Parasitism of the Hessian fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae), on Spring Wheat (Poaceae) in Southern Manitoba

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ABSTRACT

Six species of Hymenoptera were found as parasitoids of the Hessian fly, *Mayetiola destructor* (Say), in the Red River Valley of Manitoba in 2003-2005. These parasitoids were the main cause of pupal mortality. *Platygaster hiemalis* Forbes and a *Homoporus* spp. mostly parasitized only first generation Hessian flies. *Pediobius eubius* (Walker), *Aprostocetus zosimus* (Walker), *Trichomalopsis americana* (Gahan), and *Panstenon poaphilum* Heydon mostly attacked second generation flies. All parasitoid species appeared to be univoltine on the Hessian fly. In 2003-2005, 18-28% of first generation flies and 73-79% of the second generation were parasitized in experimental plots. Parasitism of second generation flies in commercial fields in 2005 was 68-85%. *Platygaster hiemalis* was the most abundant parasitoid of the first generation and *P. eubius* of second generation flies. The prevalence of *P. eubius* was greater than the total of all other parasitoid species at all sites in all years. About 25% of adult parasitoids emerged in August after completing one generation in Hessian flies. This late season emergence occurred for all six species, but was least likely for *P. hiemalis*. A further 15-35% of all parasitoids died as larvae or pupae. This study is the first documented record of *P. eubius* attacking the Hessian fly in Canada, of *A. zosimus* in Manitoba, and of *P. poaphilum* parasitizing the Hessian fly. Ten species of Hymenoptera are now known to parasitize the Hessian fly in Manitoba.

INTRODUCTION

The Hessian fly, *Mayetiola destructor* (Say) (Diptera: Cecidomyiidae), is a pest mainly of spring wheat *Triticum aestivum* L. (Poaceae) in western Canada (Criddle 1915; Mitchener 1923). In southern Manitoba, the Hessian fly completes one or two generations per year (Criddle 1915; Wise 2007) and its feeding either causes stems to break or reduces seed production on infested unbroken stems (Wise *et al*. 2006).

Many hymenopterous parasitoids attack the Hessian fly in North America (Hill *et al*. 1939; Hill 1953). Gahan (1933) documented 31 species of chalcidoid and 4 species of proctotrupoid parasitoids of Hessian fly from North America. More recent world-wide records identify the Hessian fly as a host for at least 51 species of Chalcidoidea (Natural History Museum 2004). Many of these chalcidoids are solitary parasitoids of widely disparate host species. The few species attacking Hessian fly in the superfamily Proctotrupoidea include solitary and gregarious parasitoids in the genus *Platygaster*. These species are only known from *Mayetiola* spp.

Parasitism is a frequent cause of Hessian fly mortality in North America (Pike *et al*. 1983; Schuster and Lidell 1990). In the United States, prior to the introduction of winter wheat cultivars with resistant genes to the Hessian fly (Ratcliffe *et al*. 2000), 62% of puparia in eastern states (Hill and Smith 1928) and 74% in north-central states (Hill 1953) were killed by parasitoids. In western Canada, wheat is sown mostly in the spring and no cultivars have known genes for resistance (Patterson *et al*. 1992). The extent to which the Hessian fly populations in western Canada are reduced by parasitoids is not known.

Six chalcidoids and one proctotrupoid parasitoid of the Hessian fly have been found in Manitoba (Gahan 1933; Peck 1963; Heydon and Boucek 1992; Gibson and Floate 2001). Since many of these species are polyphagous, the primary objectives of this study were to determine which species are important parasitoids of Hessian fly in Manitoba, if parasitism is an important cause of Hessian fly mortality in southern Manitoba, what is the relative abundance of parasitoid species in first and second generation Hessian flies, and if any parasitoid of Hessian fly has more than one generation per year.

MATERIALS AND METHODS

Parasitoid identification. The spring wheat cultivar 'AC Barrie' was seeded at 80 kg/ha with a double disc press drill on 4 June, 2002 at the Cereal Research Centre's Experimental Farm, Glenlea, Manitoba (49°38'N, 97°09'W). Spring wheat stems broken by the Hessian fly were collected by cutting the stems at their base in September 2002. The stems were placed in sealed plastic tubs and immediately stored at 2.5°C for four months. Samples were then moved to 20°C, lightly moistened, and placed in four-litre containers that were covered with clear plastic tops. Adult parasitoids were captured, preserved in 95% alcohol as they emerged, and sent to the Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Ottawa, Ontario for their identification to species.

Research plots. Spring wheat cv. 'AC Barrie' was seeded every one to two weeks from the third week of May on four dates at Glenlea in 2003 to 2005 and 2007 to provide suitable plants for oviposition by first and second generation Hessian flies. The wheat was sown in 10-16 m2 randomized strips in four separate blocks on each seeding date.

Adult parasitoids in 2004 and 2005 were monitored with galvanized metal cone traps and yellow sticky cards (7.5 cm x 12.5 cm). Six cards were placed in wheat stubble next to the plots in late May to early June when the earliest seeded plants were in the one to two-leaf crop stage. The cards were stapled to wooden stakes, placed at a height of 15-20 cm, and replaced weekly until mid-August. Six cone traps were pushed about

three cm into the soil on 4 June over wheat stubble near the sticky cards. The traps had a base diameter of 36 cm, two circular screened holes in the side for ventilation, and covered an area of 0.10 m^2. A plastic vial was fitted over an opening at the top to collect parasitoids.

Parasitism of first generation Hessian fly. Puparia of first generation Hessian fly were collected from the plots in late July or August, and in September or October at plant maturity. Samples of whole plants (20-25 per plot) were unearthed by a hand trowel, excess soil on the roots was removed, and stems were cut just above the first node that had no adventitious roots. The lower part of the plants, including the crown where first generation larvae mostly feed (Wise 2007), was placed into a separate plastic bag for each plot. All collections were stored at 2.5°C within a few hrs of sampling, in sealed plastic containers for at least 13 weeks.

Immediately after being moved to room temperature (20-25°C), puparia were extracted from plant material and examined for adult emergence. Empty puparia were examined for parasite remains (Hill and Pinckney 1940). Five puparia with larvae were placed on a five to eight mm layer of moistened fine quartz sand in a ten-ml glass vial and kept at room temperature.

Adults of Hessian flies and parasitoids in the vials were counted and removed as they emerged, exuviae was removed, and the parasitoids were identified to species. Three weeks after emergence had ceased the remaining puparia were examined for parasites or other mortality factors. Parasitoids still inside the puparia were identified to species, where possible.

Parasitism of second generation Hessian fly. Puparia of second generation Hessian flies were collected in September or October from mature plants in the last two seeded plots (2003 and 2004), when densities of puparia were high, or from all plots (2005) when densities were low. Plants were sampled as for previous collections, except the stems, where second generation larvae mostly feed, were retained and stored within 24 hrs in sealed containers at 2.5°C as for first generation collections.

Immediately after cold storage, puparia were extracted from the stems, examined for emergence of adults, and, if empty, for parasitoid remains (Hill and Pinckney 1940). Larvae within puparia were added to glass vials, and results were recorded as for those of the first generation flies.

Emergence of second generation parasitoids. To determine if any parasitoid species produced more than one generation per year, first generation puparia were collected early in their development in 2004. Puparia were extracted from plants within 48 hrs, examined for adult emergence, and added to vials, as for previous assays. The vials were examined for adult parasitoids for up to three weeks after emergence of the last adult.

For a second collection, spring wheat cv. 'AC Barrie' was seeded on 28 May and 4 June, 2007 in single blocks of 30 m^2 at the Cereal Research Station in Winnipeg (49°49'N, 97°08'W) and on 6 June at Glenlea in multiple blocks of 50 m^2. Broken wheat stems were collected on 13 and 14 August, and puparia were examined for parasitoid emergence. Infested stems were cut 1-2 cm above and below the infested node, and were moistened and kept at room temperature in sealed containers for five weeks. Adult parasitoids were collected and identified to species as they emerged. Another collection

on 2 October was made at Glenlea from blocks not sampled earlier, and puparia were examined for the emergence of parasitoids.

Field site collections. Broken stems of spring wheat were collected 9 September, 2005 from late maturing commercial fields at LaSalle (49°38'N, 97°12'W), Rosenhoff (49°25'N, 97°25'W), and Otterburne (49°30'N, 97°03'W) in the Red River Valley of Manitoba. Stems were cut just below the node of the break and were overwintered as for those from field plots. Puparia were extracted from the stems and analyzed for parasitism. Those with larvae were placed onto moist sand in separate glass vials, as for earlier assays, and parasitoid species and Hessian flies were identified and counted as they emerged in the vials. When adults did not emerge, puparia were examined for the cause of their mortality.

RESULTS

Six species of hymenopterous parasitoids emerged from Hessian fly collected at Glenlea, Manitoba in 2002 from spring wheat: *Platygaster hiemalis* Forbes (Platygasteridae), *Pediobius eubius* (Walker) (Eulophidae), *Aprostocetus zosimus* (Walker) (Eulophidae), *Trichomalopsis americana* (Gahan) (Pteromalidae), *Homoporus* spp. (Pteromalidae), and *Panstenon poaphilum* Heydon (Pteromalidae). Voucher specimens of all species were deposited in the J. B. Wallis Museum, University of Manitoba, Winnipeg, Manitoba.

Parasitoid species of first generation. Only *Homoporus* spp. and *P. hiemalis* emerged from overwintered first generation Hessian flies in 2003, 2005 and 2007 (Table 1). These species comprised 98% of all parasitoids that emerged from this generation in 2004. Two *P. eubius* and one *P. poaphilum* also emerged from first generation puparia in 2004 (n = 138). *Homoporus* spp. were more abundant than *P. hiemalis* in 2003 and 2007 but less abundant than *P. hiemalis* in 2004 and 2005 (Table 1). In all years an average of six *P. hiemalis* adults emerged from each parasitized puparia.

Parasitoid species of second generation. *Pediobius eubius* was the dominant parasitoid species each year at all sites, greatly exceeding the combined abundance of all other species. The chalcidoid, *A. zosimus*, was the second most abundant species at all sites and years. Two other species, *T. americana* and *P. poaphilum*, were of lesser abundance (Table 2), and were found in all years at Glenlea but in only one commercial field. The two first generation brood parasitoids, *Homoporus* spp. and *P. hiemalis*, also were found on second generation flies. *Homoporus* spp. were collected every year in low numbers at all sites, while *P. hiemalis* was found at very low levels every year at Glenlea but at only one commercial site (Table 2).

Prevelence of Parasitoids. Parasitoids were found in18% to 28% of first generation puparia collected in 2003 to 2005 at Glenlea (Table 1). Parasitoids reduced survival of second generation puparia by 73% to 79% at Glenlea in 2003 to 2005 (Table 2) and by 68% to 86% in three commercial fields in the Red River Valley in 2005 (Table 2).

Emergence of first generation adult parasitoids. No adult remains of a parasitoid, to indicate a parasitoid species produced a second generation, were found in exuviae of first generation flies in 2003 to 2005. Many first generation adults of *Homoporus* spp. and *P. hiemalis* did emerge in the same year from first generation puparia in 2004 when placed in moistened vials at room temperature (Table 1).

Adult parasitoids from second generation puparia emerged in August each year. Emergence ranged from 2% in 2004 to 20% to 28% at all sites in 2003 and 2005 (Table 2). In 2007, 96 adult parasitoids were collected at Glenlea and Winnipeg from first and second generation puparia in the same year of development. *Homoporus* spp. at 47% was the most abundant, followed by *P. eubius* (16%), *A. zosimus* (15%), *T. americana* (13%), *P. hiemalis* (6%) and *P. poaphilum* (4%).

Parasitoid mortality. Larval or pupal mortality of parasitoids in second generation Hessian fly puparia at all sites ranged from 15% in 2004 to 35% at LaSalle in 2005 (Table 2). In all years, severe decomposition of immature parasitoids at plant maturity prevented species identification.

Adult parasitoids captured on the sticky traps were too damaged by blown soil or plant debris to be identified to species. Maintaining the integrity of the parasitoids was necessary in order to differentiate these species from many others captured on the traps. Cone traps in 2004 were more selective, capturing one adult of *Homoporus* spp. on 17 June and 7 July, one *P. eubius* on 17 June and 21 July, and one *T. americana* on 21 July.

DISCUSSION

Hymenopterous parasitoids are the main cause of puparial mortality of first and second generation Hessian flies in southern Manitoba. Parasitism was highest in second generation puparia. Its prevalence of about 75% in this study was similar to levels at many sites from the spring generation in the Atlantic states (Hill *et al*. 1939), the north-central states of Illinois, Indiana, Michigan, and Ohio (Hill 1953), and in the eastern states of Pennsylvania, Maryland, and Virginia (Hill and Smith 1928) before resistant cultivars were introduced. Combined with other mortality factors, fewer than 13% of second generation puparia in Manitoba emerge as adult Hessian flies the following spring. At sites of exceptionally high parasitism, mortality of second generation puparia can exceed 99%.

By comparison, parasitism had less impact on the survival of first generation Hessian flies. Puparial mortality by parasitism reduced first generation populations during the three years by about 22%. First generation flies include univoltine and bivoltine populations (Wise 2007), and since the first generation phenology of these two populations do not differ, it is likely the early season parasitoids do not discriminate between univoltine and bivoltine flies. Thus, the impact of parasitism on reducing Hessian fly populations in Manitoba is mainly against bivoltine populations.

Parasitoid emergence and mortality. There was no evidence from the exuviae that adult parasitoids emerged in the field from first generation Hessian fly puparia in the same year of larval development. Adult emergence in the same year, though, from second generation puparia was consistently between 20% and 28% at all sites and years, except in 2004. Weather conditions that year were much colder throughout the growing season than during the two other years of the study (Wise 2007).

All four parasitoid species common to second generation populations emerged in the same year of their development (Table 3). The number of adult parasitoids collected was insufficient to provide an accurate assessment on whether this emergence impacts

the relative abundance of these parasitoid species in second generation Hessian fly, but *A. zosimus* and *T. americana* may have a higher tendency than *P. eubius* or *P. poaphilum* to emerge in the same year. All Hessian flies at this time would be too far developed to be a suitable host for all these parasitoids, and, thus, adults would need to find an alternate host species to complete a second generation.

The combination of late season adult emergence and mortality can reduce parasitoid emergence from Hessian flies in the spring by over 60%. Most dead parasitoids found in host larvae were larvae, as opposed to pupae, and had been attacked by either fungi or bacteria. In all cases, the host larvae had also died and showed similar symptoms.

Parasitism by species. The highest cause of puparial mortality of the Hessian fly in Manitoba and by far the most dominant parasitoid species of Hessian fly in southern Manitoba was *P. eubius*. Its discovery on Hessian fly is a first for Canada. Previous reports of *P. eubius* in Canada and the United States from cereal pests were from the wheat stem sawfly, *Cephus cinctus* (Thompson 1955; Peck 1963; Peterson *et al*. 1968; Herting 1977; Burks 1979). Boucek and Askew (1968) reported *P. eubius* from the Hessian fly in Europe and Asia. *Pediobius eubius* is the fourth species of this genus to be identified as a parasitoid of the Hessian fly in Canada. The Hessian fly is known to be attacked by *P. nigritarsis* (Thomson) in Saskatchewan and Alberta (Peck 1963) and by two closely related species, *P. metallicus* (Nees) and *P. epigonus* (Walker), in Ontario and further east (Thompson 1955; Peck 1963). In the United States, *P. epigonus* is the dominant Hessian fly parasitoid species of this genus. It is one of three important parasitoid species of Hessian fly in Idaho (Bullock *et al*. 2004) and is found in Washington (Pike *et al*. 1983; Clement *et al*. 2003) and throughout the north-central and Atlantic states (Hill *et al*. 1939; Hill 1953). The prevalence of *P. epigonus* on the Hessian fly in all areas of the United States is below one-tenth that for *P. eubius* on second generation Hessian flies in Manitoba.

The presence of small numbers of *P. eubius* from first generation puparia in 2004 came during a year of unseasonably cool temperatures that delayed first generation Hessian fly development (Wise 2007). This delay could have allowed an opportunity for early emerging *P. eubius* to attack immature first generation flies. The capture in June of an adult of *P. eubius* in 2004, and the absence of this parasitoid in first generation flies in other years indicates *P. eubius* can emerge early enough to attack this generation of Hessian flies but its frequency is rare.

Platygaster hiemalis was the most common parasitoid of first generation puparia and the second most important parasitoid of Hessian fly in southern Manitoba. This species occurs throughout the wheat growing areas of Canada and the United States (Muesebeck 1979). It is considered the most important parasitoid of Hessian fly in North America (Gahan 1933) and is the only parasitoid to attack the fall generation on winter wheat. Its prevalence of 10% to 24% in Manitoba is lower than in Atlantic states (Hill 1926), about equal to that in Idaho (Bullock *et al*. 2004), and mostly higher than in north central states (Hill 1953).

This parasitoid does attack the second generation in Manitoba but at far lower frequencies than in the spring. In the early season collection of 2004, adult *P. hiemalis* emerged

without overwintering, indicating this species in Manitoba does not have an obligatory diapause. Thus *P. hiemalis* in southern Manitoba may have a partial second generation. In Oregon, *P. hiemalis* is reported to have two generations per year (Gahan 1933). However, none of nearly 1150 first generation exuviae in 2003 and 2004 showed signs of parasitism by *P. hiemalis*. Parasitism of second generation flies by this species was likely from late emerging overwintered adults attacking the eggs of early ovipositing second generation female Hessian flies. Hill (1926) found *P. hiemalis* throughout the eastern states to have only one generation per year.

The second most common parasitoid of second generation flies was the eulophid, *A. zosimus*. This is the first documented evidence of its presence in Manitoba. It previously had been reported in Canada on Hessian fly from Ontario (Peck 1963). Burks (1979) reported it as being generally distributed in wheat growing areas of Canada and the United States. In most of its range in the United States, parasitism by *A. zosimus* is <1% (Hill *et al*. 1939; Hill 1953). The only reports of *A. zosimus* parasitism comparable to or higher than our 2003 or commercial field results were from unpublished notes by P. M. Myers (Gahan 1933) in Indiana (12%) and from a collection of 100 puparia in 1932 (34%) at Mannsville, New York (Hill *et al*. 1939). Adults of *A. zosimus* may emerge from Hessian fly in late summer but it is unknown if this species produces a second generation on a different host.

The pteromalid, *Homoporus* sp., collected in our studies is likely *H. destructor*, which is already known from Manitoba. A second species in this genus, *H. febriculosus*, has not been recorded from Manitoba but is found in Saskatchewan (Peck 1963). *Homoporus destructor* is found throughout the United States in many areas at a higher prevalence than in our studies (Hill *et al*. 1939; Hill 1953; Bullock *et al*. 2004). It is the most abundant parasitoid of late brood Hessian fly in Texas (Schuster and Lidell 1990), and a *Homoporus* sp. in Washington, likely *H. destructor* (Clement *et al*. 2003), was the dominant parasitoid of the Hessian fly (Pike *et al*. 1983).

The two *Homoporus* spp. known from western Canada oviposit directly into puparia (Gahan 1933). The presence of *Homoporus* sp. in first and second generation flies in all years and at all sites is consistent with the capture of an adult in cone traps in 2004 in mid-June and early July. The latter time coincides with the usual onset of second generation puparial development of the Hessian fly (Wise 2007). *Homoporus* sp. does not require an overwintering period to complete its development in Manitoba, but there is no evidence from examinations of exuviae of first generation Hessian flies that *Homoporus* sp., as for *P. hiemalis*, have more than one generation in Manitoba.

The two parasitoid species of the Hessian fly of least abundance in our studies, *T. americana* and *P. poaphilum*, greatly differ in their presence in North America. *Trichomalopsis americana* is a common Palaearctic pteromalid parasitoid of Diptera in Canada and the United States (Gibson and Floate 2001). When found on Hessian fly, it is always at very low populations (Hill 1953; Bullock *et al*. 2004). The Nearctic pteromalid, *Panstenon poaphilum,* has been found in Alberta and Manitoba in Canada and in six American states (Heydon and Boucek 1992), but this is the first record of this species parasitizing the Hessian fly. The only *Panstenon* sp. previously known to parasitize the Hessian fly is the Eurasian species, *P. oxylus* (Walker) (Herting 1978, Xiao and Huang 2000). This species is not known to occur in North America.

The addition of *P. eubius*, *A. zosimus*, and *P. poaphilum* increases the number of documented chalcidoid parasitoids of the Hessian fly in Manitoba to nine species. Three other species, *Chrysocharis pentheus* Walker (Hansson 1987), *Eupelmus allynii* French (Peck 1963; Burks 1979), and *Trichomalopsis viridescens* (Walsh) (Gibson and Floate 2001) are known from Manitoba but were not found in this study. At least four other species, including *Eupelmus vesicularis* (Retzius) and *Eurytoma atripes* Gahan, because of their presence to the west in Saskatchewan and to the south in North Dakota (Peck 1963), which have similar Hessian fly habitats, may also be present in Manitoba.

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Table 1. Parasitism by species of first generation *Mayetiola destructor* (Say) on spring wheat at Glenlea, Manitoba in 2003-2005 and 2007.

Year	Sampling Date	Puparia (n)	Parasitism (%) Total	*Platygaster hiemalis*	*Homoporus* sp.	*Pediobius eubius*	*Panstenon poaphilum*
2003	Late*	900	19.9	9.4	10.5	0	0
2004	Early†	703	23.0	21.0	2.0	0	0
	Late	497	27.7	24.2	2.9	0.4	0.2
2005	Late	344	18.3	12.2	6.1	0	0
2007	Late	80	26.3	12.5	13.8	0	0

*Puparia collected at plant maturity in September or October.
†Puparia collected in July and/or August and not overwintered.

Table 2. Parasitism of second generation *Mayetiola destructor* (Say) by species, and parasitoid losses by autumn emergence of adults and mortality of larvae and in southern Manitoba, 2003-2005.

	Glenlea			LaSalle	Otterburne	Rosenhoff
Year	2003	2004	2005	2005	2005	2005
Puparia (n)	800	433	48	200	62	365
Parasitism (%)	73.9	78.8	72.9	68.0	85.5	73.4
Platygaster hiemalis	0.9	3.5	6.3	0	0	3.0
Homoporus sp.	3.5	0.7	8.3	1.4	3.2	2.5
Pediobius eubius	52.4	69.7	41.7	58.6	59.7	49.6
Panstenon poaphilum	2.6	1.4	4.2	0	0	1.9
Aprostocetus zosimus	8.8	3.0	8.3	8.0	22.6	14.8
Trichomalopsis americana	5.6	0.5	4.2	0	0	1.4
Parasitoid Losses (%)	50.7	17.0	48.6	62.5	54.7	38.4
Early emergence*	25.7	2.0	22.9	27.9	26.4	20.5
Mortality†	25.0	15.0	25.7	34.6	28.3	17.9

*Percentage of adults that emerged without completing an overwintering diapause.
†Percentage of parasites that died as larvae or pupae in Hessian fly puparia.