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AGROMYZID LEAFMINERS AND THEIR PARASITOIDS ON VEGETABLES IN CENTRAL VIETNAM

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ABSTRACT

Vegetable crops were surveyed in three regions of Central Vietnam to record abundance and diversity of agromyzid leafminers and their associated parasitoid species. The five leafminer species were found. *Liriomyza sativae* was the most abundant species. *Liriomyza bryoniae* was new incursions, and became the second most abundant species. *Liriomyza chinensis* occurred only on onion. *L. huidobrensis* was much less abundant. *Chromatomyia horticola* was abundant on Indian mustard. In all, 13 species of hymenopterous parasitoids were reared from the leafminer-infested leaves. Eleven species were reared from *L. sativae*, and 5 from *L. chinensis*. The species composition and abundance of parasitoids varied with plants and regions. *Neochrysocharis okazakii* and *N. formosa* were most abundant in the north central coast region while *N. okazakii* and *Hemiptarsenus varicornis* were most abundant in the south central coast region. *Chrysocharis pentheus*, *Acecodes delucchii* and *N. formosa* predominated in the central highland regions. The parasitoid species most frequently reared from the leafminers on welsh onion and Indian mustard was *N. okazakii* while *N. formosa* was the most abundant species of leafminers on cantaloupe and yardlong bean. *Chrysocharis pentheus* was the most abundant parasitoid species reared from leafminers on garden tomato. *Hemiptarsenus varicornis* was reared from every type of host plant, and was the second most abundant species on cantaloupe. The number and diversity of parasitoid species in Central Vietnam indicates the potential for parasitoids to control leafminers.

Key words: Conservation, diversity, integrated pest management, *Liriomyza*, *Neochrysocharis*

INTRODUCTION

In Southeast Asia, several invasive, polyphagous *Liriomyza* species are becoming major pests in vegetable growing areas (Shepard *et al.*, 1998; Sivapragasam and Syed, 1999; Rauf *et al.*, 2000). The predominant species are *Liriomyza sativae* Blanchard, *Liriomyza huidobrensis* (Blanchard) and *Liriomyza trifolii* (Burgess) (Diptera: Agomyzidae) (Murphy and LaSalle, 1999). The Asian species *Liriomyza chinensis* (Kato) (Diptera: Agromyzidae) is not polyphagous, but is a serious pest on *Allium* spp. It has been reported in China, Japan, Malaysia and Thailand (Spencer 1973; Chen *et al.*, 2003), Indonesia (Rauf *et al.*, 2000), Korea (Hwang and Moon, 1995) and Taipei (Shiao, 2004). Besides the polyphagous *Liriomyza* species, *Chromatomyia horticola* (Goureau) (Diptera: Agromyzidae) is an important pest infesting vegetable (particularly pea and lettuce) and ornamental crops in Japan (Saito, 2004). Recently, outbreaks of *C. horticola* have been found in several countries including China (Chen *et al.*, 2003), Indonesia (Rauf *et al.,* 2000) and Malaysia (Sivapragasam and Syed, 1999).

Agromyzid leafminers are known to have rich natural enemies. Over 40 species of parasitoids have been recovered worldwide from the leafminers (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) and 8 species in Malaysia (Murphy and LaSalle, 1999). These species 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 Norris, 1987; Minkenberg, 1990). A strategy for a biological control based integrated pest management (IPM) system that is appropriate for agromyzid leafminers in vegetable production areas would include the conservation or enhancement of locally occurring natural enemies. Only if local parasitoids were shown to be ineffective would it be appropriate to consider importing appropriate natural enemy species from the area of origin of the pests or from related leafminer populations from other areas.

Because of the rapid increase in leafminer-infested crops in Vietnam, vegetable growers frequently apply large quantities of primarily broad-spectrum insecticides (Tran and Takagi, 2005). Frequent applications of these insecticides, however, will adversely affect parasitoid abundance in the vegetable agro-ecosystem (Johnson *et al.*, 1980; Saito *et al.*, 1996), can promote the development of pesticide resistance within fly populations (Keil *et al.*, 1985; Johansen *et al.*, 2003) and frequently lead to an increase in leafminer density (Murphy and LaSalle, 1999). Before an effective IPM system can be developed for these pests, it is necessary to identify the key native species and determine their distribution and abundance across different geographical areas and land use systems.

Vietnam can be divided into the following ecological regions: north east, north west and Red river delta in the north, north central coast, south central coast and central highland in the central, northeast south and Mekong river delta in the south (Nguyen, 2002; Michael and Andreas, 2004). In the north, the temperatures are subtropical. Shifting seasonal wind patterns result in dry and cold winters and wet summers. The central areas typify the tropical monsoon climate, with high temperatures and abundant precipitation. In the south, distinct wet and dry periods are evident, but temperatures are higher than in the north (Le, 1997). Central Vietnam is divided into three regions (Fig. 1). The climate of Central Vietnam is diverse. While the weather of the south central coast region is warm all the year round, it is cold in winter in the north central coast areas. The Central highland region is including some plateaus with 500–1000m above sea-level. The climate of the central highland region is large different from two other regions. There are two different seasons, the hot (from April to October) with the total rainfall and the cold (from November to March) (Le, 1997). Because of different climate, crop growing season are diverse within these regions.

While surveys for leafminers and their parasitoids have been conducted in northern and southern Vietnam (Thang, 1999; Tran, 2000; Ha, 2001; Andersen *et al*., 2002; Tran *et al.*, 2005), there is very little published information available from Central Vietnam. Because of the geographical distance, climatic and crop habitat differences, it is suspected that large variations in leafminer and its parasitoid fauna exist within Vietnam. The objectives of this study were to determine the abundance and diversity of leafminers and their parasitoids in commercial vegetable crops in the three regions of Central Vietnam.

MATERIALS AND METHODS

Field surveys of leafminers and their parasitoids were conducted in 15 major vegetable growing municipalities in six provinces of Central Vietnam in 2004 and 2006, i.e. Thanh Hoa, Nghe An and Thua Thien Hue in the north central coast region, Quang Nam in the south central coast region, and Kon Tum and Gia Lai in the central highland region (Fig. 1). Because most vegetable production was only available in the open fields from January to July, field collections were made monthly in the growing season.

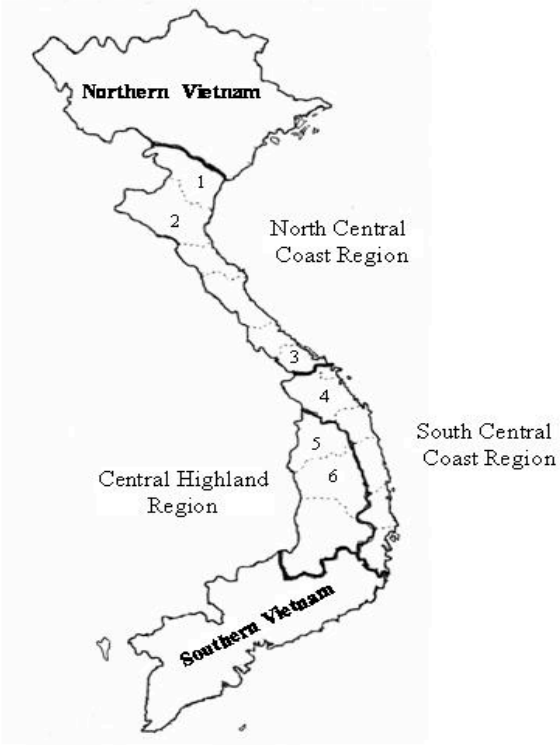

Fig. 1. A map of Central Vietnam showing study sites (based on Nguyen, 2002; Michael and Andreas, 2004). The sites are indicated in numbers: Thanh Hoa (1), Nghe An (2), Thua Thien Hue (3), Quang Nam (4), Gia Lai (5) and Kon Tum (6).

Leafminer-infested leaves were randomly collected from 20 species of vegetable crops of commercial vegetable fields (Table 1) and placed in plastic bags labeled with the name of the crop, location, date, and collector's name. Samples sizes were variable, depending on vegetable species, but generally 10–15 leaves per field were taken from crops with large leaves (e.g. cabbage, Indian mustard, eggplant, garden cucumber, etc.), whereas 20–30 leaves were removed from plants with small leaves (e.g. kidney bean, garden tomato, onion, etc.). Samples were placed in an icebox and brought to the laboratory. The leafminer flies and parasitic wasps were collected after emergence.

After clearing of other insects and residues, a piece of the leaves was placed in Petri dish (9 cm in diameter) lined with filter paper. Samples were maintained at room temperature (25 ± 5^{o}C) and supplied daily with some drops of water for maintaining appropriate humidity in the Petri dishes. The numbers of emerged adult leafminers and parasitoids were recorded daily. All flies and wasps were kept separately in small vials containing 70% ethanol for identification. Relative abundance of parasitoid species was estimated from the ratio of the numbers of emerged adults of each parasitoid species to total number of emerged parasitoid adults.

RESULTS

Leafminer species

Five agromyzid leafminer species, i.e. *L. sativae*, *L. bryoniae*, *L. chinensis*, *L. huidobrensis* and *C. horticola* were reared from the collected leaves (Table 1). *Liriomyza sativae* was the most abundant species, infesting 15 vegetable species. *Liriomyza bryoniae* was found in Thanh Hoa and Nghe An provinces, the north central region. It became the second most abundant species attacking 10

Table 1. Number of agromyzid leafminers that emerged from different host plants in Central Vietnam.

Scientific name	Common name	*L. sativae*		*L. bryoniae*		*L. chinensis*		*L. huidobrensis*		*C. horticola*	
		2004	2006	2004	2006	2004	2006	2004	2006	2004	2006
Brassicaceae											
Brassica oleracea var. *Oleracea* L.	cabbage,			6 (1/1)[a]	41 (3/3)					0 (0/1)	1 (1/3)
Brassica oleracea var. *gongylodes* L.	kohlrabi			11 (1/1)	16 (2/3)						
Brassica chinensis L.	pak choi			9 (1/1)	14 (2/2)						
Brassica juncea L.	Indian mustard	84 (2/6)	181 (7/12)	31 (2/6)	85 (7/12)					69 (2/6)	141 (7/12)
Raphanus sativus L.	radish	8 (1/1)	17 (3/3)								
Asteraceae											
Chrysanthemum coronarium L. var. *coronarium*	garland chrysanthemum	1 (1/3)	2 (1/6)	37 (1/3)	76 (4/6)			0 (0/3)	2 (1/6)	0 (0/3)	1 (1/6)
Cucurbitaceae											
Cucumis sativus L.	cucumber	12 (1/3)	33 (3/4)	24 (1/3)	49 (2/4)						
Cucumis melo L.	cantaloupe	18 (1/1)	160 (6/6)								
Momordica charatia L.	Balsam pear		23 (2/2)								
Luffa accutangula (L.) Roxb	sinkwa towelsponge		8 (2/2)								1 (1/2)
Cucurbita moschata (Duchesne ex Lam) Duchesne ex Poir	crookneck squash	13 (1/1)	45 (2/2)								

Scientific name	Common name	*L. sativae*		*L. bryoniae*		*L. chinensis*		*L. huidobrensis*		*C. horticola*	
		2004	**2006**	**2004**	**2006**	**2004**	**2006**	**2004**	**2006**	**2004**	**2006**
Citrullus lanatus (Thunb.) Matsun & Nakai	watermelon	16 (1/1)	21 (2/2)								
Fabaceae											
Phaseolus vulgaris L.	kidney bean	145 (5/5)	311 (16/16)	9 (1/5)	21 (3/16)						
Vigna radiata (L.) R. Wilczek	mung bean	7 (1/1)	37 (3/3)								
Vigna unguiculata (L.) Walp. ssp. *sesquipedalis* (L.) Verdc.	yardlong bean	69 (3/3)	149 (5/5)								
Liliaceae											
Allium fistulosum L.	welsh onion					21 (2/2)[a]	150 (4/4)				
Allium cepa L.	garden onion					8 (1/1)	26 (3/3)				
Solanaceae											
Lycopersicon esculentum L. var. *lycopersicum*	garden tomato	206 (7/7)	428 (11/11)	0 (0/7)	2 (2/11)					0 (0/7)	1 (1/11)
Solanum melongena L.	eggplant	13 (2/2)	67 (6/6)	2 (1/2)	4 (1/6)						
Solanum torvum Sw.	turkey berry		7 (2/3)		29 (2/3)						
Total no. of emerged adults		592	1489	139	327	29	176	0	2	69	145

[a](Number of infested samples/ number of collected samples)

vegetable crops. It infested a widest range of Brassicaceae, was the most abundant species on garland chrysanthemum (*Chrysanthemum coronarium* L. var. *coronarium*). *Liriomyza chinensis* occurred only on *Allium* spp. *Liriomyza huidobrensis* emerged only from garland chrysanthemum leaves collected from Hue city, Thua Thien Hue province in 2006. *Chromatomyia horticola* commonly infested Indian mustard (*Brassica juncea* L.). This leafminer was also found infesting cabbage (*B. oleracea* var. *oleracea* (L.)), kohlrabi (*B. oleracea* var. *gongylodes* L.), garland chrysanthemum, sinkwa towelsponge (*Luffa accutangula* (L.) Roxb) and garden tomato (*Lycopersicon esculentum* L. var. *lycopersicum*) in 2006.

Parasitoid species

Thirteen parasitoid species of 3 families (Braconidae, Eucoilidae and Eulophidae) were reared from leafminer-infested vegetable leaves (Table 2). Parasitoid species composition and their abundance varied by region from which vegetable infested leaves were collected (Table 2). In the north central coast region, *Neochrysocharis okazakii* Kamijo and *Neochrysocharis formosa* (Westwood) were the most abundant species, accounting for 55.1% and 29.8%, respectively, of emerged parasitoids (11 species; 423 individuals). In the south central coast region, *N. okazakii* and *Hemiptarsenus varicornis* (Girault) were the most abundant species (51.2% and 24.9%, respectively) of the 9 species recorded. In the central highland region, *Chrysocharis pentheus* (Walker) and *Acecodes delucchii* (Bou□ek) were the most abundant of the six species recorded, (45.3% and 22.1%, respectively).

Table 2. Percentage and number (in parentheses) of parasitoid species by family reared from infested vegetable leaves collected from different regions of Central Vietnam.

Parasitoids	North central	South central coast	Central highland
Braconidae			
Opius chromatomyiae Belokobylskij & Wharton	0.0 (0)	0.5 (1)	0.0 (0)
Eucoilidae			
Gronotoma sp.	0.5 (2)	0.0 (0)	0.0 (0)
Eulophidae			
Neochrysocharis okazakii Kamijo	55.1 (233)	51.2 (103)	0.0 (0)
Neochrysocharis formosa (Westwood)	29.8 (126)	9.9 (20)	17.4 (15)
Neochrysocharis beasleyi Fisher & LaSalle	2.6 (11)	0.0 (0)	3.5 (3)
Neochrysocharis sp.	0.2 (1)	0.0 (0)	0.0 (0)
Hemiptarsenus varicornis (Girault)	1.9 (8)	24.9 (50)	2.3 (2)
Diglyphus isaea (Walker)	0.5 (2)	0.5 (1)	0.0 (0)
Cirrospilus ambiguus Hansson & LaSalle	2.1 (9)	0.0	9.3 (8)
Chrysocharis pentheus (Walker)	6.1 (26)	7.5 (15)	45.3 (39)
Asecodes delucchii (Bou□ek)	0.5 (2)	4.5 (9)	22.1 (19)
Quadrastichus sp.	0.7 (3)	0.5 (1)	0.0 (0)
Pnigalio sp.	0.0 (0)	0.5 (1)	0.0 (0)
Total	100 (423)	100 (201)	100 (86)

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 9 species of parasitoids were recorded as natural enemies of leafminers on Indian mustard. The range of 5-7 parasitoid species were reared from the leafminers on welsh onion (*A. fistulosum* L.), garden tomato, cantaloupe (*Cucumis melo* L.) and yardlong bean (*Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Verdc).

Table 3 Relative abundance of parasitoid species by crop type reared from leafminer- infested leaves of various types of vegetables in Central Vietnam.

		Parasitoids		
Vegetable type	**Leafminer infested**	**Species**	**Relative abundance (%)**	**Total no. of emerged adults**
Welsh onion	*L. chinensis*	*Neochrysocharis okazakii*	92.4	105
		Neochrysocharis formosa	2.9	
		Diglyphus isaea	2.9	
		Hemiptarsenus varicornis	0.9	
		Cirrospilus ambiguus	0.9	
Indian mustard	*L. sativae*	*Neochrysocharis okazakii*	76.8	142
	L. bryoniae	*Neochrysocharis formosa*	12.7	
	C. horticola	*Hemiptarsenus varicornis*	3.5	
		Quadrastichus sp.	2.1	
		Chrysocharis pentheus	1.4	
		Asecodes delucchii	1.4	
		Gronotoma sp.	0.7	
		Neochrysocharis beasleyi	0.7	
		Opius chromatomyiae	0.7	
Garden tomato	*L. sativae*	*Chrysocharis pentheus*	47.6	42
		Neochrysocharis formosa	30.9	
		Asecodes delucchii	11.9	
		Hemiptarsenus varicornis	7.1	
		Neochrysocharis okazakii	2.4	
Cantaloupe	*L. sativae*	*Neochrysocharis okazakii*	49.5	204
		Hemiptarsenus varicornis	24.5	
		Neochrysocharis formosa	19.1	
		Chrysocharis pentheus	3.4	
		Asecodes delucchii	2.5	
		Quadrastichus sp.	0.5	
		Gronotoma sp.	0.5	
Yardlong bean	*L. sativae*	*Neochrysocharis formosa*	68.1	91
		Neochrysocharis okazakii	12.1	
		Neochrysocharis beasleyi	10.9	
		Cirrospilus ambiguus	6.6	
		Neochrysocharis sp.	1.1	
		Chrysocharis pentheus	1.1	

The most common parasitoid species reared from the leafminers on onion, cantaloupe and Indian mustard was *N. okazakii*. While *N. formosa* was the most abundant species of leafminers yardlong bean, this species was also the second most abundant on Indian mustard, garden tomato and onion. *Chrysocharis pentheus* was the most common parasitoid species reared from leafminers on garden

tomato. *Hemiptarsenus varicornis* was found on every host plant type, and was the second most abundant species on cantaloupe. *Diglyphus isaea* (Walker) was only found on onion, but it was not abundant. *Neochrysocharis* sp. was a new species of the genus from Vietnam, existing on yardlong bean in Thanh Hoa province, but it was not very common.

Host - parasitoid relationship

The parasitoid complex of *L. sativae* and *L. chinensis* was diverse (Table 4). Eleven parasitoid species were reared from leaves infested by *L. sativae*. *Neochrysocharis formosa* and *N. okazakii* were the most abundant species (31.7 and 30.1%, respectively, of all adult parasitoids that emerged). Five parasitoid species were reared from *L. chinensis* with *N. okazakii* being the dominant species, (82.5% of parasitoids reared).

Table 4. Percentage and number (in parentheses) of parasitoid species reared from leafminers *L. sativae* and *L. chinensis* in Central Vietnam.

Parasitoids	***L. sativae* being parasitized**	***L. chinensis* being parasitized**
Braconidae		
Opius chromatomyiae Belokobylskij & Wharton	0.5 (2)	0.0 (0)
Eucoilidae		
Gronotoma sp.	0.3 (1)	0.0 (0)
Eulophidae		
Neochrysocharis okazakii Kamijo	30.1 (112)	82.5 (127)
Neochrysocharis formosa (Westwood)	31.7 (118)	7.8 (12)
Neochrysocharis beasleyi Fisher & LaSalle	2.2 (8)	0.0
Neochrysocharis sp	0.3 (1)	0.0
Hemiptarsenus varicornis (Girault)	13.4 (50)	2.6 (4)
Diglyphus isaea (Walker)	0.0 (0)	5.8 (9)
Cirrospilus ambiguus Hansson & LaSalle	3.0 (11)	1.3 (2)
Chrysocharis pentheus (Walker)	13.4 (50)	0.0
Asecodes delucchii (Bou□ek)	4.8 (18)	0.0
Quadrastichus sp.	0.3 (1)	0.0
Total	100 (372)	100 (154)

DISCUSSION

Liriomyza sativae, native to the southern United States (Spencer, 1973), was found in 10 provinces in northern Vietnam (Ha, 2001) and in 27 conducted provinces of northern and southern Vietnam (Andersen *et al.*, 2002). The present study shows that *L. sativae* has also become one of the most important vegetable pests in Central Vietnam. *Liriomyza bryoniae* was relatively new incursions

into Vietnam. The first documented infestation of *L. bryoniae* in Vietnam was on mung bean in Hanoi (Red River Delta region) in 2003 (Grimstad, 2004). The present study indicated the occurrence of *L. bryoniae* on various vegetable species in the north central region. Further spread of this species within the country seems likely. Previous studies indicated the coexistence of leafminer species in vegetables in Europe (Minkenberg, 1990), America (Zehnder and Trumble 1984) and Japan (Abe and Kawahara 2001). The present study also revealed the coexistence of *L. sativae* and *L. bryoniae* in various vegetable crops in Central Vietnam. Therefore, it is necessary to compare the development, reproductive rate, migration ability, host plant exploitation and susceptibility to insecticide among the populations of these species for their control procedure finding (Abe and Kawahara 2001). Previously, *L. huidobrensis* was found only in Lam Dong province (northeast south region) at altitudes of 1000–1800 m. The species was accidentally introduced to the vegetable growing areas around Da Lat, Lam Dong most probably from imported infested plants (Andersen *et al.*, 2002). Due to its cold hardiness (Chen and Kang, 2002, 2004), *L. huidobrensis* within Vietnam may be expected of a further spread through introduction to other highland areas via infested plants (Andersen *et al.*, 2002), this species was also found on garland chrysanthemum in Hue city at low altitude. Andersen *et al.* (2002) reported that *L. chinensis* was found infesting *Allium* spp. in one province in the northeast region (Bac Ninh) and two provinces (Dong Nai and Ba Ria) in the northeast southern region. This study found that *L. chinensis* is common all over Central Vietnam. *Chromatomyia horticola* is easily separated from the others by its generally darker body and larger size. This species was reported to infest vegetable and ornamental crops throughout Asia, for instance pea in Indonesia (Rauf *et al.*, 2000), and pea and lettuce in Japan (Saito, 2004). In Central Vietnam, *C. horticola* was also found on several vegetable crops, in particular Indian mustard. The present study indicates that field vegetable growing in Central Vietnam is under siege from five agomyzid leafminers, and each crop is infested by one or more of these species. However, it is difficult for the growers to identify leafminer species occurring in their fields. Therefore, it is appropriate to consider that a control procedure for all leafminers is required (Abe and Kawahara, 2001).

Our extensive surveys revealed a parasitoid complex (13 species) among 20 vegetable crop types in three regions of Central Vietnam. The species composition of the parasitoid species varied in the different areas. Extensive surveys for natural enemies of agromyzid leafminers have been made in many countries (Konishi, 1998; Murphy and LaSalle, 1999; Thang, 1999; Rauf *et al*., 2000; Petcharat *et al.*, 2002; Chen *et al.*, 2003), but parasitoid complexes differed from one another. The spatial distribution of species and the factors limiting them are less well understood. Some species have restricted distributions whilst others have a very wide distribution in the New World (Murphy and LaSalle, 1999). In Japan, the parasitoid fauna of *L. trifolii* was different between Shizuoka and Okinawa Prefectures because of the great difference in geographic and climatic conditions (Saito *et al.*, 1996; Arakaki and Kinjo, 1998). Arakaki and Kinjo (1998) also recorded a difference in parasitoid fauna of *L. trifolii* on bean, tomato and eggplant in the open fields and greenhouses in different local agro-ecological regions of Okinawa Island, Miyako Island and Ishigaki Island, Okinawa Prefecture. Thus, it seems that climatic biotypes exist within the distribution of leafminer parasitoid species (Murphy and LaSalle, 1999).

Most of the parasitoids found in this investigation belong to the family Eulophidae. *Neochrysocharis okazakii*, *N. formos*a and *H. varicornis* predominated in the north central and south central coast regions. This result is consistent with research in Japan indicating that those species predominate in open field crops (Saito *et al.*, 1996; Arakaki and Kinjo, 1998). On the other hand, the dominant species in the central highland region were *C. pentheus* and *A. delucchii*. There is little evidence that *Liriomyza* parasitoids display any high degree of host specificity (Murphy and LaSalle, 1999; Chen *et al.*, 2003). However, a variation of the parasitoid complexes of *L. sativae* and *L. chinensis* was found in this study. It could be influenced by high level of insecticide applied to onion fields (Tran and Takagi, 2005). Since the native polyphagous parasitoids have the capacity to quickly adopt new hosts (Chen *et al.*, 2003), the species complex and abundance of these parasitoids on

vegetable crops in the different three regions could be a fundamental importance for development of biological control strategies for any agromyzid leafminer species.

Among the parasitoid complex of the leafminers on welsh onion, cantaloupe and Indian mustard, *N. okazakii* was the predominant species. *Neochrysocharis formosa* was the most abundant parasitoid associated with leafminer species in yardlong bean, and the second most abundant species in garden tomato, Indian mustard and welsh onion. Numerous studies have indicated that *N. formosa* is a dominant species in a range of ecosystems and it has been recognized as an effective biological control agents of leafminers in tomato, bean and eggplants (Saito *et al.*, 1996; Arakaki and Kinjo, 1998; Maryana, 2000). The most common parasitoid reared from tomato foliage was *C. pentheus*. Arakaki and Kinjo (1998) also reported C. *pentheus* was the second most abundant parasitoid species associated with *L. trifolii* in tomato in Okinawa, Southern Japan. The present results that *N. okazakii*, *N. formosa* and *C. pentheus* are abundant in Central Vietnam suggests that they can be nominated as potential agents for biological control of leafminers by augmentation or conservation on vegetable crops. They richly deserve further study with respect to their biology and ecology. To maximize the potential for parasitoid establishment via colonization, it would probably be best to match up the parasitoids in question with those crops from with they have demonstrated high rate of leafminer parasitism (Johnson and Hara, 1987). Thus, it would be advisable to attempt colonization of *N. okazakii* in welsh onion, cantaloupe and Indian mustard; *N. formosa* in yardlong bean, garden tomato, Indian mustard and onion; and *C. pentheus* in garden tomato.

In Central Vietnam, *D. isaea* was reared from onion leaves infested by *L. chinensis*. Previously, this species was found abundantly on green bean associated with *L. huidobrensis* in Lam Dong province (northeast south region) (Tran *et al.*, 2006). *Diglyphus isaea* is well-known parasitoid that is currently reared on a commercial basis for introduction in greenhouses. Native to Europe, the species is widely distributed and is released for biological control of a wide range of agromyzid leafminers in many countries (Van der Linden, 2004). Given that some new exotic leafminers (e.g. *L. bryoniae*, *L. huidobrensi*s) established and spread within Vietnam, it is appropriate to consider further research with respect to biology and ecology of *D. isaea* for use as a biological control agent of these leafminers.

CONCLUSION

Vegetable crops in Central Vietnam were under threat by five species of agromizid leafminers. The leafminers had rich natural enemy communities. The species composition and abundance of parasitoids varied with plants and regions.

Vegetable growers probably over-react to the present of the leafminers due to the prominence of mines in the leaves, leading too-frequent and unnecessary use of insecticides. To achieve maximum effectiveness of a leafminer integrated management program, participating farmers and extension agents will need to understand the concepts of conserving natural enemies existed or released in their localities, via reductions of pesticide use, to provide the greatest opportunities for suppression of leafminers by biological control agents. The results indicating the important of different species of leafminers and their parasitoids in vegetables could be a fundamental importance for development of strategies for farmer education in the IPM programs.

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