J. Fac. Agr., Kyushu Univ., **51** (1), 115–120 (2006)

Abundance of the Parasitoid Complex Associated with *Liriomyza* spp. (Diptera : Agromyzidae) on Vegetable Crops in Central and Southern Vietnam

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(Received October 26, 2005 and accepted November 16, 2005)

Field survey was conducted in 45 major vegetable growing municipalities in 20 provinces of five regions of central and southern Vietnam during November 2003 – July 2004 with the aim of recording parasitoid species associating with *Liriomyza* leafminers and their relative abundance on vegetable crops. Sampling of leafminer-infested leaves from 14 vegetable crops yielded 18 species of hymenopteran parasitoids. Among them, *Neochrysocharis beasleyi*, *N. okazakii*, *N. formosa* and *Asecodes delucchii* were abundant species. The most abundant parasitoid species reared from the leafminers on tomato and yard-long bean was *N. beasleyi*. This species was the second most abundant on French bean. *Neochrysocharis okazakii* was a major parasitoid species of the leafminers on onion and leaf mustard. *Neochrysocharis formosa* was the most abundant species of leafminers on casaba melon. This species was also the second most abundant on yard-long bean, tomato and onion. *Hemiptarsenus varicornis* existed on every host plant, and the second most major species on casaba melon. The results suggest the importance of different species of parasitoids in vegetable integrated pest management.

INTRODUCTION

The genus *Liriomyza* contains more than 300 species which are widely distributed in the New and Old Worlds but, nonetheless, most occur naturally in the temperate regions (Parrella, 1987). Approximately 23 species of *Liriomyza* have been reported as being economically important, and five of these are polyphagous, i.e. *Liriomyza sativae* (Branchard), *L. trifolii* (Burgess), *L. huidobrensis* (Branchard), *L. bryoniae* (Kaltenbach) and *Liriomyza strigata* (Meigen) (Spencer, 1973). Several *Liriomyza* species have been established in Vietnam (Table 1), becoming major pests in vegetable growing areas. Andersen *et al.* (2002) reported a detailed mapping of *Liriomyza* leafminers within Vietnam. Based on the report, *L. sativae* was the dominant species in 27 provinces of the north and south regions, while *L. huidobrensis* was only found in the Lam Dong province at attitudes of 1000–1800 m. *Liriomyza trifolii* has been reported from Ho Chi Minh City in the northeast south region by Tran (2000). The Asian species *Liriomyza chinensis* (Kato) has become a serious pest on onion fields in the whole country (Tran and Takagi, 2005).

Agromyzid leafminers are known to have rich natural enemy communities. Over 40 species of parasitoids have been recovered worldwide from *Liriomyza* spp. (Waterhouse and Norris, 1987) including 27 species in Japan (Konishi, 1998), 14 species in China (Murphy and LaSalle, 1999; Chen *et al.*, 2003), 11 species in Indonesia (Rauf *et al.*, 2000), 8 species in Malaysia (Murphy and LaSalle, 1999). Abundant parasitoid species belong to the families of Eulophidae (e.g. *Hemiptarsenus varicoris* (Girault), *Diglyphus isaea* (Walker), *Neochrysocharis formosa* (Westwood), *N. okazakii* Kamijo, *N.* sp., *Chrysocheris pentheus* (Walker)), Eucoilidae (e.g. *Gronotoma* sp.), Braconidae (e.g. Opius sp.), and Pteromalidae (e.g. *Halticoptera circulus* (Walker)) (Konishi, 1998; LaSalle, 1999; Murphy and LaSalle, 1999; Rauf *et al.*, 2000; Chen *et al.*, 2003). These communities of parasitoids have been recognized for their potential contribution to the integrated pest management (IPM) of leafminers in both glasshouses and open fields (Waterhouse and Noris, 1987; Minkenberg, 1990).

Because of the rapid increase and spread of leafminers, growers in Vietnam have frequently applied large quantities of insecticides, including dimethoate, fenitrothion, phenthoate, trichlorfon, fenobucarb, permethrin, ethofenprox, cypermethrin, thiamethoxam, cartap and abamectin, some of which are evidently harmful for beneficial insects. Applications of broad spectrum insecticides have resulted in a decrease of parasitoid abundance in the vegetable fields and development of pesticide resistance within fly populations, followed by an increase in leafminer density (Oatman and Kennedy, 1976; Saito *et al.*, 1996, Murphy and LaSalle, 1999, Johansen *et al.*, 2003). To control these pests by non-chemical means, it is necessary to first determine the parasitoid composition and to identify key native

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Table 1. *Liriomyza* leafminers on vegetable crops in Vietnam

Species	Location/ region	Crop	References
L. sativae	Whole country (27 investigated provinces)	French bean, tomato, cucumber, pumpkin, yard-long bean, mung bean, Chinese mustard, white gourd, pak-choi cabbage, lettuce, water melon	Andersen *et al.*, 2002
	Red River Delta	Mung bean, yard-long bean, pumpkin, tomato, cucumber, Chinese cabbage	Berit, 2001 Grimstad, 2004
	Red River Delta North Central Central Highland Northeast South	Tomato, potato, cucumber, pumpkin, beans, cotton	Ha, 2001
	Northeast South	Cucumber	Tran *et al.*, 2005b
L. huidobrensis	Central highland	Potato, garden pea, French bean, cucumber, mung bean, green bean, tomato, onion, lettuce	Andersen *et al.*, 2002
L.chinensis	Northeast South	Onion, cucumber, pumpkin	Andersen *et al.*, 2002
L. trifolii	Northeast South	Leaf mustard, lettuce	Tran, 2000; Ha, 2001
L. bryoniae	Red River Delta	Mung bean	Grimstad, 2004

species. Native parasitoids play an important role in the suppression of leafminer populations (Saito *et al.*, 1995).

Very few surveys for parasitoid fauna of leafminers has been conducted in Vietnam. The first documented parasitoid composition of leafminers, in general, was reported by Thang (1999). Eleven species of parasitoids associated with leafminers in vegetable crops were listed. Because of the great geographical distance, climatic and crop habitat difference, it is suspected that a large difference in native parasitoid fauna exists within Vietnam. The objectives of this study were to survey and identify the naturally occurring parasitoids of *Liriomyza* spp. in commercial field vegetable crops of several ecological regions of Vietnam, and also to evaluate the importance of different species as biological control agents in vegetable IPM programs.

MATERIALS AND METHODS

Field survey of parasitoids was conducted in 45 selected municipalities identified for large areas planted to vegetable crops of twenty provinces of central and southern regions of Vietnam, e.g. Thanh Hoa, Thua Thien Hue in the north central coast region, Quang Nam in the south central coast region, Kon Tum, Gia Lai and Dac Nong in the central highland region, Lam Dong, Tay Ninh, Binh Phuoc, Binh Duong and Ho Chi Minh City in the northeast south region, Dong Thap, An Giang, Tien Giang, Ben Tre, Kien Giang, Hau Giang, Soc Trang, Bac Lieu and Ca Mau in the Mekong river delta region, from November 2003 to July 2004. Samples were taken from vegetables, including Japanese bunching onion (*Allium fistulosum* L.), leaf mustard (*Brassica juncea* (L.) Czern.), eggplant (*Solanum melongena* L.), tomato (*Lycopersicon esculentum* Mill), luffa (*Luffa acutangula* Roxb.), melons (*Cucumis melo* L.), cucumber (*Cucumis sativas* L.), yard-long bean (*Vigna unguiculata* (L.) Walp), bitter melon (*Momordica charantia* L.), Chinese squash (*Cucurbita moschata* (Butternut)), green bean (*Phaseolus aureus* Roxb.), French bean (*Phaseolus vulgaris* L.) and chrysanthemum greens (*Chrysanthemum coronarium* L.).

The insects were collected by hatching wasps from leafminer infested leaves of different vegetable crops. Leafminer infested leaves were randomly collected from vegetable commercial fields and placed in plastic bags labeled with the name of crop, location, date, and collector name(s). Samples were placed in an ice chest and brought into the laboratory.

After clearing other insects and residues, samples were singly placed in petri disks (9 cm in diameter) with filter paper. Samples were maintained at room temperature and daily supplied some drops of water for keeping humidity. The infested leaves were checked daily for parasitoid emergence. The number of adult parasitoids was recorded upon emergence. All parasitoids were kept in small grass vials with 70% ethanol. Parasitoids of the family Eulophidae and Eucophidae were identified by the third author with help of Dr. Kazuaki Kamijo (Bibai, Hokkaido, Japan), and parasitoids of the family Braconidae were identified by Dr. Kaoru Maeto (Laboratory of Insect Science, Faculty of Agriculture, Kobe University, Japan).

RESULTS

Parasitoid species complex

A total of 1862 parasitoid individuals emerged from leafminer infested vegetable leaves collected, and 18

Table 2. Relative abundance of parasitoid species by family reared from infested vegetable leaves collected in Vietnam.

Parasitoid	Relative abundance (%)
Baconidae	
Opius sp.	0.2
Opius chromatomyiae Belokobylskij & Wharton	3.1
Ecoilidae	
Gronotoma sp.	0.1
Eulophidae	
Neochrysocharis okazakii Kamijo	18.8
Neochrysocharis formosa (Westwood)	10.6
Neochrysocharis beasleyi Fisher & La Salle	29.5
Neochrysocharis sp.	0.05
Hemiptarsenus variconis (Girault)	8.8
Diglyphus isaea (Walker)	8.9
Cirrospilus ambiguous Hansson & LaSalle	1.5
Chrysocharis pentheus (Walker)	5.1
Asecodes delucchii (Boucek)	13.1
Asecodes erxias (Walker)	0.05
Quadrastichus sp.	0.2
Pnigalio sp.	0.05
Stenomesius sp.	0.05
Closterocerus sp.	0.05
Closterocerus trifasciatus Westwood	0.05
Total no. of emerged adults (N)	1862

parasitoid species of 3 families (Braconodae, Eucoilidae and Eulophidae) were identified (Table 2). Among them, *Neochrysocharis beasleyi* Fisher & La Salle, *N. okazakii*, *Acecodes delucchii* (Boucek) and *N. formosa* were abundant species, accounting for 29.5%, 18.8%, 13.1% and 10.6%, respectively, of the total parasitoid adults that emerged. *Neochrysocharis* sp. is an additional species of the genus from Vietnam, existing on yard long bean in Thanh Hoa province, but was not abundant species.

Parasitoid–host plant relationship

Parasitoid species and the proportion of each species reared from the leafminer infested leaves varied with host plants (Table 3). A total of 10, 9, 7, 7, 6 and 5 species of parasitoid were recorded as natural enemies of *Liriomyza* spp. on leaf mustard, yard–long bean, tomato, casaba melon, French been and onion, respectively.

Within a given crop, the major parasitoids have been found. The most frequent parasitoid species reared from the leafminers on onion, leaf mustard and casaba melon was *N. okazakii*. While *N. beasleyi* was the most abundant species of leafminers on tomato and yard–long bean, this species was also the second most abundant on French bean. *Neochrysocharis formosa* was the second abundant species of the leafminers on onion, tomato

Table 3. Relative abundance (%) of parasitoids reared from leafminer infested leaves of various vegetable crops in Vietnam (*be continued*)

Crop	Location	Parasitoids		
		Species	Relative abundance	Total No of emerged adults
Onion	Thanh Hoa, Thua Thien Hue Quang Nam and Lam Dong	*Neochrysocharis okazakii*	92.5	108
		Neochrysocharis fomosa	2.7	
		Diglypus isaea	2.7	
		Hemiptarsenus variconis	0.9	
		Cirrospilus ambiguus	0.9	
Leaf mustard	Thanh Hoa, Thua Thien Hue, Quang Nam, Ca Mau and Bac Lieu	*Neochrysocharis okazakii*	50.9	216
		Hemiptarsenus variconis	31	
		Neochrysocharis fomosa	8.3	
		Neochrysocharis beasleyi	4.6	
		Quadrastichus sp.	1.4	
		Cirrospilus ambiguus	0.9	
		Chrysocharis pentheus	0.9	
		Asecodes delucchii	0.9	
		Gronotoma sp.	0.5	
		Opius chromatomyiae	0.5	
Tomato	Quang Nam, Thua Thien Hue, Kon Tum, Gia Lai, Lam Dong, Ho Chi Minh City, Binh Duong, Ben Tre, Kien Giang and Bac Lieu	*Neochrysocharis beasleyi*	60.3	252
		Neochrysocharis formosa	17.9	
		Asecodes delucchii	10.3	
		Chrysocharis pentheus	7.9	
		Hemiptarsenus varinonis	2.4	
		Opius sp.	0.8	
		Neochrysocharis okazakii	0.4	
Casaba melon	Thua Thien Hue and Quang Nam,	*Neochrysocharis okazakii*	49.5	204
		Hemiptarsenus variconis	24.5	
		Neochrysocharis formosa	19.1	
		Chrysocharis pentheus	3.4	
		Asecodes delucchii	2.5	
		Quadrastichus sp.	0.5	
		Gronotoma sp.	0.5	

Table 3. Relative abundance (%) of parasitoids reared from leafminer infested leaves of various vegetable crops in Vietnam (*continued*)

Crop	Location	Parasitoids		
		Species	Relative abundance	Total No of emerged adults
Yard–long bean	Thanh Hoa, Tay Ninh, Ho Chi Minh City Kien Giang, Bac Lieu, Dong Thap and Ca Mau	*Neochrysocharis beasleyi*	53.9	308
		Neochrysocharis fomosa	21.4	
		Asecodes delucchii	15.6	
		Neochrysocharis okazakii	3.9	
		Cirrospilus ambiguus	2.3	
		Hemiptarsenus variconis	1.9	
		Neochrysocharis sp.	0.3	
		Chrysocharis pentheus	0.3	
		Asecodes erxias	0.3	
French bean	Kon Tum, Ho Chi Minh City, Binh Duong, Hau Giang, Tien Giang and Soc Trang	*Asecodes delucchii*	52.6	249
		Neochrysocharis beasleyi	36.9	
		Cirrospilus ambiguus	3.6	
		Chrysocharis pentheus	3.2	
		Hemiptarsenus variconis	3.2	
		Opius sp.	0.4	

and yard–long bean. *Asecodes delucchii* was the most abundant species on French bean, and the third most abundant species in yard–long bean. *Hemiptarsenus varicoris* existed on every host plant, and was the second most major species on leaf mustard and casaba melon.

DISCUSSION

More than 40 parasitoid species have been reared from the major leafminer species world–wide (Watehouse and Norriss, 1987). Our extensive survey revealed a relatively small parasitoid complex (18 species) among 14 vegetable crops in five agro–ecological regions across Vietnam. Most of the parasitoids found in this investigation were in family Eulophinidae. Among them, *N. beasleyi*, *N. okazakii*, *N. formosa*, *A. delucchii*, *D. isaea*, *H. varicoris*, and *C. pentheus* were predominated. This result is consistent with research in Japan and Vietnam in which *N. fomosa*, *N. okazakii*, *C. pentheus* and *H. varicornis* were found to be predominant in the open field plants (Saito *et al.*, 1996; Arakaki and Kinjo, 1998; Thang, 1999). Previous research also indicated *N. beasleyi* and *A. delucchii* were the most abundant parasitoid species of *L. sativae* on cucumber in Hochiminh City (Tran *et al.*, 2005). Thus, these species appear to be the most important candidate as biological control agents of *Liriomyza* spp.

In the present study, no investigation was done in the northern Vietnam. A previous study reported a total of 12 parasitoid species associating with *Liriomyza* leafminers in vegetable crops in the northern regions (Thang, 1999). Ha (2003) reported *Quadrastichus liriomyzae* (Hansson & LaSalle), *Diglyphus pusztensis* Erodös and *Dacnusa sibirica* Telenga associating with *L. sativae* on French bean in North Vietnam. These species were not encountered in central and southern Vietnam in the present investigation.

Although many parasitoid species are polyphagous, attacking several dipterous leafminer species, some are strongly influenced by the host plant of vegetable crops (Murphy and LaSalle, 1999). The abundant parasitoids reared from *Liriomyza* species differed largely among crops (Table 3). The first and second most numerous parasitoids associated with *Liriomyza* species in tomato and yard–long bean were *N. beasleyi* and *N. formosa*. *Neochrysocharis* sp. A of Konishi (2004) was a different species from *beasleyi*, and *N.* sp. B of Konishi (2004) was *beasleyi*. *Neochrysocharis beasleyi* was described from Indonesia and Vietnam (Fisher and LaSalle, 2005) While numerous studies in Japan indicated *N. formosa* was predominated and has been recognized as an effective biological control agents of leafminers in tomato, bean and eggplants (Saito *et al.*, 1996; Arakaki and Kinjo, 1998, Ohno *et al.*, 1999; Mariana, 2000), the present study shows the first record of a predominance of *N. beasleyi* among leafminer parasitoid complex on tomato and yard–long bean in Vietnam. Among the parasitoid complex of the leafmiers on onion, leaf mustard and casaba melon, *N. okazakii* was predominant. Since a main leafminer attacking onion crops in Vietnam is *L. chinensis*, *N. okazakii* seems to be a good candidate as biological control of the leafminer. The most common parasitoid reared from French bean foliage was *A. delucchii*. This species was a Palaearctic parasitoid found recently in Southeast Asia (Joshi, 2001), and become the second most abundant parasitoid species of *L. sativae* in Ho Chi Minh region (Tran *et al.*, 2005), and the third most abundant parasitoid of *Liriomyza* spp. on yard long bean. In Japan, *A. delucchii* was recorded associating with *L. trifollii* in bean (Arakaki and Kinjo, 1998). Thus, the plant species belonging the family of Fabaceae seem to be preferred by *A. delucchii*. Since host plants can affect on development and behavior of parasitoid species (Arthur 1962; Hare and Luck, 1991; Powell and Wright, 1992; Shukla

and Tripathi, 1993), the distribution of parasitoid species and their abundance could vary among vegetable crops (Zehnder and Trumble, 1984; Johnson and Hara, 1987).

Previous studies indicated that among *Liriomyza* species established in Vietnam, *L. sativae* was clearly a dominant species found on a variety of vegetables, while *L. bryoniea* and *L. trifolii* were relatively new invasive species (Table 1). Although it may appear that some parasitoid species can be specific, there is little concrete evidence that *Liriomyza* parasitoids display any high degree of host specificity (Murphy and LaSalle, 1999; Chen *et al.*, 2003). Since native polyphagous parasitoids of *L. chinensis* have quickly adopted a newly introduced *L. sativae* in Hangzhou, China (Chen *et al.*, 2003), the species complex and abundance of these parasitoids on different vegetable crops in different agro-ecological regions could be of a fundamental importance for development of biological control strategies for any *Liriomyza* species.

ACKNOWLEDGEMENTS

We thank Dr. Kazuaki Kamijo (Bibai, Hokkaido, Japan) and Dr. Kaoru Maeto (Laboratory of Insect Science, Faculty of Agriculture, Kobe University, Japan) for their help with identification of parasitoids. We also thank to Mrs. N. T. Lan (Hongduc University, Vietnam), Mrs. L. T. T. Lam (Nonglam University, Vietnam), and the numerous Vietnamese officers of Plant Protection Departments for their assistance in the fields and the laboratory. We extend our thanks to our farmer cooperators for their assistance and collaboration on survey making in their fields. We gratefully acknowledge the critical comments by Dr. Takatoshi Ueno (Institute of Biological Control, Faculty of Agriculture, Kyushu University, Japan) to an earlier version of this manuscript. This work was supported in part by a Grand-in-Aid from the Japanese Society for the Promotion of Science and Technology (No. 15208007).

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