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PUPAL PARASITOIDS OF *YPONOMEUTA MALINELLUS* (LEPIDOPTERA: YPONOMEUTIDAE) IN NORTHEAST ASIA

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Abstract

Pupal parasitism of the apple ermine moth, *Yponomeuta malinellus* Zeller (Lepidoptera: Yponomeutidae), was investigated in northeast Asia with the goal of identifying potential biological controls of the moth, which threatened the apple industry in Washington State, USA during the 1980s. Seven primary and 2 secondary parasitoids were recorded from 27, 472 pupae collected and reared from a total of 20 collections at 16 sites in Korea, northern Honshu and Hokkaido Islands in Japan, and Shanxi Province in China during a 4-year period from 1988 to 1991. The mean total parasitism rate was highest in Korea (38.5%), while the lowest rate of 2.1% was recorded from Shanxi, China. The mean total parasitism rate detected from Hokkaido and Honshu Islands in Japan was 17.2 and 10.1%, respectively. The ichnueumonid wasp *Herpestomus brunnicornis* Gravenhorst dominated the parasitism in Korea and Japan, while *Coccygomimus disparis* (Viereck) was responsible for most mortality of the moth pupae in Shanxi, China. *Diadegma armillatum* (Gravenhorst) caused very low mortality in this study, although it is known as an important parasitoid from Europe and Eurasia. There were significantly different levels of parasitism rates of apple ermine moth pupae among geographical locations sampled, likely due to the habitat type and host plant of the apple ermine moth. *Herpestomus brunnicornis* collected from Korea and Japan was established in Washington State, USA as a biocontrol agent of the apple ermine moth.

Key Words: apple, biological control, China, Japan, Korea, *Malus*, parasitoid, *Yponomeuta malinellus*

Resumen

El parasítismo de la pupa de la polilla, *Yponomeuta malinellus* Zeller (Lepidoptera: Yponomeutidae), fue investigado en el noreste de Asia con la meta de identificar los agentes de control biológico potenciales de la polilla, que amenazó la industria de manzanas en el estado de Washington, EEUU durante la decada de los 1980. Siete parasitoides primarios y 2 parasitoides secundarios fueron registrados de los 27,472 pupas recolectadas y criados de un total de 20 colecciones en 16 sitios en Corea, la parte norte de las islas Honshu y Hokkaido en Japón, y la Provincia Shanxi Province en China durante un periodo de 4 años de 1988 hasta 1991. El promedio total de parasitismo mas alto fue en Corea (38.5%), mientras que la tasa mas baja de 2.1% fue registrado en Shanxi, China. El promedio total de parasitismo detectado de las islas Hokkaido y Honshu en Japón fue 17.2% y 10.1%, respectivamente. La avispa ichneumonido, *Herpestomus brunnicornis* Gravenhorst, domino el parasitismo en Corea y Japón, mientras *Coccygomimus disparis* (Viereck) fue responsible para la mayoria de la mortalidad de las pupas de la polilla en Shanxi, China. *Diadegma armillatum* (Gravenhorst) causo mortalidad muy baja en este studio, aunque es conocido como un parasitoide importante en Europa y Eurasia. Hubo niveles diferentes significativos en la tasa de parasitismo de la pupa de la polilla entre las localidades geográficas muestreadas, a lo mejor debido a la clase de habitat y de la planta hospedera de la polilla. *Herpestomus. brunnicornis* recolectada en Corea y Japón fue establecido en el estado de Washington, EEUU como un agente de control biológico de la polilla.

The apple ermine moth, *Yponomeuta malinellus* Zeller (Lepidoptera: Yponomeutidae), is a univoltine defoliator of *Malus* species in Europe and Asia. In Asia, *Malus pumila* Miller (Forest Research Institute 1969; Moriuti 1977; Shin et al. 1983), *M. sieboldii* (Regel) (Moriuti 1977), *M. tor-*

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ingo Nakai (Issiki et al. 1975), *M. baccata* Borkhaurs, and *M. micromalus* Mak. (Forest Research Institute 1969) are known hosts of apple ermine moth.

Apple ermine moths lay egg masses on 1-3 year-old branches from mid to late summer. Larvae hatch from eggs in about 3 weeks, but remain underneath the egg mass covering (hibernaculum) throughout winter. At bud-break in early spring, first-instars leave the hibernaculum and each mine a single leaf. Larval stages form colony-like aggregations usually composed of siblings from the same egg mass. Larvae in the second through fifth-instars consume foliage, and groups of larvae form a tent over several leaf clusters. Mature larvae aggregate and spin their cocoons together in tightly clustered groups, often under undamaged leaves. Larvae pupate in early summer and adult emerge 1-2 weeks later (Junnikkala 1960; Lee & Pemberton 2007).

In the early 1980s, the apple ermine moth was established in the Pacific Northwest area of the U.S. and adjacent areas in Canada, where it was thought to be a potentially significant pest of apples. Low rates of parasitism in these areas contrasted with high parasitism throughout its native range in temperate Eurasia (Unruh et al. 1993) and Northeast Asia (Lee & Pemberton 2005, 2007). Surveys for parasitoids of apple ermine moth pupae were undertaken in Korea, northern and central Japan, and Shanxi Province in China from 1988 to 1991 to identify agents for biological control in North America. Data on the larval parasitoid complex of the apple ermine moth in these regions have been reported previously (Lee & Pemberton 2005, 2007). The objectives of our research were (1) to determine the species composition of parasitoids which emerged from pupal stage of Asian apple ermine moth and determine the relative mortality contributed by each parasitoid, and (2) to select promising parasitoids of apple ermine moth pupae for classical biological control.

MATERIALS AND METHODS

Study Sites

The parasitoids of the apple ermine moth and their parasitism rates were determined through collection and rearing of pupae in 4 geographic regions from 1988 to 1991. Collections were made during a total of 20 apple ermine moth seasons from 16 sites located in Honshu (in 1988 and 1989) and Hokkaido (1991), Japan, Shanxi, China (1990), and Korea (1989-1991).

In Korea, collections were made in Hongchon (37.5 and 38°N latitude by 127.5 and 128°E longitude), Kangwondo and at Mt. Yongmoon (37 and 37.5°N by 127 and 127.5°E), Kyonggido both in 1989-1991. Mt. Yongmoon is 50 km east of Seoul. Collections of *Y. malinellus* were made from *Malus baccata* Borkh. at 4 sites along the Yongpochon stream, from sites 500 m apart. Hongchon is 78 km northeast of Seoul. Collections were made from *M. baccata* at 3 sampling sites that were 1-1.5 km apart. This site was a natural area site located in Kangwon Univ. Forestry Experimental Station (Bukbang-ri). *Yponomeuta malinellus* were usually collected by cutting branches with tents from positions just above the ground 0-5 m above the ground. Branches with tents were bagged and chilled during transport to the laboratory where they were transferred to rearing cages. Apple ermine moth density was low at Mt. Yongmoon, and <30 pupae were collected annually in 1990 and 1991. A total of 1307 pupae were collected in Korea in 1989-1991. Data from sites with <50 pupae were not quantitatively analyzed (Tables 1 and 3).

In Japan, collections on Hokkaido were made in 3 abandoned orchards, located within 41-42°N and 141 and 145°E, where a total of 5,194 pupae were collected in early Jul 1991. Collections in northern Honshu Island were made within a region circumscribed by 39 and 41°N by 140-141°E. Seven collections were made at 5 sites in Honshu, totaling 8,108 pupae from both natural habitats and abandoned orchards in Jul in 1988 and 1989.

Surveys in China were made in Shanxi Province (36-40°N by 110-114°E) southwest of Beijing. A total of 12,863 apple ermine moth pupae were collected from cultivated orchards at 5 sites in mid Jun, 1990-1991. Information related to these samplings including habitat characteristics is described in Table 1.

Rearing

Pupae were reared inside the laboratory at ambient temperatures to obtain parasitoids. Pupae were separated from cocoon clusters and placed in groups of 5 in Petri dishes (1.5 by 6 cm, or 1.0 by 5 cm), or in groups of 20 in Petri dishes (1.5 by 9 cm), and held for moth or parasitoid emergence.

Analysis

Parasitoids of the apple ermine moth pupae were evaluated from 20 different collections from 16 sites of 4 geographical regions in 3 countries (Table 1). Most sites were sampled once, although Korean sites were sampled in each of 3 successive years, while some were sampled in 2 consecutive years. Samples from different dates in the same season were pooled by site to calculate parasitism rates. Parasitism rates were calculated for each of the 7 primary parasitoids found in the study areas. The rate of parasitism was calculated by dividing the number of emerged parasitoids by the total number of pupae collected. Four

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TABLE 1. COLLECTION DATA FOR APPLE ERMINE MOTH PUPAE IN 4 GEOGRAPHIC REGIONS AND THEIR HABITAT CHARACTERISTICS.

Locality	Collection Date	Number of hosts collected	Host plant	Elevation	Habitat[1]
Shanxi Province, China					
Daren	Jun. 20, 90’	1952	*M. asiatica*	900m	C
Hejiabu	Jul. 18, 90’	362	*M. asiatica*	—	C
Nanzhang	Jun. 11, 91’	8608	*M. asiatica*	—	C
Song Zhuang	Jun. 18, 90’	150	*M. asiatica*	—	C
Wang Guan Ren	Jun. 19, 90’	1791	*M. asiatica*	1062m	C
Japan, Hokkaido Island					
Abashiri (NFG)	Jul. 04, 91’	5001	*M. pumila*	—	A
Abashiri (NFRI)	Jul. 04, 91’	56	*M. pumila*	—	A
Kamibibi	Jul. 02, Jul. 05, 91’	137	*M. pumila*	—	A
Japan, N. Honshu Island					
Mt. Appi	Jul. 26, 88’	446	*M. sieboldii*	850m	N
Mt. Appi	Jul 05, 89’	773	*M. sieboldii*	850m	N
Morioka	Jul. 26, 88’	512	*M. halliana*	200m	A
Morioka	Jun 27, Jul. 06, 89’	2711	*M. pumila*	620m	A
Kuzakai	Jul. 28, Jul. 06. 89’	2829	*M. baccata*	793m	N
Tashiro-Aomori	Jul. 01, 89’	158	*M. sieboldii*	610m	N
Tashiro-Iwate	Jun. 27, Jul. 05, 89’	679	*M. sieboldii*	620m	N
Korea, Kyonggi Province					
Mt. Yongmoon	Jun. 09-22, 89’	205	*M. baccata*	100-200m	N
Mt. Yongmoon	Jun. 14, 90’	19	*M. baccata*	100-200m	N
Mt. Yongmoon	Jun. 19, 91’	29	*M. baccata*	100-200m	N
Korea, Kangwon Province					
Hongchon	May 30-Jun. 27, 89’	265	*M. baccata*	200-300	N
Hongchon	Jun. 14-Jun. 27, 90’	630	*M. baccata*	200-300	N
Hongchon	Jun. 18, 91’	159	*M. baccata*	200-300	N

[1]C = cultivated orchard, A = abandoned orchard, N = natural habitat.

indices were developed to evaluate parasitoid importance by geographical region, as follows: (1) site-specific percentage parasitism for each parasitoid was calculated by dividing the number of pupae from which parasitoids emerged by the number of hosts collected from each site, (2) mean parasitism rates for each parasitoid species were obtained by averaging all the rates of parasitism across sites within each geographic region, (3) total parasitism was calculated by adding the number of host individuals parasitized by all parasitoids in the samples of a season collection at a particular site divided by total individuals collected, and (4) mean total parasitism (mean season parasitism for each geographic region) was calculated by averaging all the total parasitism values for all sites within each geographic region.

To compare parasitism rates between countries, we used mean parasitism rates for each parasitoid species and mean total percentage parasitism. Kruskall-Wallis tests in PROC Npar1way (SAS Institute 2004) were used because data were not normally distributed. Percentages were arcsine-transformed and one-way ANOVA, followed by Tukey’s Studentized Range (HSD) test in PROC GLM (SAS Institute 2004) was used to test for differences among multiple means.

Identification of Natural Enemies

Species identifications or confirmations were made by J. Papp (Braconidae) (Hungarian Natural History Museum, Budapest, Hungary), H. Shima (Tachinidae) (Kyushu University, Fukuoka, Japan), R. W. Carlson (Ichneumonidae), E. E. Grissell (Pteromalidae), and M. E. Schauff (Encyrtidae and Eulophidae) (USDA-ARS, Washington, DC).

RESULTS

A total of 7 primary and 2 secondary parasitoids (hyperparasitoids) were reared from the 4 geographical regions sampled, with each region producing 3 to 5 species of primary parasitoids (Tables 2 and 3). Parasitoid diversity was higher

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TABLE 2. PUPAL PARASITOIDS OF APPLE ERMINE MOTH IN NORTHEAST ASIA.

Taxa	Host stage (Attacked / Emerged)
Hymenoptera	
Ichneumonidae	
Coccygomymus disparis (Viereck)[1, 2, 3]	Pupa-Pupa
Diadegma armillatum (Grav.)[1, 2, 3]	Larva-Pupa
Herpestomus brunnicornis Grav.[2, 3]	Larva-Pupa
Eulophidae	
Aprostocetus sp.[1]	Larva-Pupa
Pteromalidae	
Pteromalus spp.[a, 1, 2, 3]	*D. armillatum* pupa
Tricomalopsis sp.[a, 2]	*D. armillatum* pupa
Diptera	
Tachinidae	
Bessa parallella (Meigen)[1, 2]	Larva-Pupa
Nemorilla floralis (Fallen)[2]	Larva-Pupa
Zenillia dolosa (Meigen)[3]	Larva-Pupa

[a]Hyperparasitoid.
[1]Parasitoid species found in China.
[2]Parasitoid species found in Japan.
[3]Parasitoid species found in Korea.

in Korea and Japan (5 species) than in China (3 species) (Table 3). Korea and Japan shared 3 species of primary parasitoids and these included the 2 species also found in China (Table 3). *Herpestomus brunnicornis* Gravenhorst (Hymenoptera: *Ichneumonidae*) was the most important parasitoid in Korea and Japan (Table 3). *Coccygomimus disparis* (Viereck) (Hymenoptera: Ichneumonidae) and *Diadegma armillatum* (Grav.) (Hymenoptera: Ichneumonidae) were reared from collections from all 3 countries. Total parasitism rates varied by geographic region (χ^2 =14.0568, *df* = 3, *P* = 0.0028; Kruskall-Wallis test) (Table 3), being highest (38.7%) in Korea and lowest (2.1%) in China. The mean total parasitism rates in Japan were 16.1% ± 1.4 in Hokkaido and 10.1% ± 7.6 in Honshu. The mean total parasitism rates for islands in Japan was not significantly different (*F* = 20.86, *df* = 3, *P* = <0.0001; Tukey's studentized range (HSD) test).

There was a significant difference in mean parasitism rates for three of the seven parasitoid species among the countries: *H. brunnicornis* (χ^2 = 14.2805, *df* = 3, *P* = 0.0025) (*F* = 17.42, *df* = 3, *P* = <0.0001); *Bessa parallela* (Meigen) (Diptera: Tachinidae), (χ^2 = 7.9335, *df* = 3, *P* = 0.0474) (*F* = 3.09, *df* = 3, *P* = 0.0497); and *Zenillia dolosa* (Meigen) (Tachinidae) (χ^2 = 12.5462, *df* = 3, *P* = 0.0057), (*F* = 11.70, *df* = 3, *P* = 0.0003).

When apple ermine moth was classified for habitat types such as natural, abandoned, and cultivated habitats, there was a significant difference in mean total parasitism rates among the habitat types (χ^2 = 7.757, *df* = 2, *P* = 0.0207; Kruskall-Wallis test) (Table 3). The level of mean total parasitism was 2.1% ± 4.7 in cultivated orchards, which is significantly lower than 21.4% ± 17.9 in natural habitats and 16.1% ± 7.0 in abandoned orchards (*F* = 8.49, *df* = 2, *P* = 0.031; Tukey's studentized range (HSD) test). We compared host plant specific parasitism for three different hosts such as *M. baccata*, *M. pumilla*, and *M. sieboldii*, eliminating other host plant data with single collection and found a significant difference between the mean total parasitism by parasitoids (*F* = 5.12, *df* = 2, *P* = 0.0294). The parasitism was significantly lower on *M. sieboldii* (8.0% ± 4.0) than on *M. baccata* (32.2% ± 17.4) or on *M. pumila* (18.5% ± 5.21), suggesting that host plant effect is also associated with level parasitism rates experienced in geographical regions.

DISCUSSION

Parasitoids preferring natural habitat or abandoned orchards to cultivated orchard might be a possible explanation to higher parasitism rates in Korea and Japan compared to China. Lill et al. (2002) reported that host plant identity had a large influence on parasitism levels experienced by herbivores. Similarly host plant effects also could be possible factors affecting levels of parasitism rate by the parasitoid of apple ermine moth.

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TABLE 3. PUPAL PARASITISM[1] OF APPLE ERMINE MOTH IN CHINA, JAPAN, AND KOREA, 1988-1991.

		Percentage parasitism[1] (no. hosts parasitized) by each parasitoid									
Locality (year)	Number of hosts collected	*Coccygomimus disparis*	*Diadegma armillatum*	*Herpestomus brunniconis*	*Bessa parallela*	*Nemorilla floralis*	*Zenillia dolosa*	*Aprostocetus* sp.	*Pteromalus* sp.	*Tricomalopsis* sp.	Total % parasitism
Shanxi, China											
Daren (90')	1952	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
Hejiabu (90')	362	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nanzhang (91)	8608	10.5	+[2]	0.0	+	0.0	0.0	0.0	0.1	0.0	10.54
Song Zhuang (90')	150	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wang Guan Ren (90)	1791	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean (± SD)		2.1 ± 4.7	+	0.0 ± 0.0 c	+ b	0.0 ± 0.0	0.0 ± 0.0 b	0.0 ± 0.0	0.02 ± 0.04	0.0 ± 0.0	2.1 ± 4.7 c
Hokkaido, Japan											
Abashiri (NFG) (91')	5001	15.3	+	0.0	0.2	+	0.0	0.0	+	0.0	15.6
Abashiri (NFRI) (91')	56	0.0	0.0	14.4	0.0	0.0	0.0	0.0	0.0	0.0	14.4
Kamibibi (91')	137	0.0	0.0	18.2	0.0	0.0	0.0	0.0	0.0	0.0	18.2
Mean (± SD)		5.1 ± 8.8	+	12.0 ± 10.4 b	0.07 ± 0.13 ab	+	0.0 ± 0.0 b	0.0 ± 0.0	+	0.0 ± 0.0	16.1 ± 1.4 b
Honshu, Japan											
Mt. Appi (88')	446	2.2	0.0	10.8	0.4	0.0	0.0	0.0	0.0	0.0	13.4
Mt. Appi (89')	773	0.0	0.0	1.2	2.8	0.0	0.0	0.0	0.0	0.0	4.0
Morioka (88')	512	6.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	6.5
Morioka (89')	2711	11.1	0.07	14.8	0.0	0.0	0.0	0.0	0.2	0.0	25.97
Kuzakai (89')	2829	+	0.0	5.73	0.3	0.0	0.0	0.0	0.0	0.0	6.07
Tashiro-Aomori (89')	158	0.0	0.0	4.4	3.8	+	0.0	0.0	0.0	0.0	8.2
Tashiro-Iwate (89')	679	0.0	0.0	5.5	0.7	0.0	0.0	0.0	0.0	0.0	6.2
Mean (± SD)		2.8 ± 4.3	0.01 ± 0.03	6.1 ± 5.1b	1.14 ± 1.52 a	+	0.0 ± 0.0 b	0.0 ± 0.0	0.03 ± 0.08	0.03 ± 0.08	10.1 ± 7.6 b
Kyonggi-do, Korea											
Mt. Yongmoon (89')	205	0.0	0.0	26.8	0.0	0.0	2.4	1.5	0.0	0.0	30.7
Kangwon-do Korea											
Hongchon (89')	265	0.0	0.0	44.5	0.0	0.0	1.88	0.0	0.0	0.0	46.38
Hongchon (90')	630	0.0	0.0	25.2	0.0	0.0	2.7	0.0	0.0	0.0	27.9
Hongchon (91')	159	0.6	1.3	47.8	0.0	0.0	0.0	0.0	0.6	0.0	49.7
Mean (± SD)		0.2 ± 0.3	0.3 ± 0.7	36.1 ± 11.7 a	0.0 ± 0.0 c	0.0 ± 0.0	1.70 ± 1.2 a	0.38 ± 0.75	0.2 ± 0.3	0.0 ± 0.0	38.7 ± 11.6 a

[1]Mean parasitism rates for each parasitoid and total mean parasitism for each geographic region in the same column followed by the same letter are not significantly different. Mean comparisons were analyzed by Tukey's studentized range (HSD) test at $P = 0.05$. An arcsine square root transformation was applied to the percentage data to normalize their distribution. However, original means (± SD) are used for data presentation. [2]+ Indicates presence of parasitism of <0.05.

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The most important parasitoid of apple ermine moth in Asia, *Herpestomus brunicornis,* is a solitary, oligophagous, univoltine parasitoid, passing the fall, winter, and spring as an adult. Early the following summer, females find and parasitize fifth-instars, prepupae, or pupal hosts (Kuhlmann 1996). This species was able to attack larval stages, with attacks beginning on young larvae and causing a considerable mortality in mid-instars in Korea (Lee & Pemberton 2007). However, much higher parasitism rates occur in pupae than in larvae (8.7 in Korea and 2.3% in Japan) (Lee & Pemberton 2005). The low parasitism caused by *H. brunicornis* in larvae may be due to interspecific competition caused by other larval parasitoids, such as *Ageniaspis fuscicollis* (Dalman) (Hymenoptera: Eulophidae) that share host stages with this developing ichneumonid (Lee & Pemberton 2007).

Coccygomimus disparis was the most important parasitoid in China, although it caused a mean parasitism of only 2.1%. The highest percentage single collection parasitism in China was 10.5% obtained at Nanzhang in 1991. This parasitoid was the second most important parasitoid in Hokkaido and Honshu, where it produced a mean parasitism rate of 5.1 and 2.8% respectively. Relatively high parasitism by *C. disparis* occurred in both cultivated and abandoned orchards. Tylianakis et al. (2007) reported that generalist natural enemies such as *Melittobia acasta* (Walker) (Hymenoptera: Eulophidae) were more specialized in modified habitats, because of reduced attack rates on alternative hosts. This seems to be what occurred with *C. disparis* in this study. An ecological homologue of *C. disparis*, *C. turionellae* (L.) (Hymenoptera: Ichneumonidae), causes only about 1% parasitism in European apple ermine moth populations, (Junnikkala 1960; Balchowsky 1966).

There is a similarity in a taxonomic composition and the suppressive role of the parasitoid complexes attacking the apple ermine moth in its native Asia and Europe. An apparent difference is the role of *Diadegma armilatum* (Hymenoptera: Ichneumonidae). This species is a major parasite of ermine moths in Europe (Junnikkala 1960), causing relatively high percentage parasitism, ranging from 10 to 40% (Balachowsky 1966; Zayachavskas et al. 1979). By contrast, we found it to be an incidental parasitoid of the moth in Northeast Asia, having a mean parasitism rate of 0.3% in Korea and below 0.05% in the other regions. *Diadegma armilatum* also attacks the Apple ermine larvae in Northeast Asia but produces the low rates of parasitism of <0.1 (Lee & Pemberton 2005). *Diadegma armilatum* was attacked by the hyperparasites, *Pteromalus* sp. and *Tricomalopsis* sp. (Hymenoptera: Pteromalidae) in Korea and Japan. This hyperparasitism reached levels similar to the parasitism by *D. armillatum.*

Pteromalus sp. was recorded from all 4 countries with the mean parasitism rate of 0.2% in Korea and the rates of <0.02 in other countries, and *Tricomalopsis* sp. (0.03%) was recorded from Honshu only. However the European strain of the species was designated as a candidate for biological control of *Y. malinellus* in United States because it showed a higher physiological performance against *Y. malinellus,* regardless of its natal *Yponomeuta* host species (*Y. cagnagellus*) (Herard & Prevost 1997). The French strain of the wasp was released in 1989-1993 in Washington, but it has not established (Unruh et al. 2003).

Three species of tachinid parasitoids were reared from the pupae. The parasitism by *Bessa parallela* (Meigen) (Diptera: Tachinidae) was responsible for 1.1% mortality in Honshu, dominating the parasitism by tachinids. This parasitoid is also a larval parasitoid of the apple ermine moth, producing 18% parasitism in Japan (Lee & Pemberton 2005). *Bessa parallela* is a gregarious larval parasitoid of some serious lepidopteran pests such as *Pieris rapae crucivora* Boisduval (Pieridae) and *Pryeria sinica* Moore (Zygaenidae) (Shima 1999). *Bessa parallela* females lay microtype eggs on hosts which are eaten with leaf tissue by the host, and then larvae develop within the host's body, and finally kill the host (Shima 1999). It was broadly distributed in the Palearctic region, and has more than 20 recorded lepidopterous hosts (from many families), and has 2-3 generation per year in Japan (Herting 1960). *Nemorilla floralis* (Fallen) has been recorded as a larval parasitoid of *Cacoecia piceana* Linne (Tortricidae), *Cnaphalocrocis medinalis* Guenee (Pyralidae), *Euproctis flava* Bremer (Lymantriidae), and *Palpita nigropunctalis* Bremer (Pyralidae) (Yasumatsu & Watanabe 1965). It was reported to parasitize *Yponomeuta padellus* (L.) (Friese 1963), and is a larval-pupal parasitoid of *Y. evonymelus* (Lee & Pemberton 2009).

Zenillia dolosa was recovered only in Korea where it had a mean parasitism rate of 1.7%. *Zenillia dolosa* is a solitary larval- pupal parasitoid of apple ermine moth. This fly lays microtype eggs on host plants (Ho Thi Thu & Nakamura 2006). This tachinid caused its highest parasitism in fifth instars with the rate of 5.5% (Lee & Pemberton 2007). This parasitoid has not been known to attack apple ermine moth in Europe (Affolter & Carl, 1986) or Japan (Shima H. 1989, personal communication). It has been previously recorded from nine lepidopterous insects including *Hyphantria cunea* Drurry (Arctiidae) (Shima 1989, personal communication) and *Hyponomeuta padella* L. (Yponomeutidae) (Herting & Simmonds 1975).

Aprotocetus sp. (Hymenoptera: Eulophidae) was reared from only 3 pupae that were collected at Yongmoon, Korea in 1989 during the study and not elsewhere. We are uncertain that this species

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is an obligatory primary parasitoid as its occurrence was quite limited.

The ichneumonid *Herpestomus brunicornis* was successfully established from our collections in northwestern Washington (Unruh et al. 2003). A total of 252 Korean adult wasps were released in 1989 and 1990, and 159 Japanese wasps were released in 1989.

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