

Chapter 7

Insects of Sunflower in the Northern Great Plains of North America

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Abstract. The ancestors of cultivated sunflower, *Helianthus annuus* L. (Asteraceae), are native to North America, with approximately 13 of the 51 species in the genus *Helianthus* reported to occur in Canada. Sunflower was introduced to Spain in the early 1500s and gradually spread across the European continent. Cultivated sunflower was then introduced from Russia into North America by Mennonite immigrants to Canada beginning about 1875. Many of the insect species that coevolved with native sunflowers have since made the transition onto commercial varieties. This transition has meant shifting from sparse patches of native *Helianthus* growing with other species onto large, even-aged monocultures growing at high density with synchronous flowering. Some insects have been very successful in this transition and are now economic pests. This chapter describes the biology of these insects and some of their natural enemies on native and cultivated sunflowers in the Northern Great Plains.

Résumé. Les ancêtres du tournesol cultivé, *Helianthus annuus* L. (Asteraceae) sont originaires d'Amérique du Nord, et on a signalé la présence au Canada d'environ 13 des 51 espèces du genre *Helianthus*. Le tournesol a été introduit en Espagne au début des années 1500 et s'est graduellement répandu sur l'ensemble du continent européen. Des tournesols cultivés ont ensuite été ramenés de Russie en Amérique du Nord par des immigrants mennonites, arrivés au Canada à partir de 1875 environ. Plusieurs des espèces d'insectes qui ont coévolué avec les tournesols indigènes ont depuis vécu la transition aux variétés commerciales au cours de laquelle les parcelles éparses d'*Helianthus* indigène poussant en compagnie d'autres espèces ont été remplacées par de vastes superficies de monoculture à haute densité et à floraison synchronisée. Certains insectes se sont bien adaptés et sont aujourd'hui devenus des ravageurs d'importance économique. Le présent chapitre décrit la biologie de ces insectes et certains de leurs ennemis naturels sur les tournesols indigènes et cultivés des grandes plaines du nord.

Introduction

The ancestors of cultivated sunflower, *Helianthus annuus* L. (Asteraceae), are native to North America. The genus includes 14 annual and 37 perennial species distributed throughout the United States, Canada, and Mexico (Seiler and Rieseberg 1997). Approximately 13 species occur in Canada (Scoggan 1979).

Sunflower was introduced to Spain in the early 1500s and gradually spread across Europe. Cultivated sunflower subsequently was introduced into North America by Mennonite immigrants to Canada beginning about 1875 (Putt 1997).

Sunflowers are grown commercially for their seeds. Some cultivars are grown for human consumption and as bird feed, whereas other cultivars are grown as a source of

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high-quality oil. Quality is of greater concern for seeds destined for the human food market than for the oilseed market. Insect management practices and the economic thresholds for insects that feed directly on the seeds thus vary with intended seed use. In general, fewer insecticides are used on oilseed varieties of sunflowers than on those varieties grown for human consumption. From 1990 to 1999, the average hectares of sunflowers planted per year in the three Canadian prairie provinces were 46,200 in Manitoba, 15,700 in Saskatchewan, and 1,700 in Alberta (Canada Grains Council 2000). In Manitoba in 2008, there were 72,762 ha of sunflowers grown.

Domestication of sunflower has greatly altered the plant's architecture and growth patterns. Native species have a multibranching, sequentially flowering phenotype with small seeds in multiple heads. Seed germination and flowering is prolonged, with patches of the plants scattered and growing mixed with other species. Cultivated varieties are monopodial with one stem and flower head that produces large seeds. Germination and flowering is synchronized with uniform planting dates and genetic selection. Commercial varieties are tall (100–180 cm) and produce seeds with an oil content of 40% or more (Johnston *et al.* 2002). Sunflower is a high water-use crop with roots that may extend to depths of 120–270 cm (Jaafar *et al.* 1993; Johnston *et al.* 2002). They are grown in rotation with other crops and generally not in the same field in consecutive years.

Native insects have evolved on *Helianthus* species for thousands of years (Rogers 1988a; Charlet *et al.* 1997). More than 150 phytophagous species occur on *H. annuus*, the insect orders Coleoptera, Lepidoptera, and Sternorrhyncha (formerly Homoptera) being most common (Hilgendorf and Goeden 1981). Additional insect species from other species of native sunflowers have been documented from both the northern and southern latitudes of North America (Rogers 1988a, 1988b; Charlet *et al.* 1992). The phytophagous insects that have been most successful in adapting to commercial varieties are species of *Helianthus* specialists, rather than generalist species that also feed on plants in other genera (Turnock 1977). Many such species have become economic pests, including the sunflower beetle, *Zygogramma exclamationis* (Fabricius), the sunflower stem maggot, *Strauzia longipennis* (Wiedemann), the sunflower moth, *Homeosoma electellum* (Hulst), and the banded sunflower moth, *Cochylis hospes* Walsingham (Rogers 1988a; Charlet *et al.* 1997; Charlet 1999). This chapter provides an overview of the phytophagous species that are common on native and cultivated sunflowers in the Northern Great Plains of Canada and the United States and also of the natural arthropod enemies of these species.

Feeding Guilds of Insects on Sunflowers

Root Feeders

Cutworms (Lepidoptera: Noctuidae). This group of moths includes the darksided cutworm (*Euxoa messoria* Harris), the redbacked cutworm (*Euxoa ochrogaster* Guenee), and the dingy cutworm (*Feltia jaculifera* Walker). Forewings of the adult darksided cutworm are usually light, powdery, and grayish brown with indistinct markings. The larvae are pale brown dorsally and white on the ventral areas, with numerous indistinct lateral stripes. At maturity, they are about 32–38 mm long and 5 mm wide. The forewings of the adult redbacked cutworm are reddish brown with characteristic bean-shaped markings. The larvae are dull gray to brown with soft, fleshy bodies and may be 25–32 mm long when fully grown. Larvae can be distinguished by two dull reddish stripes along the back (Fig. 1). Forewings of the dingy cutworm are dark brown with bean-shaped markings as in the redbacked cutworm adults. Hind wings in the male are whitish with a broad, dark border on the outer margin; in



Fig. 1. Redbacked cutworm.



Fig. 2. Wireworm.

the female, they are uniform dark gray. The larvae have a dull, dingy, brown body mottled with cream colour. The dorsal area is pale with traces of oblique shading. Darksided and redbacked cutworms overwinter as eggs, whereas the dingy cutworm overwinters as second- or third-instar larvae. Larvae of cutworms feed mainly at night and hide in the soil or under debris during the day. Young plants in the seedling stage are most susceptible to cutworm injury. Young leaves may be chewed, or plants may be cut off below or above the soil surface. Early instars of the dingy cutworm are commonly found feeding in mature sunflower heads in late summer or early fall (Westdal 1975; Knodel and Charlet 2007).

Wireworms (Coleoptera: Elateridae). “Wireworms” is the common name for larvae of click beetles, of which there are many species. The adults of species associated with sunflower are bullet shaped, brown to black, and about 13 mm long. Larvae are hard-shelled, smooth, and wire-like grubs that are 38–50 mm long when mature. They are yellowish-white to copper, with three pairs of small, thin legs behind the head (Fig. 2). The last body segment is forked or notched. Early in the season, larvae become active when soil temperatures warm up to 10 °C and feed just below the soil surface on germinating seeds or young seedlings. During the summer months, the larvae may move deeper in the soil where conditions are more favourable (Jones and Shirck 1942; Knodel and Charlet 2007). They feed on a variety of host plants and frequently cause economic damage to cultivated sunflower.

Sunflower root weevil - *Baris strenua* (LeConte) (Coleoptera: Curculionidae). Adults are 6 mm long, oval-shaped, and dull black, with a short, almost blunt, downward-projecting snout. The legless larvae are 5–6 mm long at maturity, creamy white with a small brown head capsule, and normally found in a curled or C-shaped position. Adults emerge in late June and feed initially on sunflower foliage. After about two weeks, they congregate around the root zone near the soil surface to feed on stem tissue. This feeding causes the plant to produce callus tissue, under which adults deposit groups of two to three bright yellow eggs. Larvae are free living in the soil and feed on the epidermis and cortical cells of roots (Casals-Bustos 1976; Charlet *et al.* 1997). Pupation occurs among the roots. Host plants include several species of wild sunflowers (Table 1) and other species of Asteraceae (Tuttle 1952; Casals-Bustos 1976; Rogers 1988*b*).

Banded sunflower moth – <i>Cochylis hospes</i> Walsingham	6, 3, 6	9	6	6	6	6	3	3	3
Sunflower bud moth – <i>Suleima helianthana</i> (Riley)	3, 3, 3, 6	3	3	3	6	6	3	3	3
Sunflower moth – <i>Homoeosoma electellum</i> (Hulst)	10	11	11	11	11				
Sunflower seed maggot – <i>Neotephritis finalis</i> (Loew)	6, 6	6	6	6	6, 12	12	12	12	3
Sunflower midge – <i>Contarinia schulzi</i> Gagné	6, 13, 14	6, 13, 14					14		
Red sunflower seed weevil – <i>Smicronyx fulvus</i> LeConte	3, 6, 6, 9, 15, 16	6, 6, 9, 15, 16	15	6, 9, 16	6, 6, 16		6		9
Gray sunflower seed weevil – <i>Smicronyx sordidus</i> LeConte	6, 16, 17	6, 6, 16	17	16	16				

¹ Casals-Bustos (1976); ² Tuttle (1952); ³ Rogers (1988b); ⁴ Kissinger (1968); ⁵ Westdal and Barrett (1960); ⁶ Charlet *et al.* (1992); ⁷ Criddle (1922); ⁸ Charlet (2003b); ⁹ Rogers (1988a); ¹⁰ Goodson and Neunzig (1993); ¹¹ Chippendale and Cassatt (1986); ¹² Goeden *et al.* (1987); ¹³ Schulz (1973); ¹⁴ Rogers *et al.* (1979); ¹⁵ Oseto and Branness (1979a); ¹⁶ Charlet and Seiler (1994); ¹⁷ Anderson (1962).

Stem Feeders

Black sunflower stem weevil - *Apion occidentale* Fall (Coleoptera: Curculionidae).

Adults are shiny black beetles, 2.5 mm long, with a very narrow snout that protrudes forward from the head. The head is small in relation to the rather large, almost globose body. The larvae are similar in appearance to those of the sunflower root weevil, but are 2.5–3 mm long at maturity (Knodel and Charlet 2002). Adults overwinter in soil or plant residue and emerge from late May to early June to feed on leaf and stem tissue until late July. Eggs are laid under the epidermis in leaf petioles or in stems near the point of leaf attachment. Larvae feed in vascular and pith tissue of stems and petioles, and then pupate in the feeding tunnels to emerge as adults in August. Newly emerged adults feed on stem and leaf tissue and congregate under the bracts surrounding the maturing sunflower capitula prior to moving into the soil to overwinter (Gaudet and Schulz 1981; Knodel and Charlet 2002). Hosts include several species of wild sunflower (Kissinger 1968; Rogers 1988b) (Table 1).

Sunflower stem weevil - *Cylindrocopturus adpersus* (LeConte) (Coleoptera: Curculionidae).

Adults are 4–5 mm long and grayish brown with varying-shaped white spots on the elytra (wing covers) and thorax (Fig. 3). The snout, eyes, and antennae are black. Larvae are similar in appearance to those of the sunflower root weevil, 5–6 mm long at maturity, and are normally found in a curled or C-shaped position within the sunflower stalk (Casals-Bustos 1976; Knodel and Charlet 2002).

Adults overwinter in sunflower stalks and root crowns. On the Northern Great Plains, they emerge in early to mid-April to feed on stem and leaf tissue. Adults are present until late August, with peak densities in mid-July (Charlet 1987). Eggs are laid under the epidermis at the base of sunflower stalks (Rogers and Serda 1982; Charlet 1987) and hatch in early July. Larvae initially feed in the vascular tissue in the upper portions of the stem until early August. As they mature, the larvae tunnel down through the stem pith to reach the lower portion of the stalk or root crown by late August. There, the larvae excavate overwintering chambers by chewing cavities into the stem cortex. There is one generation per year (Rogers and Serda 1982; Charlet 1987).

The sunflower stem weevil has been implicated in the epidemiology of sunflower pathogens. These include Phoma black stem (*Phoma macdonaldii* Boerma), which has been implicated as one of the major biotic causes of premature ripening syndrome (early dry



Fig. 3. Sunflower stem weevil adult.



Fig. 4. Long-horned beetle adult.

down) of sunflower in North Dakota (Gaudet and Schulz 1981; Gulya and Charlet 1984), and *Macrophomina phaseolina* (Tassi) Goid, which is the causative agent of charcoal stem rot in the southern plains (Yang *et al.* 1983).

The sunflower stem weevil occurs in most states west of the Mississippi River and on the prairies of Canada (Schulz 1978; Arthur and Mason 1990; Charlet *et al.* 1997). Its host range includes several species of sunflower (Charlet *et al.* 1992) (Table 1), ragweed (*Ambrosia artemisifolia* L.), pigweed (*Amaranthus* spp.), Russian knapweed (*Centaurea repens* L.), lambsquarter (*Chenopodium album* L.), golden ragwort (*Senecio aureus* L.), perennial sowthistle (*Sonchus arvensis* L.), red clover (*Trifolium pratense* L.), cocklebur (*Xanthium strumarium* L.), and kochia (*Kochia scoparia* L.) (Mitchell and Pierce 1911; Casals-Bustos 1976; Goeden and Ricker 1976; Schulz 1978).

Long-horned beetle - *Dectes texanus* LeConte (Coleoptera: Cerambycidae). Adults are pale gray beetles, 6–11 mm long, with the characteristic long antennae that give beetles in the family Cerambycidae the common name of “long-horned” beetles (Fig. 4). Eggs are 2 mm long and elongate, and they turn dark yellow prior to hatching. Mature larvae are yellowish and 7–13 mm long; they bear fleshy protuberances on the first seven abdominal segments (Hatchett *et al.* 1975) (Fig. 5).

Adults appear in late June through August to oviposit in leaf petioles. Newly hatched larvae tunnel and feed in petioles and stem pith. In late summer, the mature larvae tunnel down to internally girdle the lower stalk or root crown, move below the girdle, and then pack frass into the tunnels to better protect the larvae during the winter (Rogers 1977, 1985). Larvae are cannibalistic, such that stalks usually harbour only one larva even though several may have been present originally (Charlet *et al.* 1987). There is one generation per year (Rogers 1985; Charlet *et al.* 1997).

Larval girdling often causes stalks to break, which reduces yields in crops of commercial sunflower. The beetle has been recognized as a pest since the early 1970s and is known from Kansas, North Dakota, South Dakota, and Texas (Rogers 1977, 1985; Charlet *et al.* 1997; Michaud and Grant 2005). It has also become a significant pest of soybean in the High Plains (Hatchett *et al.* 1975; Michaud and Grant 2005). The sunflower long-horned beetle feeds on wild sunflower species, giant ragweed (*Ambrosia trifida* L.), and cocklebur (*Xanthium strumarium* L.) (Rogers 1985).

Sunflower maggot - *Strauzia longipennis* (Wiedemann) (Diptera: Tephritidae). This fly is the only tephritid species found feeding in stalks of cultivated sunflower. The bright yellow adult has a wing span of about 13 mm with a body about 8 mm long. The eyes are bright green and the wings bear broad dark bands that form a fairly distinct F pattern near the wing tip. Eggs are 1 mm long, white, and elongate. The larvae are yellow white, tapered from anterior to posterior, and approximately 9 mm long and 2.5 mm wide at maturity (Knodel and Charlet 2007).

Adults emerge in mid-June, are active diurnally, and remain present in fields until late July. Eggs are deposited singly in stem tissue near the apical meristem. Larvae feed in the stem, creating large tunnels in the stalk pith, and develop through three instars in approximately six weeks (Westdal and Barrett 1960). Fully developed larvae emerge from the stalk beginning in mid-August and overwinter as pupae in the soil at the base of the sunflower plant (Westdal and Barrett 1960). Secondary fungal infections are often associated with tunnelling by the larvae within the stalk (Westdal and Barrett 1962). This fly occurs in most areas of the United States and in many of the Canadian provinces

(Westdal and Barrett 1960), feeding on several species of native sunflower (Westdal and Barrett 1960; Charlet *et al.* 1992) (Table 1).

Foliage Feeders

Sunflower beetle - *Zygogramma exclamationis* (Fabricius) (Coleoptera: Chrysomelidae). Adults of this species may be easily confused with Colorado potato beetles. The head is reddish-brown with a pale cream-coloured thorax accented by a reddish-brown patch at the base (Fig. 6). Elytra are cream coloured with three dark lateral stripes that extend full length. A fourth shorter lateral stripe ends mid-length in a small dot that resembles an exclamation point. The beetle is 6–12 mm long and 2–4 mm wide. Eggs are 1.5–2 mm long, cigar-shaped, and creamy yellow. Larvae are yellowish green with a brown head capsule and are humpbacked in appearance. Newly hatched larvae are 1.5–1.8 mm long and will reach a length of 8–10 mm when fully developed (Charlet *et al.* 1997).

Adults and larvae feed on the foliage of both cultivated sunflowers and native *Helianthus* spp. Adults emerge from overwintering sites to feed on the true leaves of sunflower seedlings, seldom on the cotyledons (Criddle 1922; Westdal 1975). Adults feed during the day, whereas larvae are nocturnal feeders; during the day, larvae congregate among the bracts of the flower bud and in the axils of the leaves. There is one generation per year in the Northern Great Plains (Charlet 1992). The sunflower beetle is native to North America and feeds only on species of sunflower (Criddle 1922; Charlet 2003b) (Table 1).

Thistle caterpillar or Painted lady butterfly – *Vanessa cardui* L. (Lepidoptera: Nymphalidae). Painted lady butterflies overwinter in tropical and subtropical areas and then annually migrate to the northern regions of the United States and Canada (Williams 1970). The body of the adult is about 25 mm long with a wingspread of about 50 mm. The upper wing surfaces are brown with red and orange mottling and white and black spots (Fig. 7). The undersides of the wings are marble gray, buff, and white. Each hind wing possesses a row of four distinct and obscure eyespots. Eggs are small, spherical, and white. The larvae are brown to black and spiny, with a pale yellow stripe on each side, and reach a mature length of 32–38 mm. The chrysalis, or pupa, is molten gold and about 25 mm long (Charlet *et al.* 1997).

Larvae can extensively defoliate sunflowers, but also feed on over 100 other plant species that include thistle (*Cirsium* spp. and *Carduus* spp.), burdock (*Arctium* spp.), canola



Fig. 5. Long-horned beetle larva in stalk.



Fig. 6. Sunflower beetle adult.

(*Brassica napus* L.), and soybean (*Glycine max* (L.) Merr.) (Williams 1970; Klassen *et al.* 1989). The larvae produce loose silk webbing that covers them during their feeding activity. Black fecal pellets produced by the larvae are often found in close proximity to the webbing (Charlet *et al.* 1997).

Other defoliators. Aphids (Aphidae) are small, pear-shaped, and soft-bodied insects, with or without wings, that vary from green to yellow or black. Species that feed on sunflowers include the sunflower aphid, *Aphis helianthi* (Monell), and several species in the genus *Uroleucon* (Robinson and Lamb 1991). Plants with high aphid populations take on a wet or shiny appearance because of the buildup of aphid honeydew on the foliage, which can promote the growth of sooty molds (*Capnodium* spp., *Fumago* ssp. and others) in the lower leaf canopy where humidity is high. Aphids are not economic pests of sunflower in North America.

Species of grasshoppers (Orthoptera: Acrididae) that are occasional pests of sunflower include the differential grasshopper, *Melanoplus differentialis* (Thomas); migratory grasshopper, *M. sanguinipes* (Fabricius); two-striped grasshopper, *M. bivittatus* (Say); red-legged grasshopper, *M. femurrubrum* (DeGeer); and clear-winged grasshopper, *Camnula pellucida* (Scudder). These grasshoppers feed on many species of plants such that infestations in sunflowers usually originate from adjacent areas of weeds and grains that have matured or have been harvested. Grasshoppers will feed on all above-ground parts of sunflower, but damage is greatest to foliage and developing seed (Schulz 1978; Charlet *et al.* 1997).

Species of Lepidoptera common on wild and cultivated sunflower include the salt marsh caterpillar, *Estigmene acrea* (Drury) (Arctiidae), and *Chlosyne lacinia* Geyer (Nymphalidae) (Rogers 1988a, 1988b).

Head and Seed Feeders

Banded sunflower moth - *Cochylis hospes* Walsingham (Lepidoptera: Tortricidae).

This is a small moth with a 6-mm long body that is covered with light tan scales. A distinct, dark brown triangular scale patch covers the mid portion of the forewings, and the edge of the forewings has a small brown patch of scales (Fig. 8). Eggs are 0.5 mm long and 0.3 mm wide, and they change from white to light brown with maturity. The colour of early-instar larvae is light pink, changing to red or green in late instars (Westdal 1975; Charlet and Gross 1990; Mundal *et al.* 2006).



Fig. 7. Painted lady butterfly.



Fig. 8. Banded sunflower moth adult.

Adults typically rest in vegetation along field margins during the day, with females moving into fields at twilight to oviposit. The average life span of adults is 7–10 days, but the annual flight lasts two months (Beregovoy *et al.* 1989). Oviposition occurs from early July to mid-August, preferentially on the outer whorl of involucre bracts of sunflowers prior to bloom. There are five larval instars. Newly emerged larvae move to the disc flowers to feed on pollen. Third-instar larvae tunnel through the disc flowers and feed on young developing seeds. Older larvae will move across the seed head and produce webbing, each larva consuming several seeds as they ripen (Charlet and Gross 1990) (Fig. 9). At maturity, larvae drop from the head and enter the soil to overwinter in silken cocoons. Pupation occurs in late June the following year (Westdal 1975; Charlet and Gross 1990).

The banded sunflower moth has a widespread distribution and probably occurs wherever species of wild *Helianthus* grow (e.g., see Rogers 1988a, 1988b; Charlet *et al.* 1992) (Table 1). Arthur and Powell (1990) described a second species of *Cochylis* from sunflower in Saskatchewan. The ecology and biology of *C. arthuri* Dang is similar to that of *C. hospes*, but it is much less common than the banded sunflower moth.

Sunflower bud moth - *Suleima helianthana* (Riley) (Lepidoptera: Tortricidae). Adults have a wingspread of about 16–18 mm. Each gray-brown forewing has two dark transverse bands. One band extends across the middle of the wing and the second band is near the wing tip. The larva has a dark head capsule with a smooth cream-coloured body and is 8–11 mm at maturity (Charlet *et al.* 1997; Knodel and Charlet 2007) (Fig. 10). There are typically two generations per year in the Northern Great Plains.

Females deposit eggs in leaf axils of vegetative sunflowers and in the bud of reproductive stage sunflowers. Young larvae burrow through the epidermis, usually at a leaf axil or a tender area at the back of the receptacle (Rogers 1979), to feed in the tissue of the stalk or receptacle (head). Larvae continually push frass to the entrance so that a large black mass accumulates at the entrance hole. As the infested plant matures, abnormal plant growth may occur at the site of injury, sometimes resulting in loss of apical dominance. Mature larvae pupate in the burrow near the entrance hole. The second-generation adults appear in July and August (Charlet *et al.* 1997; Knodel and Charlet 2007). Hosts of this moth include wild and cultivated sunflower (Rogers 1988b; Charlet *et al.* 1992) (Table 1), ragweed, and Canada thistle, *Cirsium arvense* (Charlet *et al.* 1997).



Fig. 9. Banded sunflower moth larva.



Fig. 10. Sunflower bud moth larva.

Sunflower moth – *Homoeosoma electellum* Hulst (Lepidoptera: Pyralidae). The adult is a small shiny-gray moth with nondescript fringed hind wings (Fig. 11). The forewings are marked with a small centred dot and two or three smaller dots toward the distal end of the wing. At rest, the wings are held alongside the body. Larvae have alternate dark and light lateral stripes on a buff-coloured body (Wesdal 1975) (Fig. 12).

The seasonal appearance of the insect depends on latitude. Infestations are first seen in Texas in April and early May and may be found in North Dakota and the Canadian prairie provinces in mid-July to August (Arthur and Bauer 1981). In the northern limits of their range, the sunflower moth does not successfully overwinter. Infestations in those areas are sporadic and dependent on migration aided by southerly winds (Arthur and Bauer 1981; Rogers and Westbrook 1985).

Eggs are deposited in and among the florets of blooming sunflower heads. First-instar larvae feed primarily on pollen. Second-instar larvae feed on pollen and may burrow through the corolla to feed on pollen inside disc flowers. Larvae in the corollas also feed on anthers and styles. Larval feeding may sever the style and prevent the ovary from being fertilized, resulting in empty seeds. Third-instar larvae also feed on ovaries (Rogers 1978), leaving webbing over the face of the sunflower head. Physical damage from larval feeding may predispose the head to *Rhizopus* infection, which can cause greater yield loss than the direct feeding of the larvae alone (Rogers 1978; Klisiewicz 1979).

This insect has widespread distribution (Charlet *et al.* 1987; Rogers 1988a), with more than 40 different host species of Asteraceae (e.g., Chippendale and Cassatt 1986; Goodson and Neunzig 1993) (Table 1).

Sunflower receptacle maggot – *Gymnocarena diffusa* (Snow) (Diptera: Tephritidae). Adults are yellow flies with bright green eyes and yellowish-brown wings with a somewhat mottled appearance. They emerge in late June to feed on secretions of extra-floral nectaries of native *Helianthus* spp. before moving to cultivated sunflowers. Females lay eggs between the second and fourth layers of bracts of developing sunflower heads. Larvae tunnel into the spongy tissue of the receptacle, or beneath the receptacle and down some distance into the peduncles. After a development period of about 30 days, the larvae form an exit hole in the back of the sunflower head and drop to the soil to pupate prior to overwintering (Kamali 1973).



Fig. 11. Sunflower moth adult.



Fig. 12. Sunflower moth larva in head.

Sunflower seed maggot - *Neotephritis finalis* (Loew) (Diptera: Tephritidae). Adults are about 6 mm long, with wings that have a brown lace-like appearance. They emerge in early July to lay eggs on the corolla of partially opened inflorescences. Larvae feed for about 14 days within the undeveloped ovaries of flowers, often completely consuming the floret before the seed is fertilized. The first generation pupates in the head, and the second generation overwinters as pupae in the soil. The small brown pupae can sometimes be found on the face of sunflower heads, usually surrounded by a small number of damaged florets (Kamali 1973; Arthur and Mason 1989). Host plants include several species of native sunflower (Goeden *et al.* 1987; Charlet *et al.* 1992) (Table 1) and other species of Asteraceae (e.g., *Actinomerus* sp., *Encelia* spp., *Dahlia* sp., *Eriophyllum lanatum* (Pursh) Forbes, *Helianthella uniflora* (Nuttall) Torrey and Gray, *Wyethia* spp., *Balsamorhiza* sp., and *Chrysothamnus* sp.) (Goeden *et al.* 1987).

Sunflower midge - *Contarinia schulzi* Gagne (Diptera: Cecidomyiidae). Adults are small (2–3 mm) delicate flies that live only two to three days (Samuelson 1976) (Fig. 13). In North Dakota, adult emergence begins in late June. Females lay yellow eggs singly or in masses of about 50 in the depressions between the involucral bracts of the sunflower bud. Feeding by newly hatched larvae produces necrotic depressions at the base of the bracts (Schulz 1973; Charlet *et al.* 1997) (Fig. 14). Larval development is complete in 10–14 days. The whitish mature larvae, 1–2 mm long, drop from the head and burrow into the soil. If conditions are favourable, they pupate and emerge in the same season. Otherwise, they remain in the soil and overwinter as larvae in cocoons or as pupae. With a life cycle of 31–35 days, there can be several generations per year (Samuelson 1976). At high densities, larval feeding causes sunflower receptacles to become gnarled and inwardly cupped, often with a hole or depression in the centre, and producing few or no seeds.

Despite its wide distribution throughout the Great Plains of North America, the sunflower midge has been an economic pest on sunflower crops only in North Dakota, Minnesota, and Manitoba (Schulz 1973; Rogers *et al.* 1979). Its host plants include only species of *Helianthus* (Schulz 1973; Rogers *et al.* 1979; Charlet *et al.* 1992) (Table 1).

Sunflower headclipping weevil - *Haploryhynchites aeneus* (Boheman) (Coleoptera: Curculionidae). Adults are shiny black beetles with soft wing covers, about 8 mm in



Fig. 13. Sunflower midge adult.



Fig. 14. Sunflower midge larvae.

length. The area behind the head and thorax is large and “squared” in relation to the narrow and prolonged head and snout. Headclipping weevil larvae are cream coloured, somewhat C shaped and grub like, and 4–6 mm long. Adults emerge in late July and lay eggs in the florets (Hamilton 1973). Females chew a line of feeding punctures in the stalk just beneath the sunflower head, and then return to the head to feed on pollen and to oviposit. The feeding punctures weaken the stem, such that the maturing head eventually breaks off from the top of the stalk. Larvae feed on the severed head and later move into the soil to overwinter (Hamilton 1973).

Red sunflower seed weevil – *Smicronyx fulvus* LeConte (Coleoptera: Curculionidae).

Adults are 2.5–3 mm long and covered with reddish-orange oval scales (Fig. 15). Older weevils have fewer scales and are darker in appearance. The rostra or snout is black and slightly curved (Anderson 1962). They emerge from the soil beginning in late June and move to sunflower heads to feed on pollen, which is a prerequisite for egg maturation by females. Females lay white eggs (about 0.3×0.7 mm) inside the pericarp of developing seeds. An infested seed usually contains one larva, which is cream coloured, legless, and about 1–2 mm long. It will usually consume the upper third of the kernel (Oseto and Braness 1979a, 1979b), reducing seed weight and oil content. In late August, mature larvae (fifth instars) chew an exit hole in the seed, drop to the ground directly beneath the sunflower head, and overwinter in the soil. Pupation occurs the following year during early June through early July (Oseto and Braness 1979a; Brewer 1991).

The red sunflower seed weevil occurs from the Appalachian Mountains westward through the Great Plains to the Pacific Northwest (Anderson 1962) and is more common than the gray sunflower seed weevil (see the following description) in the northern latitudes (Gednalske and Walgenbach 1984; Charlet *et al.* 1997). Its host plants include several species of *Helianthus* (Oseto and Braness 1979a; Rogers 1988a, 1988b; Charlet *et al.* 1992) (Table 1), as well as ironweed, *Veronia interior* Small, and *Heliopsis helianthoides* L. (Tuttle 1952).

Gray sunflower seed weevil – *Smicronyx sordidus* LeConte (Coleoptera: Curculionidae).

Adults are covered with gray scales (Fig. 16), which can rub off with time such that older adults may be black (Anderson 1962). They emerge from the soil about 10 days earlier than the red sunflower seed weevil and move to the developing sunflower heads, where females



Fig. 15. Red sunflower seed weevil adult.



Fig. 16. Gray sunflower seed weevil adult.

oviposit into the tips of the immature disc flowers. Eggs are nearly elliptical to oval, with one end distinctly larger than the other, averaging 0.7 mm long with widths at the two ends being 0.2 and 0.3 mm. The larvae resemble the red sunflower seed weevil larvae in colour and shape, but are larger (3–3.5 mm). Larvae pass through four instars, feeding inside and usually toward the base of the seed (Brewer 1991). Once the plant reaches anthesis, it is no longer attractive to adults, which leave the plant. Mature larvae chew an exit hole in the pericarp and drop to the ground (Brewer 1991). Infested seeds are enlarged and lack a kernel (Gednalske and Walgenbach 1984; Brewer 1991).

The gray sunflower seed weevil occurs from Mexico north to Manitoba and Saskatchewan. Its host plants include commercial and native species of sunflower (Anderson 1962; Charlet *et al.* 1992) (Table 1), as well as *Silphium perfoliatum* L., *S. terebinthaceum* Jaquin, *Medicago sativa* L., and *Cassia* spp. (Anderson 1962).

Tarnished plant bug – *Lygus lineolaris* (Palisot de Beauvois) (Heteroptera: Miridae).

The most common *Lygus* species in sunflower fields is the tarnished plant bug (Charlet 2003a). This species attacks at least 385 different plant species (Young 1986). Adults are small, cryptically coloured insects, 4–5 mm long, with a distinctive yellow triangle or “V” on the wings (Fig. 17). They vary from pale green to dark brown. The immature stages, or nymphs, are similar in appearance to the adults, but lack wings and are usually green (Knodel and Charlet 2007). They are often confused with aphids, but move much more rapidly. Feeding often causes necrosis at the feeding site from the injection of enzymes (Schwartz and Footit 1992). Tarnished plant bug feeding on developing sunflower seed causes kernel brown spot, a serious problem in confection sunflowers (Charlet 2003a).

Nectar Feeders and Pollinators

Native sunflowers and early cultivars were self-incompatible and required insect pollination for seed set. Through selective breeding, most commercial hybrids now possess levels of self-compatibility of up to 80–90%. Even for these cultivars, however, yields can be further increased by cross-pollination (Fick 1979). This is mainly due to the activities of honey bees, *Apis mellifera* L. (Hymenoptera: Apidae), but also of native bees (e.g., *Bombus*



Fig. 17. Adult lygus bug.



Fig. 18. Bumble bee and hover fly on a sunflower.



Fig. 19. Adult parasitoid (*Nealiolus curculionis* (Fitch)) of sunflower stem weevil.



Fig. 20. Adult parasitoid (*Glypta prognatha* Dasch) of banded sunflower moth.

spp., *Melissodes* spp., *Halictus* spp. (Sosa 1988)). The latter deposit clumps of pollen that are subsequently spread across many florets by honey bees. Interspecific interactions further increase movement of honey bees from male to female plants to improve seed set (Greenleaf and Kremen 2006). Wasps, flies, butterflies, skippers, moths, and beetles also visit the flowers of wild and cultivated sunflowers (Fig. 18).

Predators and Parasitoids

There is evidence that many natural enemies have followed the phytophagous sunflower insects from wild *Helianthus* to the cultivated crop. However, a number of parasitoids attack their hosts mainly in wild sunflowers. These parasitoids are limited in their ability to exploit hosts in cultivated sunflower because of factors that include crop domestication, phenology, habitat, and nutrient availability (Charlet 1999; Chen and Welter 2002). Parasitoids and predators for some of the major sunflower insect pests are listed in the following paragraphs.

For the sunflower stem weevil, eggs are attacked by the wasp *Anaphes pallipes* (Ashmead) (Hymenoptera: Mymaridae) (Charlet and Balsbaugh 1984). Ten species of larval parasitoids have been recovered from overwintering larvae in cultivated sunflower in the central and northern Plains of the United States: *Nealiolus curculionis* (Fitch) (Fig. 19), *N. collaris* (Brues), *Bracon* sp. (Braconidae), *Neocatolaccus tylodermae* (Ashmead), *Chlorocytus* sp., *Mesopolobus* sp., *Pteromalus* sp. (Pteromalidae), *Quadrastichus ainsliei* Gahan (Eulophidae), *Eurytoma tylodermatis* Ashmead (Eurytomidae), and *Eupelmus* sp. (Eupelmidae) (Charlet 1983; Charlet *et al.* 2002). Other larval parasitoids include *Rhaconotus cressoni* Muesebeck and Walkley (Braconidae), *Eupelmus cushmani* (Crawford), *E. cyaniceps* (Ashmead) (Eupelmidae), and *Zatropis incertus* (Ashmead) (Pteromalidae) (Casals-Bustos 1976; Krombein *et al.* 1979).

Parasitoids of the banded sunflower moth in cultivated sunflower fields on the Northern Great Plains include *Bassus arthurellus* Sharkey, *B. mellitor* (Say), *Chelonus shoshoneanorum* Viereck, *C. phaloniae* Mason, *Macrocentrus ancylicivorus* Rohwer (Braconidae), *Glypta prognatha* Dasch (Fig. 20), *Glypta* sp., *Mastrus* sp., and *Trathala* sp. (Ichneumonidae) (Westdal 1975; Krombein *et al.* 1979; Sharkey 1985; Sharkey *et al.* 1987; Bergmann and Oseto 1990; Charlet 1999, 2001).

Parasitoids of the sunflower moth include *B. nuperus* Cresson, *B. mellitor*, *Chelonus altitudinus* Viereck, *Dolichogenidea homoeosomae* Muesbeck, *Bassus buttricki* (Viereck), *M. ancylivorus* (Braconidae), *Spilochalcis flavopicta* (Cresson) (Chalcididae), *Cremastus epagoges* Cushman, *Diadegma openangorum* (Viereck), *Pristomerus pacificus* (Cresson) (Ichneumonidae), *Clausicella floridensis* (Townsend), *Erynnia tortricis* (Coquillett), *Leskiomima tenera* (Wiedemann), and *Lixophaga variabilis* Coquillett (Diptera: Tachinidae) (Satterthwait and Swain 1946; Satterthwait 1948; Westdal 1975; Schulz 1978; Krombein *et al.* 1979). From the sunflower moth on native *H. annuus*, *Gaillardia pulchella*, and *Coreopsis tinctoria* Nuttall (Asteraceae), Beregovoy (1985) recovered 16 species of primary parasitoids, in five families of which *Pristomerus austrinus* Townes and Townes (Ichneumonidae), *Elasmus setioscutellatus* (Crawford) (Eulophidae), *Goniozus floridanus* (Ashmead) (Bethyidae), *Blondeliini* sp., and *Pseudachaeta* sp. (Tachinidae) were new host associations. In Saskatchewan and Alberta, a survey of sunflower moth parasitoids from both native and cultivated sunflower revealed 10 species of Hymenoptera, of which two species of *Agathis* (Braconidae) and two new species of *Cremastus*, *Scambus canadensis* Walley and *S. tecumseh* Viereck (Ichneumonidae), were new records (Arthur and Campbell 1979). Sharkey *et al.* (1987) expanded the list of parasitic Hymenoptera in Canada with the addition of *Bassus nigripes* (Cresson) (Braconidae), *Parania geniculata* (Holmgren), *P. pulchra* Dasch, and *Trichomma maceratum* (Cresson) (Ichneumonidae). No parasitic Diptera have been reported from Canada, but tachinids reared from sunflower moth in North Dakota include *E. tortricis* and *Lixophaga plumbea* Aldrich (Schulz 1978).

Red sunflower seed weevil in cultivated fields of sunflower is parasitized by many species. These include *Eupelmus amicus* Girault (Eupelmidae), *B. mellitor*, *Nealiolus curculionis* (Fitch), *Triaspis aequoris* Martin (Braconidae), *Pteromalus* sp., *Trimeromicrus maculatus* Gahan, *Zatropis incertus* (Ashmead) (Pteromalidae), *Torymus capillaceus albitarsis* (Huber), *Zaglyptonotus schwarzi* Crawford (Torymidae), and *Eurytoma* sp. (Eurytomidae) (Cockerell 1915; Bigger 1930, 1931, 1932, 1933; Oseto and Braness 1979a, 1979b; Charlet and Seiler 1994; Charlet 1999, 2002). Studies from North Dakota reveal only *Urosigalphus femoratus* Crawford (Braconidae) as a parasitoid of the gray sunflower seed weevil in cultivated sunflower (Charlet 1999).

Parasitoids of red and gray sunflower seed weevils on native *Helianthus* revealed some of these species and additional parasitoid species. *Smicronyx fulvus* from wild *H. annuus* in southeastern North Dakota were parasitized by *Mesopolobus* sp. and *T. maculatus* (Pteromalidae) (LDC, unpublished). A mixed collection of the two seed weevil species from different sunflower species in the Central and Northern Great Plains of the United States was parasitized by *T. aequoris*, *N. curculionis*, *N. rufus* (Riley), and *U. femoratus* (Braconidae), as well as by *Eutrichosoma mirabile* Ashmead (Pteromalidae) (Charlet and Seiler 1994).

Eggs and adults of the sunflower beetle are parasitized by *Erixestus winnemana* Crawford (Hymenoptera: Pteromalidae) and *Myiopharus neilli* O'Hara (Diptera: Tachinidae), respectively. The larvae are parasitized by *Myiopharus macellus* (Reinhard) and *M. doryphorae* (Riley), although the latter species is rare and has been recovered only in Manitoba, Canada (Westdal 1975; Neill 1982; Charlet 1992, 2003b; O'Hara 2007). Predators that feed on different life stages of the sunflower beetle include the lady beetles *Hippodamia tredecimpunctata tibialis* (Say) and *H. convergens* Guerin-Meneville (Coccinellidae); the green lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae); the spined soldier bug, *Podisus maculiventris* (Say); the stink bugs *Perillus bioculatus* (Fabricius) and *P. circumcinctus* (Stal) (Hemiptera: Pentatomidae); and the beetle *Lebia atriventris* Say (Coleoptera: Carabidae) (Westdal 1975; Charlet *et al.* 2002).

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