters in the egg stage in roses, strawberries, or raspberries. Wingless females hatch from the eggs in the spring and reproduce parthenogenetically to produce winged forms that disperse to new hosts such as flax and potatoes, where they continue laying live young. The potato aphid is an efficient herbivore of flax, with a conversion rate of plant tissue to aphid tissue of near 1 mg/mg (Lamb and Grenkow 2008). Wise *et al*. (1995) demonstrated the pest status of the potato aphid in flax and determined the yield loss in flax is 0.021 t/ha per aphid per plant for crops sampled at full bloom and 0.008 t/ha per aphid per plant for crops sampled at the green boll stage. Most of this yield loss was due to a reduction in the number of seeds.

Aster leafhopper - *Macrosteles quadrilineatus* Forbes (Cicadellidae). This species is of economic importance in flax because of its potential to vector aster yellows (*Candidatus Phytoplasma asteris*). However, its feeding is not specific to flax and the information for *Brassica* crops provided earlier also applies.

Nectar Feeders and Pollinators

Canola and Mustard

Canola is an excellent source of nectar and pollen for many insects. Insect pollination is more important for *B. rapa* (open pollinated) than for *B. napus* (80% self-pollinated). However, insect pollination can reduce the flowering period and improve yields in *B. napus*, as has been shown with honey bees (Sabbahi *et al*. 2006) and with wild bees, which are more abundant in canola fields adjacent to uncultivated land (Morandin and Winston 2006). The production system used to grow canola can influence the abundance of wild bees and subsequent pollination deficit of the crop. Wild bees were two to three times more abundant in organic canola compared with conventional and herbicide-tolerant canola fields, respectively (Morandin and Winston 2005). Furthermore, there was a clear negative correlation between wild bee abundance and the degree of pollination deficit in both canola species.

The honey bee, *Apis mellifera* L., is perhaps the most abundant bee pollinator in canola. Throughout the grasslands and especially in northern Alberta, apiculture is a thriving industry for the production of honey. In recent years, the widespread adoption of growing hybrid canola cultivars has increased dramatically throughout the grasslands, made possible only through reliance on honey bees and leafcutter bees, *Megachile rotundata* (Fabricius), for pollination.

Inventories of pollinators in *Brassica* oilseed crops are rare. Observations from accidental trapping of *Bombus* species (Hymenoptera: Apidae) in traps baited with a pheromone to attract bertha armyworm (*Mamestra configurata*) were reported in four ecoregions of Manitoba (Turnock *et al*. 2006). Over eight years, 15 species of bumble bees were caught in traps in canola fields, with *Bombus rufocinctus* Cresson and *B. borealis* Kirby being the most abundant species.

In addition to bees, other prevalent insect pollinators include hover flies (Syrphidae) and bee flies (Bombyliidae) (Diptera). Adults of hover flies (Fig. 12) are effective pollinators of oilseed rape crops, and larvae are important predators of aphids (Jauker and Wolters 2008). Bee flies (Fig. 13) resemble bumble bees, and are moderately good pollinators (http://www.seeds.ca/proj/poll/index.php?k=107). Adult bee flies have hairy brown, black, or yellow bodies, long legs, and a characteristic long proboscis. Bee fly larvae are parasitoids or predators of many insect pests (e.g., grasshoppers). Adult syrphids and bee flies are often seen "hovering" over flowers.

Flax

The degree of cross-fertilization in flax is less than 5% and averages only 1–2%, depending on distances among donor plants (Gurbuz 1999). Flax is also considered a poor source of nectar and pollen. Therefore, it is not expected to harbour a large population or

Fig. 12. Hover fly (Syrphidae). Photo by H. Goulet.

Fig. 13. Bee fly (Bombyliidae). Photo by H. Goulet.

assemblage of pollinators. In addition to pollinators such as honey bees, wild bees, and flies discussed for canola and expected to occur in flax, thrips have been identified as potential pollinators (Henry and Tu 1928).

Predators and Parasitoids

A great diversity of parasitoids and predators inhabit oilseed agroecosystems in Canadian grasslands. This overview focuses on the natural enemy species of the principal herbivores of oilseed crops, including root maggots, flea beetles, cabbage seedpod weevil, diamondback moth, bertha armyworm, flax bollworm, lygus bugs, potato aphid, and grasshoppers.

Parasitoids and Predators of Root Maggots

Seven species of larval and pupal parasitoids were recorded in a survey of commercial canola fields from several locations in western Canada (Hemachandra 2004). Of these, all except *Aleochara bilineata* Gyllenhal (Hymenoptera: Staphylinidae) and *Trybliographa rapae* (Westwood) (Hymenoptera: Figitidae) are considered of minor importance because of their rare occurrence (Turnock *et al*. 1995; Hemachandra 2004).

Adult *A*. *bilineata* are predators and parasitoids of several root maggot species (Read 1962; Klimaszewski 1984; Tomlin *et al*. 1985; Maus *et al*. 1998). One adult can consume an average of 23.8 eggs or 2.6 larvae of *D*. *radicum* per day (Read 1962). Larvae of *A*. *bilineata* are parasitoids of root maggot pupae. The first instar chews an opening in the root maggot puparium, enters, and consumes the developing pupa within (Royer *et al*. 1998). Larvae overwinter in the puparia, and adults emerge during the following spring (Colhoun 1953). In central Alberta, emergence and seasonal activity of *A*. *bilineata* in canola is well synchronized with development of pre-imaginal life stages of its principal hosts, *D*. *radicum* and *D*. *platura*, with beetle emergence beginning shortly after the onset of root maggot oviposition (Broatch *et al*. 2008). As both a predator and a parasitoid, *A*. *bilineata* is an important natural control agent of cabbage maggot populations (Mukerji 1971). In western Canada, parasitism of cabbage maggot puparia by *A*. *bilineata* in cole crops can be as high as 94% (Turnock *et al*. 1995).

Trybliographa rapae females oviposit into all larval instars of *D*. *radicum*, *D*. *floralis*, and *D*. *platura*, although first- and second-instar larvae may be attacked more frequently (Wishart and Monteith 1954). *Trybliographa rapae* larvae develop endoparasitically in their hosts until pupariation occurs (Block *et al*. 1987). The third-instar parasitoid larvae then exit the host body cavity and feed within the puparia as ectoparasitoids on the pupae (Wishart and Monteith 1954).

Parasitoids of Flea Beetles

The most common parasitoid of flea beetles is the wasp *Microctonus vittatae* Muesebeck (Hymenoptera: Braconidae). It has been reported to parasitize 15–53% of *P*. *cruciferae* and 3–15% of *P*. *striolata* collected in Manitoba (Wylie 1982; Wylie and Loan 1984). First-instar parasitoid larvae overwinter within adult beetles and resume their development in spring. Development is relatively rapid in spring, and parasitoid larvae emerge from beetles in mid-May, pupate, and emerge as adults in late May to early June (Wylie 1982).

Parasitoids of Cabbage Seedpod Weevil

Adults of cabbage seedpod weevil can be parasitized by *Microctonus melanopus* (Ruthe) (Hymenoptera: Braconidae) (Fox *et al*. 2004). The parasitoid overwinters as a first instar within the adult weevil, emerges from its host in the spring, and pupates in soil (Jourdheuil 1960). The new generation of parasitoids attacks the same generation of overwintered weevils, completing two generations per year, even though the weevil is univoltine (Harmon and McCaffrey 1997).

Fourteen parasitoid species representing four families of Chalcidoidea have been associated with larvae of the cabbage seedpod weevil (Fig. 14) (Gibson *et al*. 2005; Dosdall *et al*. 2006, 2009). Of these, *Necremnus tidius* (Walker) (Eulophidae), *Trichomalus lucidus* (Walker), *Chlorocytus* sp., and *Pteromalus* sp. (Pteromalidae) were the species most frequently reared, although parasitism levels rarely exceeded 15% in Alberta and Saskatchewan (Dosdall *et al*. 2006, 2009). Females of these species lay their eggs through the canola pod onto the weevil larva within. The parasitoid larva is an idiobiont, preventing any further development of the host after initial parasitization. Once the parasitoid larva is mature, it emerges from the canola pod by creating an exit hole in the pod wall (Dosdall *et al*. 2007).

Parasitoids of Diamondback Moth

The parasitoid complex of diamondback moth in Canadian grasslands is dominated by three species of Hymenoptera. *Diadegma insulare* (Cresson) (Ichneumonidae) and *Microplitis plutellae* (Muesbeck) (Braconidae) attack larvae of *P. xylostella*, whereas *Diadromous subtilicornis* (Gravenhorst) (Ichneumonidae) attacks the prepupal and pupal stages (Braun *et al*. 2004; Sarfraz *et al*. 2005). *Diadegma insulare* accounted for 30–45% of total parasitism; *M. plutellae* and *D. subtilicornis* were less common parasitoids, each responsible for approximately 8–14% of parasitism (Braun *et al*. 2004; Dosdall *et al*. 2004).

Fig. 14. Larva of cabbage seedpod weevil, *Ceutorhynchus obstrictus*, and parasitoid larva in canola pod. Photo by L. Dosdall.

Diadegma insulare is a solitary larval endoparasitoid of *P. xylostella* (Sarfraz *et al.* 2005). It can parasitize all four larval instars, but it kills and emerges from the pre-pupal stage of its host (Harcourt 1960). Field populations of *D. insulare* can be aggregated in patterns correlated with distributions of hosts (Ulmer *et al.* 2005). The parasitoid is attracted to brassicaceous crops damaged by feeding of *P. xylostella* larvae (Mitchell *et al.* 1999). *Microplitis plutellae* females can parasitize all four larval instars of *P. xylostella*, but they kill and emerge from fourth instars (Sarfraz *et al.* 2005). *Microplitis plutellae* can be multivoltine, depending on the number of generations of its host. Unlike *D. insulare*, *M. plutellae* can enter pupal diapause (Putnam 1978). Its ability to diapause and overwinter in western Canada enables *M. plutellae* to attack *P. xylostella* early in the season (Putnam 1978). *Diadromus subtilicornis* is a solitary pupal endoparasitoid of *P. xylostella*. Females oviposit in pre-pupae or pupae, but the frequency of oviposition declines dramatically from two-day-old pupae to three- and four-day-old pupae (Tran and Takasu 2000).

Parasitoids of Bertha Armyworm

The bertha armyworm infests canola crops more frequently than flax (Mason *et al.* 1998*a*) and presumably is subject to parasitism and predation by the same species in both crops. All immature stages of *M. configurata* are attacked by one or more species of parasitoids. *Trichogramma inyoense* Pinto and Oatman (Hymenoptera: Trichogrammatidae) was found to attack bertha armyworm eggs in Saskatchewan (Mason *et al.* 1998*b*), but its importance is not well understood. Larvae and pupae are parasitized by approximately 15 species of Hymenoptera (mainly Ichneumonidae) and Diptera (mainly Tachinidae) (Wylie and Bucher 1977; Wylie 1979). Of these, *Banchus flavescens* Cresson (Ichneumonidae) and *Athrycia cinerea* (Coquillette) (Tachinidae) are most common (Mason *et al.* 1998*a*).

Banchus flavescens was found in up to 95% of larvae in field populations in Saskatchewan during 1971–1973 (Arthur and Ewen 1975) and in 94% of larvae in Manitoba in 1981 (Turnock and Bilodeau 1984). The parasitoid is univoltine and overwinters as a pre-pupa in a cocoon in the soil in obligatory diapause (Wylie and Bucher 1977; Arthur and Mason 1985). Adults emerge from mid-June to the end of July and parasitize first, second, and third instars of *M. configurata* (Arthur and Mason 1985).

Athrycia cinerea is univoltine and overwinters in the soil as a pupa in facultative diapause (Wylie and Bucher 1977; Wylie 1977*b*). Adults emerge in June and July. Females lay eggs on third- to sixth-instar larvae of *M. configurata* (Wylie 1977*a*). Parasitoid larvae hatch a few minutes later and burrow into their host. One or more larvae will develop within a host (Wylie and Bucher 1977; O'Hara 1999), killing it in the fifth or sixth instar. The parasitoid pupates either within the dead host or nearby in the soil (Wylie and Bucher 1977).

Parasitoids of Flax Bollworm

Only *Trichomalopsis sarcophagae* (Gahan) (Hymenoptera: Pteromalidae) has been reported as a parasitoid of the flax bollworm, *H. ononis*, in the grasslands (Gibson and Floate 2001). However, other North American species of *Heliothis* can be attacked by a considerable diversity of parasitoids (e.g., Danks *et al.* 1979; Pair *et al.* 1982; De Moraes *et al.* 1999), principally braconid hymenopterans. Hence, more intensive study will likely reveal additional natural enemies of *H. ononis*.

Parasitoids of Lygus spp.

Numerous species of Hymenoptera parasitize *Lygus* spp. in North America. Broadbent *et al.* (2002) listed four egg parasitoids, five nymphal parasitoids, and four adult parasitoids reared from lygus bugs, all of which were Hymenoptera representing four families. Cárcamo *et al*. (2008*a*) identified *Anaphes iole*, *Telenomus* sp., and *Polynema* sp. (Mymaridae) as putative egg parasitoids, but parasitism rates were <5%. *Peristenus carcamoi* Goulet, *P. broadbenti* Goulet, and *P. braunae* Goulet (Braconidae) parasitize *Lygus* nymphs, with *P. carcamoi* as the dominant species on the first generation of *Lygus* spp. Rates of parasitism from nymphal dissections reached as high as 60% (Cárcamo *et al*. 2008*b*).

Predators and Parasitoids of Potato Aphids

The potato aphid, *M. euphorbiae*, is preyed upon by lady beetles, lacewings, and hover fly larvae (Walker *et al*. 1984; Wise and Soroka 2003). In addition, parasitic wasps (principally Hymenoptera: Braconidae) can attack *M. euphorbiae*. However, predators and parasitoids are generally ineffective for controlling populations when aphids rapidly colonize crops (Walker *et al*. 1984; Wise and Soroka 2003).

Parasitoids of Grasshoppers

Various grasshopper species eat oilseed crops in the grasslands, and it follows that their parasitoids reported in other crops such as cereals should also occur in oilseed crops. For example, *Blaesoxipha atlanis* (Aldrich) (Diptera: Sarcophagidae) is a common parasitoid of several species of grasshoppers that can occur in oilseed crops (Danyk *et al*. 2000), such as *Melanoplus sanguinipes* (Fabricius) and *Camnula pellucida* (Scudder), and consequently the parasitoid almost certainly also occurs in oilseed crops.

Predators in Oilseed Crops

Oilseed crops harbour a large diversity of predators, but to date little taxonomic study has been conducted on this fauna. The main predators include various species of lady beetles (Coleoptera: Coccinelidae), ground beetles (Coleoptera: Carabidae), syrphids (Diptera: Syrphidae), and lacewings (Neuroptera: Chrysopidae); several families of spiders (Araneae); and rove beetles (Coleoptera: Staphylinidae). Ground beetles are perhaps the best studied group of predators in canola agroecosystems, having been used in a number of studies to test for various treatment effects (e.g., Cárcamo and Spence 1994; Butts *et al*. 2003). A total of 59 species of carabids were collected during a three-year period from canola from one site in central Alberta (Broatch 2008).

High populations of the western damsel bug, *Nabis alternatus* Parshley (Hemiptera: Nabidae), have been swept from oilseed crops in the Canadian prairies and have been observed attacking adults of *Phyllotreta cruciferae* and lygus bug nymphs in the sweep net (Burgess 1982*b*). Larvae of lacewings have also been swept from oilseed crops and have been observed preying on aphids, diamondback moth larvae, and adults of *P. cruciferae* (Burgess 1980*b*). Adults of *Collops vittatus* Say (Coleoptera: Melyridae) were moderately abundant in rapeseed plots in Manitoba and were observed preying on adults of *P. cruciferae* (Gerber and Osgood 1975). Although populations of these predators can at times be high in fields of oilseed crops, their impact on populations of insects that feed on the crop is not known.

Conclusions

The biology and effects of the major insect pests on oilseed crops generally has been well studied. However, more research is still needed on the diversity of the non-pest arthropods in these agroecosystems. More research is also needed on the parasitoids and predators found in oilseed crops and on how growing oilseed crops affects the abundance and diversity of arthropods that live in the soil. Crop scouts and those who regularly sample insects in oilseed crops have expressed a need for resources that could enable them to identify the beneficial insects present in these crops; however, such resources currently are limited and include only commonly known species.

More research is still needed on how agronomic practices affect the biodiversity and abundance of insects in oilseed crops. In Saskatchewan, seeding canola in late April and dormant seeding in fall increased canola yields by 44% and 34%, respectively, relative to seeding canola in mid-May (Kirkland and Johnson 2000). How such changes in seeding date may affect the abundance and diversity of arthropods found in fields of canola is not known. More research is also needed on the potential effects of altered seeding rates, varieties of seed grown, and commonly used seed treatments on the abundance and diversity of insects in oilseed crops. Such studies should not be restricted to the effect of these practices on potential pest insects, but should also include the effects on beneficial insects and pollinators.

Insecticides can be applied in oilseed crops as both a foliar treatment and/or as a seed coating to control pest insects. The insecticides currently used on canola, mustard, and flax are mainly broad spectrum and affect diverse arthropod species in different orders. Thus, their use may have profound effects on the arthropod community present at the time of application, as well as on those species that recolonize the crop after application. Little is known about how these crops are recolonized after insecticide applications or the long-term effects on potential pests, predator and parasite populations, and pollinators.

The sublethal effects of agricultural chemicals on beneficial arthropods have recently received more attention (Desneux *et al*. 2007; Echegaray *et al*. 2009). For example, sublethal doses of imidacloprid, a neonicotinoid insecticide, potentially delay return visits to a feeding site by honey bees, *A*. *mellifera* (Yang *et al*. 2008).

In addition to the direct feeding on the tissues of oilseed crops, insects also play many vital roles related to the protection and pollination of the plants, decomposition of crop residue, and health of the habitat. A better understanding of how insect populations and communities are affected and reconstructed after habitat disturbances such as insecticide applications, tillage treatments, removal of alternate hosts, and so forth is needed and would also aid in the management of insects on these crops.

The introduction of new insects, both accidentally and intentionally, is likely to result in future changes to the complex of arthropods inhabiting oilseed crops in the Canadian prairies. For example, swede midge, *Contarinia nasturtii* Kieffer (Diptera: Cecidomyiidae), has recently been detected at low densities in canola in Saskatchewan and Manitoba. A bioclimatic model indicates that population growth of this insect in the Prairie Ecozone of western Canada could be greatest in years with above-average precipitation (Olfert *et al*. 2006). The potential of introducing exotic biological control agents into the prairie agroecosystem to help manage insect pests of canola is also being investigated.

The introduction and expansion of both oilseed crops and foreign insects has had a major impact on the arthropods that are associated with Canadian grasslands. Several introduced crucifer specialists now have an abundance of host plants and are a regular and often abundant component of the arthropod fauna. Our management of these introduced crops, and attempts to manage the insects associated with them, has resulted in massive changes in the structure of the arthropod fauna of the Canadian grasslands.

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