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Parasitoid community structure of leaf miner *Liriomyza* spp. (Diptera: Agromyzidae) and the rate of parasitization on vegetable crops in Lesser Sunda Islands, Indonesia

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Abstract. *Wahyuni S, Supartha IW, Ubaidillah R, Wijaya IN. 2017. Parasitoid community structure of leafminer* Liriomyza *spp. (Diptera: Agromyzidae) and the rate of* parasitization *on vegetable crops in Lesser Sunda Islands, Indonesia. Biodiversitas 18: 593-600.* Parasitoids such as leafminer have long been known to play an important role in reducing potential pest populations. However, detailed information about the parasitoid community in many agroecosystems is still very limited. To attempt to address this data gap, we assessed the rate of parasitism, diversity, abundance and dominance of leafminer parasitoids in different agroecosystems. The survey was carried out from February to July 2015 in Lesser Sunda islands of Lombok, Sumbawa, Flores and Timor. Samples were taken from three different vegetable ecosystem types the forest edge (H1), agricultural (H2) and settlement (H3). In each ecosystem, 50 leaves were sampled from 20 kinds of vegetable crops attacked by *Liriomyza* spp. Samples were taken five times per location every week. The sampling results found three distinct species of leafminer flies present: *Liriomyza huidobrensis*, *L. sativae*, and *Chromatomyia horticola*. The sampling also successfully identified 7 other parasitoids with parasitization rates between 0.09%-32.58% i.e. *Neochrysocharis formosa* (8.20%-32.58%), *Hemiptarsenus varicornis* (4.57%-24.21%), *Opius chromatomyiae* (0.88%-22.35%), *Opius dissitus* (0.49%-5.08%), *Neochrysocharis okazakii* (0.69 %-1.24%), *Asecodes deluchii* (0.51%-5.89%) and *Gronotoma micromorpha* (0.09%-0.34%). Indices of abundance (R) and diversity (H') were also calculated, with the highest species abundance being found on the Lombok and the lowest on the Sumbawa. *Neochrysocharis formosa* abundance was found in all the islands sampled, while the dominance (D = 0.43) was found on the Sumbawa. *N. formosa* was found to have the highest population abundance and parasitism rate, and was found on every island in Lesser Sunda including on the Lombok (1853 adult; 31.16%), Sumbawa (472 adult; 8.2%), Flores (1117 adult; 15.96 %) and Timor (984 adult; 22.18%). The results of these studies suggest a strong need for effective pest control policies for *Liriomyza* spp. in the research locations, as well as for other vegetable crops in Indonesia

Keywords: Agronomy, community structure, Indonesia, Lesser Sunda Islands, *Liriomyza*, parasitoids, vegetable crop

INTRODUCTION

Liriomyza (Diptera: Agromyzidae) is a cosmopolitan insect which is an important pest for a variety of vegetable crops in tropical and subtropical countries. It can spread quickly within vegetable and ornamental crop ecosystems in the uplands and lowlands in Indonesia (Shepard et al. 1998; Rauf et al. 2000; Supartha et al. 2005). Almost all commercial vegetable crops in Indonesia and especially those in important growing regions like Java, Bali, Sumatra, Sulawesi, Kalimantan and Lombok, have been attacked by *Liriomyza* (Supartha 1998; Rustam et al. 2008). There are nine leaf miner species which have been recorded in Indonesia, namely *L. brassicae, L. caulophaga, L. chinensis, L. huidobrensis, L. katoi, L. pusila, L. sativae, L. chinensis, L. katoi, L. yasumatsui* and *Chromatomyia horticola* (Malipatil and Ridland 2008). Two species which have been found in Bali and Lombok are *L. huidobrensis* and *L. sativae*, each of which is dominantly distributed through the highlands and lowlands (Supartha 2003; Supartha et al. 2005). *Liriomyza* spp. infestation of potato crops in Bali can reduce yields up to 60% (Supartha 2003) and in Palu, losses of up to of 81.96% have been recorded (Lologau 2010). In 2012, a research found that *Liriomyza* spp. infestation had also to the failure of 24 Ha of onion in Palu (Sahabuddin et al. 2012).

Liriomyza spp. control efforts have been made in some areas in Indonesia with scheduled insecticide applications, but such efforts have not been able to suppress the population or damage done to crops (Baliadi 2009). In addition, the application of insecticides has also had a negative effect on beneficial non-target organisms, particularly parasitoids and can trigger the development of resistance to the pests to insecticides (Georghiou and Saito 2012), which makes pest control efforts even more difficult. Alternative use of biological agents, particularly parasitoids for *Liriomyza* spp. population control, has not been carried out intensively in Indonesia because there is a lack of information on its species composition as well their potential roles in parasitism. In some countries, biological control efforts have been carried out by utilizing information on the parasitoids whereabouts (Trumble 1990; Murphy and La Salle 1999; Chow and Heinz 2004; van der Linden 2004; Abd-Rabou 2006). At least 23 parasitoids species have been used in biological control programs to *L. trifolii* Burgess and *L. sativae* Blanchard (Diptera: Agromyzidae) in Senegal, California, Hawaii, Barbados, Marianas, Tonga, Taiwan and Guam (Petcharat 2002). Today, research on the existence and role of parasitoids in populations of *Liriomyza* spp. in nature has gained the attention of the researchers from various countries around the world. Some researchers in Indonesia have discovered as many as 17 species of parasitoids which parasitize *Liriomyza* spp. (Rauf et al. 2000; Ubaidillah 2003; Supartha et al. 2005; Syamsudin 2008). Among those parasitoids, *H. varicornis* has been found to be adapted to the vegetable crops of Indonesia (Baliadi and Tengkano 2010) and has been found to be able to parasitize *L. huidobrensis* at rates of 40.63% (Setiawati and Suprihatno 2000), however, the potential of this parasitoid has not been widely considered as a means of pest control. The composition and distribution of agricultural pest and their parasitoids are known to be influenced by differences in ecosystems, climate, and by the diversity of biotic and abiotic factors found in the various regions of the Indonesian archipelago (Hondikson and Casson 2008). Geographically, Lesser Sunda has a climate and ecosystem which are unique and different from the Western part of Indonesia (Monk et al. 2013). Due to this unique agroecology, these areas many have a different community of agricultural pest and their parasitoids. In order to develop a better understanding of the structure of the community of leafminer pests and their parasitoids, a survey was conducted in different agricultural landscapes spread across four islands of Lesser Sunda. It is hoped that determining the parasitoid community structure of *Liriomyza* spp. affecting vegetable crops may help in optimizing the control of the pest, especially in the development of localized control strategies.

MALTIERIALS AND METHODS

Study area

Leafminer and their parasitoids were sampled simultaneously on the island of Lombok, Sumbawa, Flores and Timor from February to July 2016 in selected vegetable ecosystems. Three types of these ecosystems were selected, namely (i) the edges of forests, (ii) agricultural areas, and (iii) residential areas located in both highlands and lowlands (ranging in elevation from 42 meters above sea level-1,301 meters above sea level) (Figure 1). Climate information including temperatures ranging from 24.7-35.6°C and humidity ranging from 48-86% were recorded. The samples were identified by genera and species using the key provided by Spencer and Steyskal (1986) and Malipatil et al. (2004) for flies and parasitoid based on the key of South East Asian Leafminers provided by Fisher et al. (2005) and Li (2011).

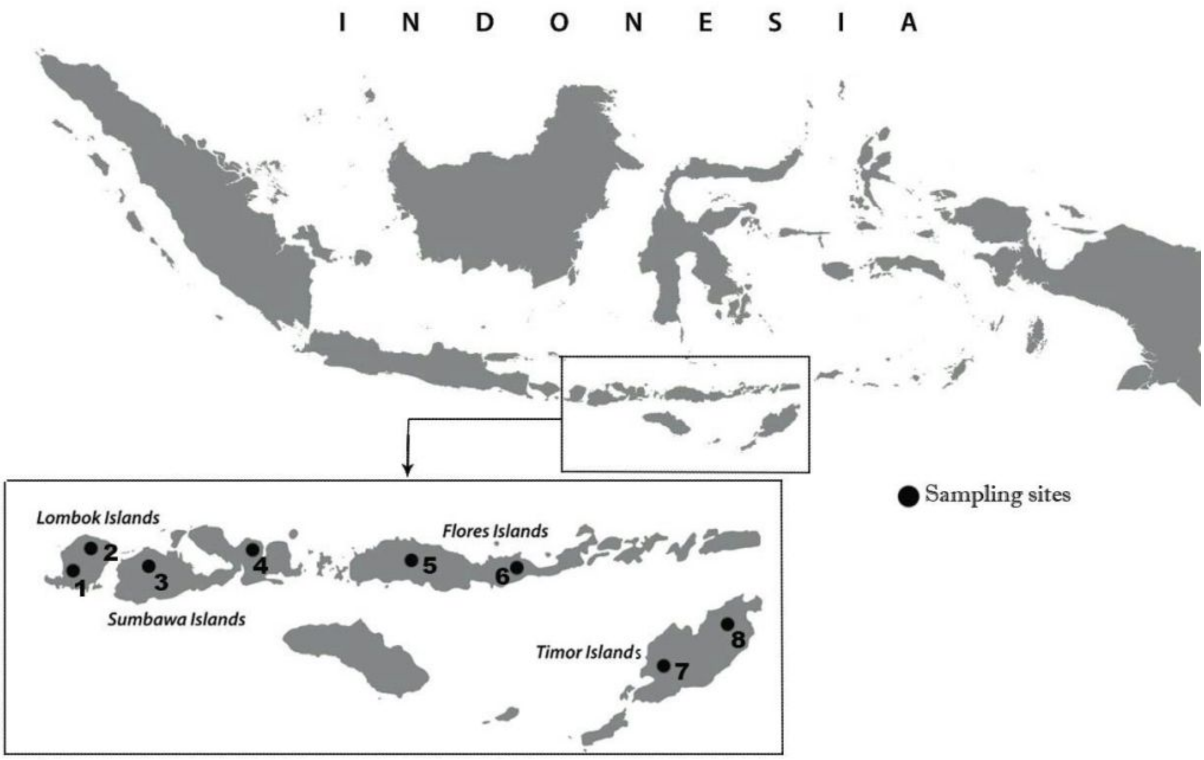

Figure 1. The sampling location of leaves infested by *Liriomyza* spp. in Lesser Sunda Islands, Indonesia. 1. Darmasaba, 2. Sembalun, 3. Jereweh, 4. Sakuru, 5. Welak, 6. Kelimutu, 7. Oetune, 8. Kasangnana

Procedures

Sampling was done by purposive method (Tongco 2007; Montong et al. 2015) of 20 varieties of vegetable crops which were indicated with leaf miner attack symptoms. All leafminer infested leaves were collected every day for one week. All the collected samples were put in plastic bags separately for each sample unit (50 leaves attached per varieties) which were then stored temporarily in a cool box to be brought to the laboratory. All samples were then transferred into a growth chamber and maintained at room temperature (28^{o}C, 80^{o}H) for further development of flies and their parasitoids. The emerged adults of leafminer flies and their parasitoids were carefully separately, and each was kept in a small vial containing 96% alcohol for further identification.

Data analysis

Rate of parasitization according to Russell (1987)

$$\text{Rate of parasitization} = \frac{\text{total parasitoids that emerged}}{\text{total parasitoids that emerged} + \text{total host that emerged}} \times 100\%$$

Abundance index using Margalef index (Magurran 2004)

$$R1 = \frac{S-1}{\ln N}$$

Where:
R1= Abundance index
S= Total species found
N= Total individuals

Species diversity index calculated by Shannon-Winner (Magurran 2004)

$$H' = -\Sigma Pi.\ln Pi$$

Where:
H'= diversity index
Pi= Proportion types to-i

Dominance index calculated using Menheinick index, (Magurran 2004)

$$D = \Sigma \frac{(ni(ni-1)}{N(N-1)}$$

Where:
D = Dominance index
Ni= Total individuals types to-I
N= Total individuals

RESULTS AND DISCUSSION

Results

Three leaf miner species were found in Lesser Sunda (*Liriomyza huidobrensis, Liriomyza sativae* and *Chromatomyia horticola*) along with 7 parasitoid species (*Hemiptarsenus varicornis, Neochrysocharis formosa, Neochrysocharis okazakii, Opius dissitus, Opius chromatomyiae, Gronotoma micromorpha* and *Asecodes deluchii*). The diversity and abundance of leaf miner species and their parasitoids on each island studied show variations of parasitoids and different number of total individuals (Table. 1)

Sumbawa Island was found to have the lowest species abundance of *Liriomyza* spp. (S = 2) and parasitoids (S = 5), the highest individual abundance of *Liriomyza* spp. (5284 adults) and the lowest parasitoid abundance (825 adults, R1 = 0.60) among the sampled islands. Meanwhile, the diversity index in Sumbawa was the lowest (H '= 0.75) among other islands but it had the highest the dominance index value (D = 0.43). This condition indicated that agricultural ecosystems in Sumbawa are less stable ecologically, especially in the relationship among plant-host-parasitoids. Instead, Flores has the highest diversity index value (H'= 1.44) indicating a more stable agricultural environment in comparison to other sampled islands

In this study, five parasitoids species have been found on four islands and two types, *G. micromorpha* and *N. okazakii* are found only on the Lombok and Flores. The highest levels of parasitization from the five parasitoids species was *N. form*osa (32.58%), *H. varicornis* (24.21%), *O. chromatomyiae* (22.35%), *O. dissitus* (5.08%), and *A .deluchii* (5.89%). This level of parasitization indicates that there are five parasitoid species that have the ability to spread and adapt well to the environment of vegetable crops in Lesser Sunda. The type of ecosystem plays an important role in determining the structure of insect host communities and their natural enemies. Table 2 shows the community structure and level of parasitization from 7 parasitoids on three types of agroecosystem in Lesser Sunda.

In this study, it was found that the index of diversity, abundance, and dominance of parasitoids in all vegetable crops in highland areas was higher than in lowland areas. Table 2 also shows that the index values of diversity, abundance, dominance, and level of parasitization on agroecosystem at the edge of forest (H1) is higher than the index value in agricultural areas (H2) and around residential areas (H3) despite the fact that individual abundance (N) in H1 is lower compared to H2 and H3.

The level of parasitization was found to vary from crop to crop (Table 3) both in agricultural ecosystems of highlands and lowlands. The results show that long beans, red bean, and tomato tend to have pests with a high level of parasitization compared to other varieties. These results prove that *Liriomyza* spp., parasitoids and host plant communities developed in accordance with the surrounding environment. Parasitoid diversity, abundance, and dominance on the various types of vegetables is displayed in Table 3.

The highest levels of parasitization sequentially occurred in long bean (23.02%), tomato (21.36%), common bean (17.25%), red bean (13.18%), dolichos bean (12.46%), and potato (12.23%). In this study, it was also found that several species of wild plants that grow in similar environments to food crops were also under attack by *Liriomyza* spp. with high parasitoid abundance index value (R> 5.0), such as *Emilia sonchifolia* (R: 6.697), *Tephrosia candida* (R: 6.228), *Centrosema pubescens* (R: 5.823), *Indigofera suffruticosa* (R: 5.387), and *Crotalaria juncea* (R: 5.346), 5 species of those plants included in the Leguminosae family.

Discussion

The high individual abundance of *Liriomyza* spp. in Sumbawa (Table 1) is supported by the availability of year-round vegetable crops grown in monoculture by most farmers. From this phenomenon, it can be assessed that the vegetable farming systems applied in Sumbawa greatly affect the low diversity of parasitoid species and high abundance of pests. Previous research has proven that monoculture farming systems may increase pests (Bianchi et al. 2006), as occurred in Sumbawa. The implications of this research are that monoculture farming systems in Sumbawa may increase the risk of *Liriomyza* spp. attack. In theory, monoculture systems are unsustainable environments, in particular for the relationship between the host plant, pests, and their parasitoids (Bianchi et al. 2006) which are what pest dominance tends to be higher in these systems.

Table 1. Structure of leaf miner *Liriomyza* spp. parasitoid community in Lesser Sunda

Parasitoid species / Indications	Lombok Islands	Sumbawa Islands	Flores Islands	Timor Island
	Total Individuals (adult) / Parasitization rate (%)			
H. varicornis	1225 / 24.21	253 / 4.57	832 / 12.32	674 / 16.34
N. formosa	1853 / 32.58	472 / 8.20	1117 / 15.87	984 / 22.18
N. okazakii	48 / 1.24	0 / 0	41 / 0.69	0 / 0
O. dissitus	205 / 5.08	26 / 0.49	162 / 2.66	177 / 4.88
O. chromatomyiae	491 / 22.35	47 / 0.88	319 / 5.11	303 / 8.07
A. deluchii	240 / 5.89	27 / 0.51	277 / 4.47	164 / 4.54
G. micromorpha	13 / 0.34	0 / 0	2 / 0.03	3 / 0.09
N parasitoids	4075	825	2750	2305
N *Liriomyza* spp.	3834	5284	5921	3452
S parasitoid	7	5	7	6
S *Liriomyza* spp.	3	2	3	3
R1	0.76	0.60	0.73	0.65
H'	1.36	0.75	1.44	1.38
D	0.32	0.43	0.28	0.29

Note: N = Individual abundance, S = Species abundance, R1= Abundance Index, H' = Diversity index, D = Dominance Index

Table 2. Structure of leaf miner *Liriomyza* spp. parasitoid community in three types of agroecosystem in the highlands and lowlands in Lesser Sunda

Parameter	Lombok Island			Sumbawa Island			Flores Island			Timor Island		
	H1	H2	H3	H1	H2	H3	H1	H2	H3	H1	H2	H3
Lowland data												
N	82	1662	471	34	572	219	95	566	376	86	521	403
S	5	6	6	5	5	5	5	6	6	5	5	5
R1	0.91	0.67	0.81	1.13	0.63	0.74	0.88	0.79	0.84	0.9	0.64	0.67
H'	1.49	1.22	0.82	1.59	0.75	0.80	1.32	1.35	1.22	1.16	1.52	1.01
D	0.24	0.38	0.58	0.21	0.63	0.63	0.33	0.330	0.41	0.38	0.24	0.44
TP	29.38	25.86	19.35	5.75	5.03	3.87	19.93	12.22	3.76	18.87	17.94	12.40
Highland data												
N	36	1334	490	-	-	-	102	428	1173	52	390	853
S	6	7	7	-	-	-	5	6	7	5	5	6
R1	2.79	0.83	0.97	-	-	-	0.86	0.83	0.85	1.01	0.67	0.74
H'	1.73	1.43	1.20	-	-	-	1.61	1.28	1.44	1.50	1.34	1.36
D	0.19	0.27	0.37	-	-	-	0.20	0.32	0.26	0.24	0.31	0.30
TP	30.45	30.07	24.95				23.14	18.07	3.85	26.31	19.75	16.79

Note: N = Individual abundance, S = Species abundance, R1 = Abundance index, H' = Diversity index, D = Dominance Index, TP = Parasitization rate, H1 = the edges of forests, H2 =) agricultural areas, H3 = residential areas

Table 3. Community structure and level of parasitization of leaf miner *Liriomyza* spp. parasitoids on any type of host plants in Lesser Sunda types of host plants

Common name	Scientific name	Index value				
		N	TP	R1	H’	D
Leek	*Allium fistulosum* L.	158	2.298	3.804	0.066	0.26^{-3}
Spinach	*Amaranthus* L.	89	2.487	4.222	0.043	8.15^{-5}
Winter melon	*Benincasa hispida* (Thunb.) Cogn.	55	1.783	3.802	0.029	3.11^{-5}
Chinese cabbage	*Brassica pekinensis* L.	73	1.778	4.195	0.036	5.48^{-5}
Leaf green	*Brassica juncea* L.	72	2.551	3.274	0.01^{-3}	5.33^{-5}
Cabbage	*Brassica oleracea* L.	60	2.135	3.419	0.031	3.71^{-5}
Bok choy	*Brassica rapa* L.	322	3.512	3.262	0.112	1.07^{-3}
Calopo	*Calopogonium mucunoides* Desv.	21	2.482	3.942	0.013	4.54^{-7}
Centella	*Centella asiatica* (L.) Urb	15	0.646	4.431	0.010	2.32^{-5}
Centro	*Centrosema pubescens* Bth.	22	0.543	5.823	0.014	4.98^{-6}
Watermelon	*Citrullus vulgaris* (Schard.) Fursa	90	2.183	4	0.043	8.34^{-5}
Brown hemp	*Crotalaria ferruginea* Grah.	29	0.714	5.346	0.017	8.65^{-6}
Cucumber	*Cucumis sativus* L.	602	8.835	2.703	0.171	0.004
Pumpkin	*Cucurbita moschata* Duchesne	275	3.827	3.203	0.100	0.78^{-3}
Zucchini	*Cucurbita pepo* L.	361	8.218	3.057	0.121	1.34^{-3}
Lilac tassel flower	*Emilia sonchifolia* L.	6	7.220	6.697	0.005	3.71^{-7}
Guatemalan indigo	*Indigofera suffruticosa* Gaertn.	37	0.918	5.387	0.021	1.41^{-5}
Dolichos bean	*Lablab purpureus* (L) Sweet.	574	12.462	2.833	0.166	0.003
Angled luffa	*Luffa acutangula* (L.) Roxb.	164	1.653	3.993	0.068	0.28^{-3}
Red bean	*Vigna angularis* Willd.	1233	13.177	2.13	0.260	0.016
Common bean	*Phaseolus vulgaris* L.	1446	17.25	2.47	0.282	0.022
Gooseberry	*Physalis angulata* L.	82	2.895	3.177	0.040	6.92^{-5}
Pueraria	*Pueraria javanica* (Benth.)	34	1.221	3.97	0.020	1.19^{-5}
Rorippa	*Rorippa indica* (L.) Hiern	41	1.007	4.847	0.023	1.73^{-5}
Chayote	*Sechium edule* (Jacq.) Sw	183	3.174	3.23	0.074	0.35^{-3}
Tomato	*Solanum licopersicum* L.	1298	21.335	2.422	0.267	0.017
Eggplant	*Solanum melongena* L.	189	2.131	3.559	0.076	0.04^{-2}
Potato	*Solanum tuberosum* L.	562	12.234	2.843	0.163	0.003
White hoarypea	*Tephrosia candida* (Roxb.) DC.	18	0.444	6.228	0.012	3.33^{-6}
Long bean	*Vigna sinensis* (L.) Savi ex Hassk.	1747	23.027	2.352	0.307	0.031

Note: N = Total individuals in the population, H'= Diversity index, D=Dominance, Index, R = Abundance Index, TP = Level of parasitization

According to Aquilino (2005), a stable environment has a high diversity index value (H') and high abundance (R1) and low dominance (D). Flores has a higher diversity index value (H') than the other islands. The high parasitoid diversity will encourage the balance of *Liriomyza* spp. pest populations in nature. The mixed farming systems commonly found in Flores contribute to the relationship stability between *Liriomyza* spp. pests and their parasitoids, in accordance with the findings of previous researchers in other places (Robinson and Sutherland 2002). The high diversity and abundance of parasitoids in Flores prove that mixed farming system can suppress the development of pest populations and increase the role of natural enemies (Andow 1991; Altieri 1999; Paulsen et al. 2006). The increased role of parasitoids in these mixed farming environments leads to high levels of parasitization as indicated by *N. formosa* on each island in Lesser Sunda. Five of the seven parasitoid species found in Lesser Sunda are highly adapted to the islands on which they live, possessing distinctive characteristics that allow them to adapt to their environment (Doutt et al. 1976). Those characteristics are utilized by each parasitoid so that it can multiply and spread successfully within the vegetable ecosystems in Lesser Sunda.

Data in Table 2 shows that the community structure component in the highlands is higher compared to the lowlands. These high indexes are due to the agroecosystems in the highlands, which have to acclimate that supports the implementation of diversified agricultural systems so that the supporting components (prey species, adequate shelter, etc.) for parasitoid success are available continuously. Table 2 also indicates index values of diversity, abundance, and dominance of leafminer parasitoids in the three ecosystem types that show very significant differences in the context of agricultural ecosystem management. The diversity displayed in the index is not merely measured by the number of species but also by the disparity of individuals in each species. The data is in accordance with the findings of other studies on the diversity of insects in general (Fottit and Adler 2009). The average index of diversity, abundance, and dominance in Lesser Sunda indicates that there has been a combination of ecological processes taking place among the host plants, host parasitoids, and the surrounding environment (Hunter 2002)

The stability of the insect community not only depends on its diversity but also on the natural density of trophic levels (Southwood and Way 1970). The study results show that the diversity of insect pests, parasitoids (Thies and Tscharntke 1999; Thomson 2010) and predators (Schmidt et al. 2008) are also affected by the interaction of uncultivated (often native) plants and insects. Multicultural cropping systems allow uncultivated plants to grow around the agroecosystem, creating a microhabitat that has a strong influence on species diversity of the host plant, host, and parasitoid (Arthur and Abrahamson 1985; Lawson et al. 2014; Tantowijoyo and Hoffman 2010). The findings of this study suggest a strong ability of parasitoids such as *Liriomyza* spp. to develop within more complex ecosystems. This finding highlights the importance of the conservation of agricultural ecosystems with refugia plants planted in monoculture around cropping areas or that employ the use of intercropping so that shelter, food resources or other resources for natural enemies such as predators and parasitoids can be provided (Letourneau et al. 2012). Results of previous studies have proven that various types of weed from the family of Umbelliferae, Leguminosae, and Compositae play an important role as a food source for adult parasitoids to suppress the populations of insect pests (Altieri 1999).

The highest level of parasitization in all three ecosystem types is H1 in both highlands and lowlands (Table 2). These findings reinforce a better role for parasitoids within complex and stable ecosystems. Ecosystems on agricultural (H2) and settlement (H3) areas are not stable due to the common use of monocultural cropping patterns applied leading. The pattern of monoculture crops can increase agroecosystem vulnerability to pests (Shah et al. 2015) due to the availability of food or similar host plants continuously over time and space (Mujica and Kroschel 2011). Therefore, the action of pest management through the use of natural enemies and increasing the diversity of plants through the application of intercropping, crop rotation and open lands cultivation is highly important because it can increase the stability of the ecosystem and reduce the risk of pests (Altieri and Nicholls 2004) because it makes it more difficult for pests to find the main host (Gurr et al. 2004). Several articles have supported the hypothesis that high commodity diversification or multiculturalism can reduce the role of herbivores and enhance the role of natural enemies (Altieri 2012). Additional restrictions on the use of pesticides, especially those with broad-spectrum effects, is an effort to restore the stability of at-risk ecosystems (Ohno et al. 1999). The application of these findings provides natural enemies in the ecosystem and has a major role in regulating populations of *Liriomyza* spp. naturally, which would then fluctuate dynamically around a position of general equilibrium.

Diversity, abundance, and dominance of parasitoid on different varieties of vegetable crops in Lesser Sunda is considered moderate. The previous study reported that *Liriomyza* spp. can attack at least 21 plant families (Rauf et al. 2000; Supartha 2003; Andersen et al. 2008) but the parasitoid in Lesser Sunda still plays a role in controlling the population of *Liriomyza* spp. The research results in Table 3 show that the level of parasitization is still high in some varieties of vegetable crops, especially for long bean (23.02%), tomato (21.36%), common bean (17.25%), red bean (13.18%), dolichos bean (12.46%), and potato (12.23%). This is consistent with results of previous studies that show that *Liriomyza* spp. is known to have severe attacks and has become a major pest in the Solanaceae family, especially potato and tomato (Jones and Parella 1986; Trumble and Nakkakihara 1983) and will also select types of plants from legume family (Tryon et al. 1980) as the best breeding ground among other crops (Maryana 2000). The high levels of parasitization for each type of plant shows that neither the host nor the parasitoid has the main host, since the nutrient content and morphology of multiple host plants are useful for the shelter and reproduction (Mujica and Kroschel 2011). This phenomenon proves that the existence and the level of parasitization of parasitoid depend heavily on the relationship between the host plant, insect host, and its parasitoids. The discovery of five species of wild plants around the crops with a value of R> 5.0 proves that the refugia plants are required to enhance the parasitoids role. These findings are consistent with the findings of Baliadi (2009), which used weed *Rorippa indica* (L.) as refugia plants so to improve the *H. varicornis* performance by 12%.

The results of this study reveal that *N. formosa* is the parasitoid species that has the highest of parasitization in Lesser Sunda, while the results of previous studies have shown that *H. varicornis* have the highest level of parasitization in several areas in Java, Bali, Lombok, and Sulawesi (Rustam et al. 2008). This high level of parasitization is found in all types of ecosystems and vegetable crops. Similar results are shown by Herlianadewi et al. (2013) where the *N. formosa* population is most commonly found on various host plants in the lowlands in Bali. *Neochrysocharis formosa* dominates the agroecosystem in Sumbawa island (D ≥ from 0.30 to 0.60) meaning that *N. formosa* has a good adaptability to the environment, is able to multiply rapidly, and has a distribution area used to locate and utilize required resources (Murdock 1974). Another interesting finding is that an *O. chromatomyiae* parasitoid, newly found in Indonesia and though to be dominant in the highlands (Rauf et al. 2000; Supartha 2003; Herlinadewi et al. 2013) was found to be able to breed and spread in the lowlands as proven by the similar levels of parasitization in both highlands and lowlands. The phenomenon indicates the shifting role between *H. varicornis* and *N. formosa*. Meanwhile, *O. chromatomyiae* is estimated to have been able to adapt to *L. sativae* as its host and is also known to have been abundant in the highlands. This shifting role may have been caused by the shift of cropping patterns between regions and over time (Baideng 2016). It also shows that there has been a co-evolution of *L. sativae* with host plant (Westwood et al. 2010) demonstrated by the abundance of the *L. sativae* population in the highlands followed by the presence of *N. formosa* parasitoids which were initially only abundant in the lowlands (Baideng 2016) and of *O.*

chromatomyiae in the highlands (Li 2011). These conditions are reflected in the vegetable ecosystems in Lesser Sunda.

The results of this study are particularly interesting in the context of the unfolding potential of leafminer parasitoids, *Liriomyz*a spp. It should be noted that findings presented here are the results of an initial assessment of parasitoid potential as a candidate for biological agents of leafminer pest control in Lesser Sunda. The research concluded that among the seven species of parasitoids found, the parasitoid with the highest potential as a candidate for biological control agents, and therefore for further research, was *N. formosa.* Secondary candidates also to be considered are *H. varicornis* and *O. chromatomyiae,* which are able to demonstrate high levels of parasitization and adaptation in various vegetable crops. This finding of the potential of the three parasitoids should be considered as a control agent for regulating the populations of *Liriomyza* spp. in agricultural crops in Lesser Sunda. Further research into mass rearing technology and release techniques for these species is highly recommended. In addition, diversified agroecosystems containing multiple crop species as shown in highland agricultures in Lesser Sunda have been able to increase the parasitoids role. The future prospect and challenges of the potential parasitoid community structure leaf miner pest and their parasitoid needs comprehensive research to establish the pest management strategies in an integrated manner and in the long term.

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