Parasitoids of the Hop Aphid (Homoptera: Aphididae) on *Prunus* during the Spring in Washington State[1]

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ABSTRACT In 1999, 802 primary parasitoids and 1,448 hyperparasitoids were reared from 83 samples of hop aphids, *Phorodon humuli* (Schrank), collected from *Prunus* sp. at 47 sites in the hop-growing area of south central Washington. In 2000, we collected 94 primary parasitoids and 180 hyperparasitoids in 59 samples from 28 sites. Parasitoids (primary plus hyperparasitoids) were reared from over 86% of the samples in 1999 and 61% of the samples in 2000. *Lysiphlebus testaceipes* (Cresson) was the most abundant primary parasitoid, accounting for 81.6% of the primary parasitoids in 1999 and for 52.1% in 2000. *Praon unicum* Smith was second in abundance with 14.3% in 1999 and 37.2% in 2000. Other primary parasitoids were Aphelinidae (0.9% in 1999 and 4.3% in 2000), *Aphidius ervi* Haliday (1.0% in 1999 and 1.1% in 2000), *Diaeretiella rapae* (M'Intosh) (0.3% in 1999 and 0% in 2000), and *P. occidentale* Baker (0.4% in 1999 and 0% in 2000). Aphelinidae have not been reported previously from hop aphids. *D. rapae* and *P. occidentale* Baker are new records for the hop aphid on *Prunus*. Hyperparasitoids were in the genera *Alloxysta* (Charipidae), *Asaphes* and *Pachyneuron* (Pteromalidae), and *Dendrocerus* (Megaspilidae). This initial study indicates that the primary parasitoids have potential as biological control agents.

KEY WORDS Homoptera, Aphididae, *Phorodon humuli*, *Humulus lupulus*, hops, *Prunus*, parasitoids, *Lysiphlebus testaceipes*, *Brachycaudus helichrysi*, *Praon unicum*

The hop aphid, *Phorodon humuli* (Schrank), alternates between hop, *Humulus lupulus* L., in the summer and certain *Prunus* spp. in the winter (Wright et al. 1995), and is a major pest of hops in most of the hop-growing areas of the Northern Hemisphere (Neve 1991). Heavy infestations reduce hop yield and lower quality by producing honeydew, which allows sooty mold to grow in the hop cones (Neve 1991). In Washington, hops are grown in the south central part of the state, where growers usually apply insecticides at least once during the growing season to control hop aphids. On fruit trees, growers typically apply a delayed-dormant spray to control aphids. Large numbers of hop aphids on ornamental trees are a

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nuisance because of the honeydew they produce and their tendency to reduce tree growth.

Hop aphid parasitoids are rare on hops in Washington (Campbell & Cone 1994, Pike & Starý 1995) and England (Copland 1979). The use of pesticides has been given as a reason for the low numbers on hops, but parasitization is also rare on unsprayed hops (Pike & Starý 1995). The hop aphid is an introduced insect, therefore, the indigenous parasitoids may not have adapted to the aphid on hops. However, hop aphids are commonly parasitized during the spring on *Prunus* trees. The purple-leaf ornamental tree, *Prunus cerasifera* Ehrhart, also known as cherry plum or Myrobalan plum ('Thundercloud' is probably the most popular variety), appears to be the major source of hop aphids in the spring in south central Washington (L. C. W., unpublished data). At least part of the reason for this is because ornamental trees are more abundant than fruit trees. The ornamental trees are not usually treated with insecticides, so they may be good sites for parasitoids to increase and reduce the number of hop aphids.

Pike & Starý (1995) listed the known hop aphid parasitoids from around the world. Pike et al. (2000) list eight primary parasitoids (Braconidae: Aphidiinae) of hop aphids from the northwest United States, four of which were found only on hops. No work has been reported on the relative numbers of the primary parasitoids or on the hyperparasitoids. Our objective was to identify and determine the relative abundance of primary parasitoids and hyperparasitoids attacking hop aphids on *Prunus* during the spring in the hop growing areas of Washington.

Materials and Methods

Leaf samples were collected from the hop growing areas of the Yakima and Moxee Valleys in south central Washington. We sampled from 22 April to 16 June 1999 and from 31 March to 14 June 2000. Most of the hop aphids had emigrated from *Prunus* by the middle of June in both years. *Prunus* trees were located by driving the roads of the area with observers visually searching for trees. The sampling method was similar to that used by Pike & Starý (1995). Trees were examined for hop aphids, and infested leaves were clipped and placed in 10 cm diameter × 4 cm deep (300 ml) round plastic containers covered with fine nylon screen. One sample was taken from each infested site. No site was more than about 0.5 ha. The number of leaves per sample was not constant because the number of infested leaves varied among trees and the number of trees varied among sites. The aphids were identified and the relative number of each species was estimated. Parasitoids were allowed to emerge in the containers, which were stored in the laboratory at 20–26°C. Parasitoids were removed from the containers every 2 to 3 days and were placed in vials of 70% ethanol. About 2 months after the last collection, we removed the dead parasitoids that remained in the containers and placed them in the ethanol vials. In 1999, 83 samples were collected from 47 sites. Seventy-eight samples were from purple-leaf ornamental varieties and five were from green-leaf varieties. In 2000, 59 samples were taken from 28 sites, all from purple-leaf plum trees. We identified the parasitoids using the key in Pike et al. (1997). The key in Pike & Starý (1995) was also used to confirm the identification of some of the primary parasitoids. We used the keys in Goulet & Huber (1993) to confirm the identifications of the Aphelinidae to family. The keys allowed identification of *Praon* and *Aphidius* males only to genus. If a

sample had only one species of *Praon* or *Aphidius* female, we assumed the males were the same species. In mixed-species samples or samples that had only males, the males were identified to genus only. Hyperparasitoids (secondary parasitoids), which parasitize primary parasitoids, were identified to genus. The keys did not separate *Asaphes* from *Pachyneuron*, therefore, they are combined in this paper. Relative abundance is defined as (P / T) × 100, where P = the number of individuals of a species or genus and T = total number of parasitoids. Primary parasitoids and hyperparasitoids were calculated separately.

Results and Discussion

In 1999, the hop aphid was found alone in 36 samples, the leaf-curling plum aphid, *Brachycaudus helichrysi* (Kaltenbach), was found alone in one sample, and 46 samples had both species. The mealy plum aphid, *Hyalopterus pruni* (Geoffroy), was found in two samples with the other two aphids. Hop aphids were more abundant than the leaf-curling plum aphid in all but five of the mixed colonies. In 2000, hop aphid was the only species in 52 samples, *P. humuli* and *B. helichrysi* were found together in the remaining seven samples, and of those, *P. humuli* numbers were the largest in five. No *H. pruni* were found in 2000.

Parasitoids were very common in both years, but the percentage of samples with parasitoids declined dramatically from 1999 to 2000 (Table 1). We collected about 30% fewer samples in 2000 compared with 1999, but the number of parasitoids declined over 87%. Parasitism apparently varies considerably from year to year. Hyperparasitoids outnumbered primary parasitoids both years at a ratio of approximately 65% to 35% (Table 1).

Lysiphlebus testaceipes (Cresson) was the most common primary parasitoid both years (Table 2). It accounted for over 81% of the primary parasitoids and was found in over 62% of the samples in 1999. In 2000, just over one-half of the primary parasitoids were *L. testaceipes* and it was found in almost 24% of the samples (Table 2). This parasitoid previously has been found parasitizing hop aphids on *Prunus* and hops (Pike & Starý 1995, Pike et al. 2000). It has a wide host range, is probably native to North America, and is common in Washington (Mackauer & Starý 1967, Pike et al. 1997, 2000).

Hop aphid eggs hatch in February and March (L. C. W., unpublished data), therefore, parasitoids must be able to reproduce and develop during the late winter and early spring when temperatures are still low. *L. testaceipes* completed development at 12.8°C (Tyler & Jones 1974a) and emerged from aphid mummies at temperatures as low as 3.3°C (Tyler & Jones 1974b). *L. testaceipes* is active from April through November in Washington (Pike et al. 1997). Our earliest collections were on 26 April 1999 and 11 April 2000. Carroll & Hoyt (1986) found the parasitoid was most active during midsummer in north central Washington apple orchards and it overwintered on the shrub *Viburnum opulus* L., a host of *Aphis fabae* Scopoli. *L. testaceipes* appears to be well adapted to parasitizing hop aphids on *Prunus*.

Praon unicum Smith was second in abundance, accounting for over 14% of the primary parasitoids in 1999 and 37% in 2000 (Table 2). It was found in over 33% of the samples in 1999 and in over 11% in 2000 (Table 2). Because most of the *Praon* females were *P. unicum*, most of the *Praon* males are also likely to have been this species. Carroll & Hoyt (1986) studied the biology of *P. unicum* in north

Table 1. Number of samples with hop aphid parasitoids and total number of parasitoids collected from *Prunus* in 2 years of sampling.

	Year	
	1999	2000
Total no. of samples	83	59
Samples with parasitoids	72 (86.8%)	36 (61.0%)
Samples with no parasitoids	11 (13.3%)	23 (39.0%)
Samples with primary parasitoids	58 (69.9%)	26 (44.17%)
Samples with hyperparasitoids	61 (73.5%)	23 (39.0%)
No. of primary parasitoids	802 (35.6%)	94 (34.3%)
No. of hyperparasitoids	1,448 (64.5%)	180 (65.7%)

central Washington and concluded that it was the most important parasitoid of the apple aphid, *Aphis pomi* De Geer, mainly because it was active early in the season. *P. unicum* has been reported on hop aphids on hops and on *Prunus salicina* (Pike et al. 2000).

Aphidius ervi Haliday, *Diaeretiella rapae* (M'Intosh), *P. occidentale* Baker, and the Aphelinidae together comprised less than 3% of the primary parasites in 1999 (Table 2). Only one *Aphidius* sp., a male, was collected in 2000. Aphelinidae were present in low numbers both years (Table 2). Neither *D. rapae* nor *P. occidentale* were recovered in 2000. All of the primary parasitoids except *D. rapae* and *A. ervi* were found in samples containing only hop aphids; this is verification that they parasitize hop aphids. The one sample with *B. helichrysi* alone (1999) contained *L. testaceipes* and a *Praon* male.

We found some parasitoids not previously recorded for the hop aphid or they have not been found on *Prunus*. Aphelinidae have not been reported from the hop aphid. *Aphidius ervi* was listed as an uncertain parasitoid of *P. humuli* on *Prunus* in western Washington (Pike et al. 2000). *D. rapae* has been reported attacking *P. humuli* and *B. helichrysi* on hops, but not on *Prunus* (Mackauer & Starý 1967, Pike & Starý 2000). *Praon occidentale* was found parasitizing hop aphids on hop, but not on *Prunus* (Pike & Starý 2000).

Several parasitoids have been reported parasitizing the hop aphid, but were not found in this survey. *Aphidius matricariae* Haliday has been found parasitizing hop aphids on hops in Washington, Europe, and Iran (Pike & Starý 1995, Pike et al. 2000). *Binodoxys conei* Pike & Starý has been recovered from Washington hops (Pike & Starý 1995). *Monoctonus campbellianus* Pike & Starý was reared from a mixed collection of aphids on *Prunus*, which included *P. humuli*. *Ephedrus persicae* Froggatt, *E. plagiator* (Nees), *P. volucre* (Haliday), and *Trioxys humuli* Mackauer have been reported as parasitoids of hop aphids in Europe (Pike & Starý 1995).

Wasps in the genus *Alloxysta* were the most numerous hyperparasitoids in 1999, followed by the pteromalids, *Asaphes* and *Pachyneuron*, and finally by *Dendrocerus* (Table 2). In 2000, *Asaphes* and *Pachyneuron* were the most abundant, closely followed by *Alloxysta* and only one *Dendrocerus*. Hyperparasitoids

Table 2. Primary parasitoids and hyperparasitoids reared from aphid samples collected from *Prunus* sp. in the hop growing areas of Washington during the spring of 1999 and 2000.

	Primary parasitoids																			
			Aphidiidae												Hyperparasitoids					
	Aphelinidae		*Aphidius ervi*		*Diaeretiella rapae*		*Lysiphlebus testaceipes*		*Praon occidentale*		*P. unicum*		*Praon* males		Charipidae *Alloxysta* sp.		Pteromalidae *Asaphes* and *Pachyneuron* sp.		Megaspilidae *Dendrocerus* sp.	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
No. of parasitoids	7	4	8	1[a]	2	0	654	49	3	0	115	35	13	5	845	80	514	99	89	1
Percent of parasitoids	0.87	4.26	1.00	1.06	0.25	0	81.55	52.13	0.37	0	14.34	37.23	1.62	5.32	58.36	44.44	35.50	55.00	6.15	0.56
No. of samples with parasitoids	4	4	3	1	2	0	52	14	2	0	28	7	6	5	51	16	42	13	12	1
Percentage of samples with parasitoids	4.82	6.78	3.61	1.69	2.41	0	62.65	23.73	2.41	0	33.74	11.86	7.23	8.47	61.45	27.12	50.60	22.03	14.46	1.70

[a]This specimen was a male, which could be identified only to genus.

exceeded primary parasitoids in both years. Over 73% of the samples in 1999 and 39% in 2000 contained hyperparasitoids (Table 1), indicating that they were well distributed among locations. *Alloxysta* wasps are endohyperparasitoids, which tend to be host specific and are generally the most abundant hyperparasitoids in native systems. The other hyperparasitoids we collected are ectohyperparasitoids, which are generalists and usually most numerous in exotic primary parasitoids (Sullivan & Völkl 1999).

This initial survey indicates that *L. testaceipes* and *P. unicum* may be promising biological control agents for the hop aphid on *Prunus*. The abundance and efficacy of overwintering parasitoids is likely to be a critical factor in regulating hop aphid populations on *Prunus* during the spring. The large number of hyperparasitoids may be a cause for concern, but the negative impact of hyperparasitoids on biological control is not necessarily of primary importance (Mackauer & Völkl 1993, Sullivan & Völkl 1999).

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