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The diversity and abundance of weeds in sugarcane (*Saccharum officinarum*) plantations and its relationships with Hymenoptera parasitoids diversity

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Abstract. *Wibowo D, Rahardjo BT, Karindah S, Muhammad FN. 2023. The diversity and abundance of weeds in sugarcane* (Saccharum officinarum) *plantations and its relationships with Hymenoptera parasitoids diversity. Biodiversitas 24: 2342-2349.* Sugarcane (*Saccharum officinarum* L.) is an important plantation commodity in Indonesia. One of the strategies to improve sugarcane production is by controlling pest populations in sugarcane plantations which can be done by increasing the role of natural enemies as control agents, such as Hymenoptera parasitoids. The presence of parasitoids is influenced by the diversity of vegetation, including weed plants, due to the nectar contained in its flowers. The aim of this study was to investigate the diversity, abundance and composition of weeds in sugarcane plantations and their relationships with the diversity and abundance of Hymenoptera parasitoids that have the potential to control pests in sugarcane plantations. The study was conducted from June to August 2022 in four locations in East Java, i.e. Karangploso and Kalipare (Malang), Pasirian (Lumajang) and Gandusari (Blitar). Observation of weed vegetation was carried out by taking samples using 1 m x 1 m frame inside the observation point at each observation plot. Collection of Hymenoptera parasitoids used yellow pan trap and modified farmcop to determine the diversity of Hymenoptera parasitoids in the field. Observations were made at intervals of 1 week. We found that the highest abundance of weeds found across the four sugarcane plantations was *Digitaria ciliaris* (Retz.) Koeler, *Ipomoea triloba* L. and *Ageratum conyzoides* L. The highest abundance of Hymenoptera parasitoid species found were *Trichogramma chilonis* Ishii and *Telenomus dignus* Gahan. There were positive relationships between weed density and Hymenoptera parasitoid diversity and abundance at each sugarcane plantation. Weed species with the most presence of Hymenoptera parasitoids were *A. conyzoides*, *I. triloba* and *Mimosa pudica* L. In conclusion, the presence of weed vegetation on sugarcane plantations affected the composition of the Hymenoptera parasitoid community. The results of this study can be the rationale that the conservation of wild weeds in sugarcane fields is very important to support the existence of beneficial parasitoids.

Keywords: Diversity, Hymenoptera, parasitoids, sugarcane, weeds

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is an important plantation commodity in Indonesia that is used as the main raw material in sugar production. Sugar industry has a strategic role in the national economy of Indonesia, with a total production of 2.12 million tons and a total area of 418,996 hectares (BPS 2021). East Java Province alone had the largest sugar production in 2020 with 1.00 million tons, or equivalent to 47.24% of Indonesia's total sugar production (BPS 2021). Because of the increasing population and the high demand for sugar consumption, the government through Presidential Decree 59 (2020) promotes the growth of the domestic sugar industry, which certainly require sugarcane as a raw material (BPS 2021). Besides being produced into sugar, sugarcane plants can also be used as molasses and an ingredient for Monosodium Glutamate (MSG).

Nonetheless, there are several problems in the production of sugarcane, one of which is caused by the low yield of sugarcane plantations. The low yields in the cultivation of sugarcane, especially ratoon sugarcane, is related to the prevalence of pests, diseases, and weeds. Pests that often damage sugarcane include moth borers, such as *Chilo auricilius* (Dudgeon, 1905), *Chilo sacchariphagus* (Bojer, 1856), and *Scirpophaga excerptalis* (Walker, 1863), which can reduce sugarcane production between 14.5-15.8% (Goebel et al. 2014). A strategy to control pest populations in sugarcane plantations can be done by increasing the role of natural enemies as control agents, such as Hymenoptera parasitoids. The presence of natural enemies is related to vegetation diversity in a positive way, thus increasing the type of vegetation in agricultural land can influence the interactions between arthropod species both directly and indirectly to create a more sustainable agroecosystem (Ebeling et al. 2018).

Among the vegetation types in agricultural landscape, there are weeds that might co-occur with the primary crops, including sugarcane. Weeds are unwanted wild plants that grow on cultivated land and interfere with the process of cultivation, often in a negative way. Weeds directly or indirectly harm cultivated plants because they compete for nutrients, sunlight and water. However, the presence of weeds, especially the flowering ones that grow on sugarcane fields, might function as a shield from natural enemies and might serve as an alternative host of the preys of the natural enemies when the sugarcane plants are entering the harvest period. Nonetheless, the role of weeds in sugarcane is not yet fully understood as part of the sugarcane agroecosystem.

The presence of weeds in the agricultural landscapes can create an environmental balance. Naturally, pests and diseases in sugarcane can be controlled by their natural enemies, such as predators, parasitoids and pathogens (Ebeling et al. 2018). Some types of weeds attract herbivorous insects which are the natural enemies of pests and diseases. Some parasitoids might have an association with weeds plants due to the presence of nectar in their flowers which attracts parasitoids to come and use it so (Grasso et al. 2015). Plants that can produce nectar are considered important in terms of their role in animal-mediated pollination, as well as being consumed by many pollinators and also natural enemies. The nectar contained in flowers can be consumed by natural enemies so that it can increase its abundance and reduce the abundance of herbivores in some plants (Pearse et al. 2020).

The presence of various types of weeds that produce flowers is expected to increase the diversity and abundance of beneficial insects to facilitate the presence of natural enemies, especially parasitoids. Previous studies have revealed the dominant weed species in sugarcane plantations, including Fabaceae with 16 species and Asteraceae with 11 species (Hariri and Irsyam 2019). However, other weeds associated with sugarcane, especially weeds that produce flowers (e.g. *Ipomoea triloba* L. and *Mimosa pudica* L.) have not been widely studied. Such flowering weeds might be able to attract particular natural enemies such as parasitoids *Telenomus* spp., *Trichogramma* spp., and *Tetrastichus* spp.

There have been many studies on the diversity of parasitoids in sugarcane, but little information is available in the context of sugarcane plantations as an ecosystem. Sugarcane plantation is not only inhabited by sugarcane plants at the first trophic level, but also there are several types of plants, including weeds, that might co-occur in the sugarcane plantation ecosystem. The vegetation other than the sugarcane plants has the potential as refugia that can increase parasitoids diversity. Therefore, this study aimed to investigate the diversity, abundance and composition of weeds in sugarcane plantations and their relation with the diversity and abundance of Hymenoptera parasitoids that have the potential to control pests in sugarcane plantations. We expected this study can provide information about the importance of weeds in supporting the existence of parasitoids in sugarcane plantations.

MATERIALS AND METHODS

Study area

The study was conducted from June to August 2022 in four different sugarcane plantations in East Java, i.e. (i) Karangploso, Malang (7°54’23”S; 112°37’27”E); (ii) Kalipare, Malang (8°12’02”S; 112°27’01”E); (iii) Pasirian, Lumajang (8°13’21”S; 113°08’53”E); and (iv) Gandusari, Blitar (8°01’49”S, 112°17’14”E) (Figure 1). The study locations were selected since they were productive plantations with the age of sugarcane plants ranging from 6-10 months and a minimum field area of 50 m x 50 m (2,500 m^2) to be feasible to make a research plot.

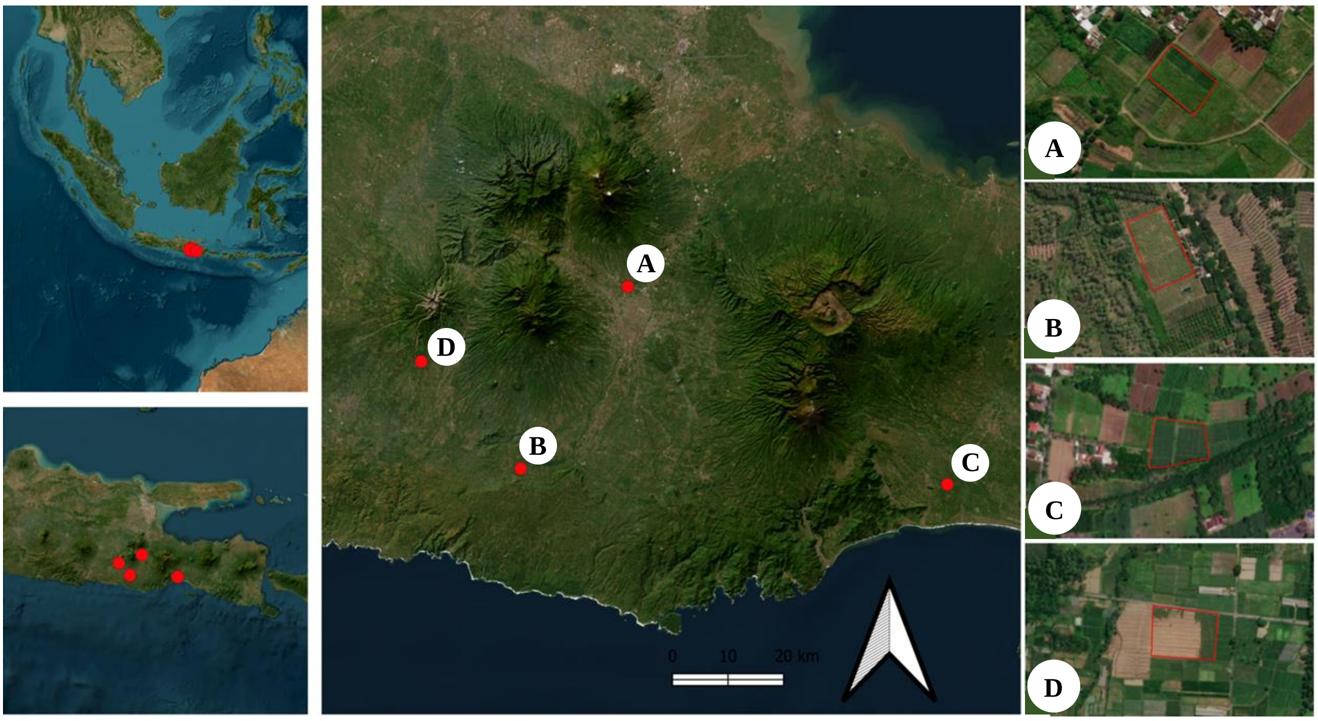

Figure 1. Location of sugarcane plantation: A. Karangploso, Malang; B. Kalipare, Malang; C. Pasirian, Lumajang; and D. Gandusari, Blitar, East Java, Indonesia

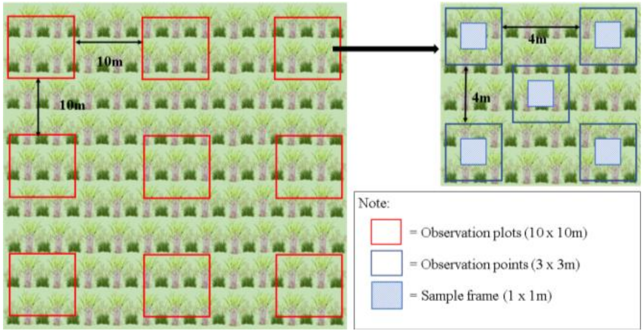

Figure 2. The sampling plot design of weed collection. Each research location consisted of nine observation plots with size each plot of 10 m x 10 m and the distance between plots was 10 m. Each plot consisted of five observation points (3 m x 3 m) with a distance of 4 m. Sample frames was randomly placed inside the observation point

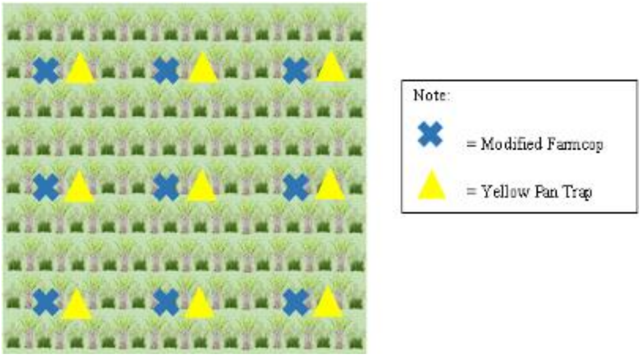

Figure 3. Hymenoptera parasitoids collection design plots with each study location consisted of nine observation plots for yellow pan trap and modified farmcop method

Collection of weed samples

Weed sampling at each study location was carried out on 9 plots with a size of 10 m x 10 m each. Each plot consists of 5 observation points (3 m x 3 m). A total of 45 samples were taken per location (Figure 2). Observation of weed vegetation was carried out using a 1 m x 1 m frame that was randomly placed inside the observation point to determine the number of species and individual weed vegetation. Weed samples were then kept in a cool box to keep them fresh. The identification process was carried out in the laboratory based on morphological characters using weed identification book written by Xu and Zhou (2017), Xu and Deng (2017), and Xu and Chang (2017).

Collection of Hymenoptera parasitoid samples

Yellow pan trap

The collection of Hymenoptera parasitoids was carried out using yellow pan traps with a diameter of 20 cm placed on the soil surface to sample parasitoids around the weeds. The pan was filled with 5% detergent solution and covered with plastic with a slope to protect it from rainwater entering the pan trap. Sampling at each study location was carried out on the nine observation plots with intervals of 1 week (Figure 3). Samples were taken and put into collection bottles containing 70% alcohol and labeled to be identified in the laboratory using an insect identification book written by Goulet and Huber (1993), and Johnson and Triplehorn (2005).

Modified farmcop

Observation of Hymenoptera parasitoids using a modified farmcop was carried out by collecting parasitoids directly in the weeds. Sampling at each study location was carried out on the nine observation plots with intervals of 1 week (Figure 3). Samples were taken and put into collection bottles containing 70% alcohol and labeled to be identified in the laboratory using an insect identification book written by Goulet and Huber (1993), and Johnson and Triplehorn (2005).

Data analysis

Observational data were tabulated using Microsoft Excel 2019. Population data of weed species were analyzed using Summed Dominance Ratio (SDR). While data of Hymenoptera parasitoid species were analyzed using the Simpson Dominance Index (D), the Shannon-Wiener Diversity Index (H'), the Evenness Index (E), the Bray-Curtis Similarity (BC). Analysis of weed vegetation and the diversity of Hymenoptera parasitoids on sugarcane plantations were analyzed using ANOVA and continued with Tukey test if there was a significant difference with an accuracy level of 95%. Prior to ANOVA analysis, Shapiro-Wilk normality test was performed on each response variable. If the data were not normally distributed, transformation log(x) was conducted. Pearson correlation analysis (r) was used to determine the relationship between the diversity of Hymenoptera parasitoids and the diversity of weed vegetation. Data analysis was performed using R Statistics Software (R Core Team 2022).

RESULTS AND DISCUSSION

Diversity, abundance and composition of weed vegetation in sugarcane plantations

There were 13 species belonging to six families of weeds across the studied plots in four sugarcane plantation locations with a total number of individuals of 1879. The six families were Asteraceae with three species, Amaranthaceae with one species, Poaceae with four species, Fabaceae with two species, Euphorbiaceae with two species, and Convolvulaceae with one species (Table 1). Poaceae had the highest abundance with 947 individuals, while the lowest abundance was Amaranthaceae with 46 individuals.

Weed abundance showed significant differences across the four study locations ($F_{3.32}$ = 199.1; P<0.001) (Figure 4A). The highest abundance of weed vegetation was found in Pasirian which consisted of 13 species with a total of 794 individuals. The abundance of weeds in sugarcane plantations can be influenced by various factors such as light and nutrient availability on the field. This is in line with the statement of Nicholls and Altieri (2013) that weed populations differ from one area to another according to the factors that influence them. Climatic factors that determine the growth, reproduction and distribution of weeds include light, temperature, wind and water or nutrient availability. Agricultural areas with high rainfall can lead to fast growth and highly diverse and density of weeds.

Digitaria ciliaris (Retz.) Koeler had the highest Summed Dominance Ratio (SDR) value compared to other weed species with 18.94%, 19.42%, 17.68%, and 18.77% at Karangploso, Kalipare, Gandusari and Pasirian, respectively (Table 1). Weed species with high SDR values show a high level of domination and better adaptability compared to other species (Whitney et al. 2017). *D. ciliaris* at each study site had the highest individual abundance compared to other weed species. The highest abundance of *D. ciliaris* was found at the Pasirian location with 236 individuals. According to Park et al. (2020), *D. ciliaris* is widely reported to be a problematic weed in agricultural areas. *D. ciliaris* weed lives in clumps with creeping stems and produces a lot of seeds, so it is often dominant in cultivated plant areas. Roy and Chakraborty (2017) reported that *D. ciliaris* was relatively tolerant of salt, showing greater resistance and adaptability.

Diversity and abundance of Hymenoptera parasitoids in sugarcane plantations

The total number of Hymenoptera parasitoids found in sugarcane plantations was 2341 individuals belonging to six families and 17 species. The six families were Braconidae with five species, Eulophidae with two species, Evaniidae with five species, Ichneumonidae with five species, Trichogrammatidae with one species, and Scelionidae with one species (Table 2). Trichogrammatidae had the highest abundance with 849 individuals, while the lowest abundance was Ichneumonidae with 39 individuals.

Hymenoptera parasitoids abundance showed significant differences across the four study locations ($F_{3.32}$ = 52.14; P<0.001, Figure 4B). *Trichogramma chilonis* Ishii and *Telenomus dignus* Gahan had the highest abundance of individuals compared to other parasitoid species. The highest abundance of *T. chilonis* and and *T. dignus* was found at Karangploso with 326 individuals and 284 individuals, respectively. The high abundance of *T. chilonis* and *T. dignus* is likely due to the abundant source of feed in sugarcane plantations. According to Aldinas et al. (2020), these parasitoid imagos require feed in the form of nectar or pollen provided by flowering plants for their growth and survival.

The analysis of the diversity index, evenness, and dominance of Hymenoptera parasitoids at the four study sites showed that the highest diversity index was found at the Karangploso location with 1.707, the highest evenness index was at the Gandusari location with 0.625, and the highest dominance index was at the Pasirian location with 0.736 (Table 3).

The diversity index values of the four study locations is classified as moderate (1<H'<3). Meanwhile, the evenness indexes at the Karangploso, Kalipare, and Gandusari are categorized as high (E>0.6), while the Pasirian is classified as moderate (0.4<E<0.6). The dominance index of the four study locations are classified as high (D>0.6), meaning that there was a parasitoid species that dominated the four study locations. This is in line with Ikhsan et al. (2020), explaining that a community has high diversity if the community is composed of many species. Conversely, if a community has a few types or species, then the community is classified as low diversity.

The similarity index of the composition of the Hymenoptera parasitoids at the four study sites was analyzed using the Bray-Curtis similarity index. It was found that the level of similarity in the composition of Hymenoptera parasitoids at the Karangploso and Pasirian locations was 0.877, and at the Kalipare and Gandusari locations, it was 0.830 (Table 4).

Table 1. Diversity, abundance, and Summed Dominance Ratio (SDR) value of weeds at four sugarcane plantation locations

Species	Karangploso		Kalipare		Gandusari		Pasirian	
	ind.	SDR (%)	ind.	SDR (%)	ind.	SDR (%)	ind.	SDR (%)
Asteraceae								
Ageratum conyzoides L.	58	9.90	10	8.74	24	7.13	106	10.59
Bidens pilosa L.	23	6.16	8	6.48	18	6.86	33	5.99
Synedrella nodiflora (L.) Gaertn.	33	7.08	18	10.99	30	9.05	39	6.37
Amaranthaceae								
Alternanthera sessilis (L.) DC.	12	3.63			13	5.08	21	5.24
Poaceae								
Cynodon dactylon (L.) Pers.	45	8.70	19	12.12	26	8.51	62	7.82
Digitaria ciliaris (Retz.) Koeler	156	18.94	45	19.42	93	17.68	236	18.77
Eleusine indica (L.) Gaertn.	76	11.56	34	17.18	51	11.93	80	8.95
Pennisetum purpureum Schumach.	12	5.65			5	2.33	27	5.18
Fabaceae								
Desmodium intortum (Mill.) Urb.	5	2.99					30	5.80
Mimosa pudica L.	25	3.82	19	11.27	37	10.01	14	4.36
Euphorbiaceae								
Euphorbia heterophylla L.	23	5.66			15	5.90	28	5.68
Euphorbia hirta L.	22	6.57			14	5.21	30	5.80
Convolvulaceae								
Ipomoea triloba L.	52	9.34	25	13.80	39	10.29	88	9.45
Total	**542**	**100**	**178**	**100**	**365**	**100**	**794**	**100**

Table 2. Diversity and abundance of Hymenoptera parasitoids at four sugarcane plantations sampled with different trapping methods

Species	Karangploso		Kalipare		Gandusari		Pasirian	
	Yellow pan trap	Farmcop	Yellow pan trap	Farmcop	Yellow pan trap	Farmcop	Yellow pan trap	Farmcop
Braconidae								
Apanteles sp. 1	11	12	5	3			13	14
Apanteles sp. 2	16	13	4	2	4	3		
Aleiodes sp.	3	1					4	3
Cotesia sp.	14	24	6	3	3		13	11
Fopius sp.	4	3						
Eulophidae								
Necremnus sp.	14	10	6	3	7	6	14	12
Tetrastichus schoenobii Ferr.	60	27	39	29	26	18	44	49
Evaniidae								
Evania sp. 1	2	1						1
Evania sp. 2	1	1	1				1	
Evania sp. 3			2		2	1	2	
Evania sp. 4	2	1		1			3	2
Evaniella sp.	11	6	5	2	6	6	14	10
Ichneumonidae								
Ichneumonidae sp. 1	9	4			2	1	5	4
Ichneumonidae sp. 2	2			1	3	1	1	1
Ichneumonidae sp. 3	1	3						1
Trichogrammatidae								
Trichogramma chilonis Ishii	197	129	66	31	114	38	160	114
Scelionidae								
Telenomus dignus Gahan	142	142	119	40	103	40	200	27
Total	**489**	**377**	**253**	**115**	**270**	**114**	**474**	**249**
Grand total	**866**		**368**		**384**		**723**	

Table 3. Indices of diversity, evenness, and dominance of Hymenoptera parasitoids at four sugarcane plantations

Biodiversity indicators	**Karangploso**	**Kalipare**	**Gandusari**	**Pasirian**
Biodiversity index (H')	1.707	1.510	1.440	1.462
Evenness index (E)	0.616	0.608	0.625	0.540
Dominance index (D)	0.735	0.707	0.689	0.736

Table 4. Bray-Curtis similarity index of Hymenoptera parasitoid composition in four sugarcane plantations

	Karangploso	**Kalipare**	**Gandusari**	**Pasirian**
Karangploso	1			
Kalipare	0.593	1		
Gandusari	0.606	0.830	1	
Pasirian	0.877	0.664	0.676	1

At the Karangploso and Pasirian locations, there were 15 similar parasitoid species, including *Apanteles* sp., *Aleiodes* sp., *Cotesia* sp., *Necremnus* sp., *T. schoenobii*, four species of *Evania* sp., *Evaniella* sp., three species of *Ichneumonidae*, *T. chilonis*, and *T. dignus*. According to Magurran et al. (2019), the closer the value to 1, the higher the community similarity. This means that the composition contained in the field tends to be the same or not different. The higher the similarity index value, the fewer the different species composition. Conversely, the lower the similarity index value, the more different species composition. This explains that the high similarity index value of Hymenoptera parasitoid composition can occur because field management in each sugarcane plantation is able to maintain the sustainability of Hymenoptera parasitoids.

Relationship between weeds and Hymenoptera parasitoids

The abundance of Hymenoptera parasitoids found in weeds varied across the study locations. The highest abundance of parasitoids in Karangploso was found in *I. triloba* with a total of 127 individuals. In Kalipare, the highest abundance of Hymenoptera parasitoids was found in *M. pudica* with 79 individuals. Meanwhile, in Pasirian and Gandusari, the highest abundance of Hymenoptera parasitoids was found in *A. conyzoides* with 104 and 45 individuals, respectively (Figure 5).

The results of Pearson correlation analysis showed that weed vegetation density has a positive effect on the number of parasitoid species (r = 0.054; P<0.001, Figure 6A) and parasitoids abundance (r = 0.702; P<0.001, Figure 6B). The higher the density of weed vegetation, the higher the number of species and parasitoids abundance. The existence of flowering weeds actually has benefits for parasitoids which are natural enemies of sugarcane pests. To complete its life cycle, parasitoids require nutrition such as nectar and honeydew which can be found on flowering weeds that live around cultivated plants (Rusch et al. 2012; Belz et al. 2013). Besides being able to obtain nectar and pollen from flowering vegetation, natural pest enemies can also obtain prey from other insects that visit the flowering vegetation, so natural enemies easily obtain their prey (Karenina et al. 2019). Weeds that grow wild around sugarcane plantations not only function as a shelter or refugia for natural enemies when conditions are not suitable, but can also be a source of food or a source of natural enemies (Ikhsan et al. 2020). Furthermore, flowering weeds or undergrowth plants were plant communities that constructed underground stratification near the soil surface (Amarullah et al. 2017).

In this study, we found that *I. triloba*, *A. conyzoides*, and *M. pudica* were flowering weeds that attracted more Hymenoptera parasitoids than the others. The high number of Hymenoptera parasitoids attracted to them is thought to be due to the role of allelochemical compounds that can attract parasitoids to approach them. This was validated by similar studies on maize. The growth of *I. triloba* associated with maize in the field can influence the chemical ecological behavior of *Ostrinia furnacalis* (Guenée, 1854) in the Philippines (Calumpang and Navasero et al. 2013). According to Sheikh (2017), allelochemicals play an important role in insect chemical communication, such as kairomon compounds which play a role in helping parasitoids in their habitat preferences.

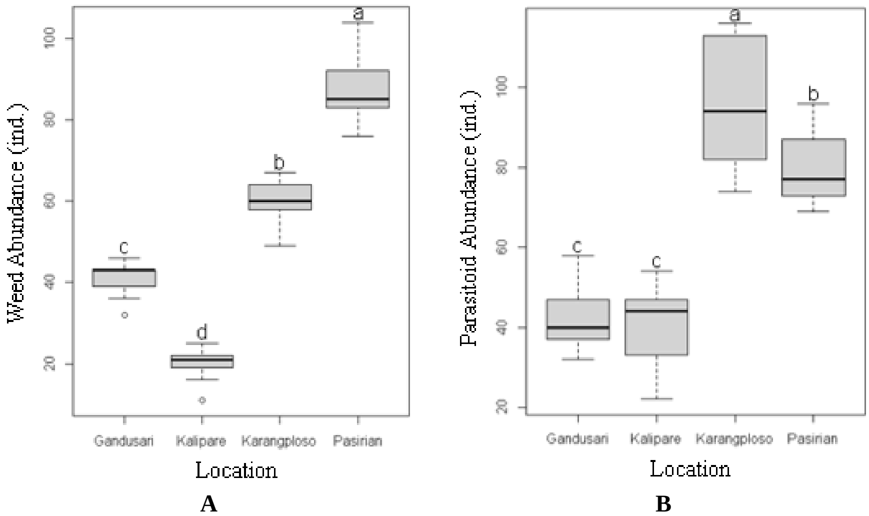

Figure 4. Differences in (A) weeds abundance, and (B) Hymenoptera parasitoids abundance among four sugarcane plantations. Boxplots with different letters are significantly different at P < 0.05 according to Tukey Test

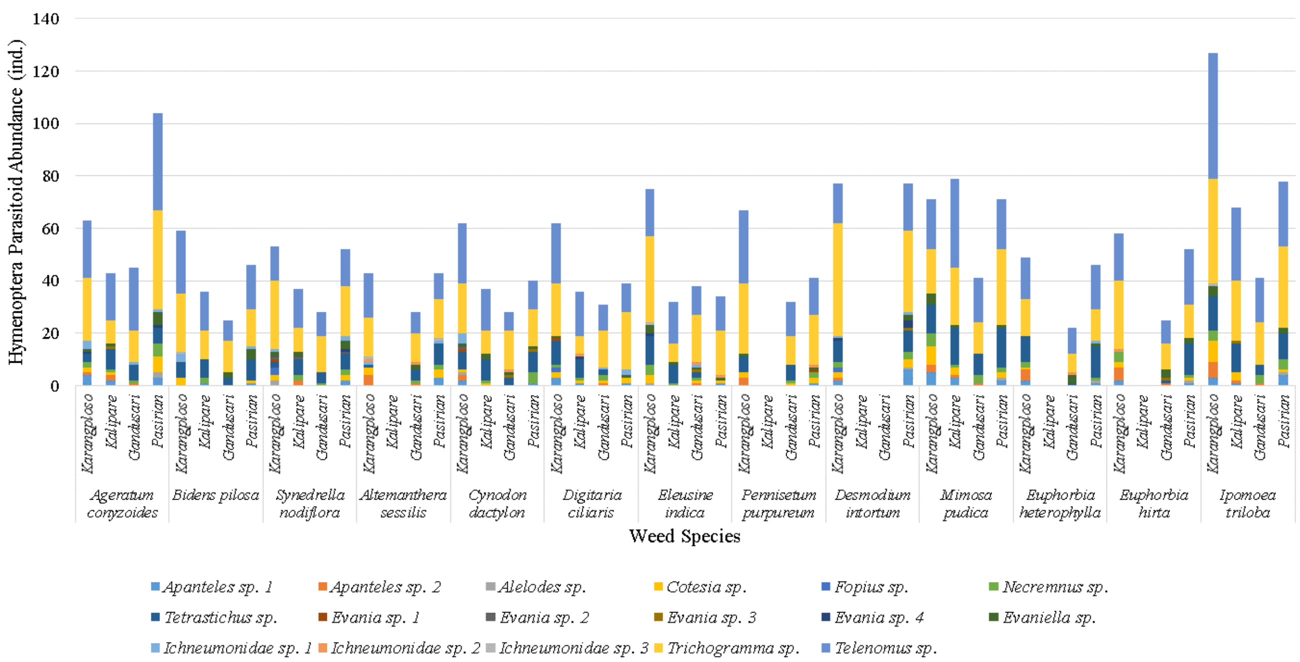

Figure 5. Hymenoptera parasitoid composition based on the type of weeds in each sugarcane plantation

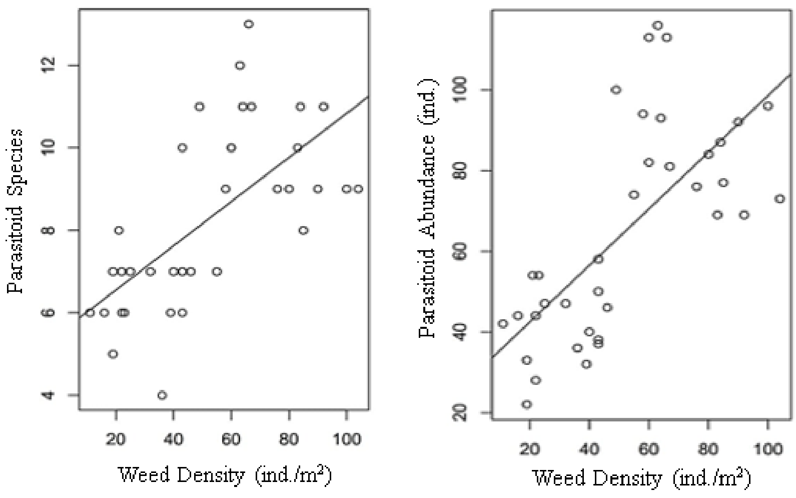

Figure 6. Relationship between weed vegetation density and: (A) number of parasitoid species, (B) parasitoid abundance

In conclusion, the diversity and abundance of weeds in the Pasirian location were higher than in other locations, while the diversity and abundance of Hymenoptera parasitoids in Karangploso were higher than in other locations. *T. chilonis* and *T. dignus* dominated the four sugarcane plantations. The flowering weeds *I. triloba*, *A. conyzoides*, and *M. pudica* were able to attract the presence of Hymenoptera parasitoids. The presence of weed vegetation on sugarcane plantations affected the composition of the Hymenoptera parasitoid community in which the higher the density of weed vegetation, the higher the diversity and abundance of the Hymenoptera parasitoid in it. The results of this study can be the reason that the conservation of wild weeds in sugarcane fields is very important to support the existence of parasitoids. However, further research on the effect of each wild weed species on sugarcane needs to be carried out with experiments such as weed exclusion, comparisons of several weed species, as well as comparisons of flowering and non-flowering weeds.

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