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Population dynamics of *Arthroschista hilaralis* pest and its parasitoid diversity in various jabon (*Anthocephalus cadamba*) cropping patterns in South Sumatra, Indonesia

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Abstract. Utami S, Triwidodo H, Pudjianto, Rauf A, Haneda NF. *2018. Population dynamics of* Arthroschista hilaralis *pest and its parasitoid diversity in various jabon (*Anthocephalus cadamba*) cropping patterns in South Sumatra, Indonesia. Biodiversitas 19: 239-245.* Jabon (*Anthocephalus cadamba*), a native tree species in Indonesia exhibit natural distribution, spreading over an enormous area in this region. In South Sumatra, jabon has long been cultivated in both communities and industrial plantation forests. *Arthroschista hilaralis* (Lepidoptera: Pyralidae) is the most damaging insect pest of jabon in South Sumatra. This study analyzed the population dynamics of *A. hilaralis* in jabon monoculture and two agroforestry systems, and assessed the diversity of the pest parasitoids and their parasitism level on *A. hilaralis*. Our results showed that planting systems, climatic factors, and the presence of parasitoids could significantly affect the population dynamics of *A. hilaralis*; its mean population density was highest in monocultures plantation during the rainy season compared with population densities in agroforestry systems. Three parasitoids species attacking *A. hilaralis* were found in these agroforestry systems, including *Phanerotoma* sp., *Apanteles* sp. and *Brachymeria* sp., while only one species (*Apanteles* sp.) was found in a monoculture. The rate of parasitization of *A. hilaralis* within agroforestry systems was higher than in monocultures, and the level of larval parasitization by *Apanteles* sp. in the agroforestry system was higher in instar 1 than in other larval stages.

Keywords: *Arthroschista hilaralis*, *Anthocephalus cadamba*, parasitization, population dynamics, South Sumatra Indonesia

INTRODUCTION

The jabon tree (*Anthocephalus cadamba* (Roxb.) Miq.) is a typical native tree species in Indonesia with a wide natural distribution extending from Aceh on the northern tip of the island of Sumatra eastward to Papua (Martawijaya et al. 1989). Jabon is used in numerous ways, including as raw material for wood industries and a herbal medicine. Jabon wood can be used as casting board and egg or vegetable crates, as well as in furniture items, molding media, pencils, and paper. Elsewhere, the fruit extract, roots, and stem bark of jabon plants provide beneficial and effective medicines (Mansur 2013).

In Indonesia, the jabon tree is currently cultivated in a large-scale community and industrial-plantation forests in both monoculture or agroforestry systems. However, several herbivorous insects, among them a defoliating insect *Arthroschista hilaralis* Walk. (Lepidoptera: Pyralidae) infest the jabon stands and can be especially damaging. The growth of insect pests is affected by several biotic and abiotic factors. Such biotic factors include the presence of natural enemies as well as the fecundity of the pest. An earlier study by Thapa and Bhandari (1976) reported that some parasitoids among them *Apanteles balleatea* and *Cedria paradoxa* attacked a defoliator pest, *A. hilaralis*. These parasitoids, reduced the extent defoliation caused by this pest. Meanwhile, abiotic factors, such as temperature, humidity, and rainfall, can also affect the growth of insect pests. For example, Kwon et al. (2012) suggested that temperatures and humidity affect population dynamics of pest and incidence level of pest.

Environmental factors can limit plant resistance to pests and have direct impacts on the presence of pests in a particular ecosystem. Berryman (1981) reported that the environmental factors affecting the abundance of a pest population in a particular ecosystem included all external factors, such as food, living space, climate, competitors, and natural enemies. A study by Pribadi and Anggraeni (2011) found that environmental factors affect the behavior of *A. hilaralis* attacking the jabon plants, and consequently the intensity of damage it causes to jabon leaves. The temperature and humidity of the environment so significantly affect the intensity of damage to jabon leaves by *A. hilaralis*.

Natural enemies, such as parasitoids, have also provided a substantial impact on the occurrence and expanse of pest attacks. In a forest ecosystem, which exhibits greater biodiversity than an agricultural ecosystem, it might be possible to use the service of a pest's natural enemies that already exist in that setting (Agus 2014). Accordingly, to secure sustainable forestry, habitat management should be a priority in attempting to prevent or to cope with pest attacks, particularly those occurring in plantation forests.

This study has two main objectives: (i) to analyze the population dynamics of *A. hilaralis* in three differing cropping settings; and (ii) to assess the species diversity of parasitoids and the level of parasitism they cause to *A. hilaralis.*

MATERIALS AND METHODS

Study area

The population dynamic of *A. hilaralis* study was carried out in three locations: Karang Anyar Village, within Banyuasin II Sub-District; Sumber Mekar Mukti Village, within Tanjung Lago Sub-District; and Tanjung Lago Village, within Tanjung Lago Sub-District. Administratively all the sampling sites are within Banyuasin District, in South Sumatra Province, Indonesia. The map is presented in Figure 1 and the position of each location is presented in Table 1. Research regarding the species and families of parasitoids was conducted in Karang Anyar Village. Identification of parasitoids and observations on the rate of parasitoid parasitization occurred in the Laboratory of Forest Protection, under the Forestry and Environment Research and Development Institute of Palembang, South Sumatra Province, Indonesia. The research was conducted from May 2015 until November 2016.

Procedure

Delineation of observation plots

Observations on the population dynamics of *A. hilaralis* and associated parasitoids were preceded by establishing the study plots. The plots were delineated in three area with the difference in the planting system. The plots named as a monoculture, agroforestry 1, and agroforestry 2. The monoculture plot covered area with only homogenous jabon stands. The agroforestry 1 delineated an area with 2-years old jabon stands mixed with a paddy crop and oil-palm plants. The remaining, the agroforestry 2 covered an area with 2-years old white jabon stands mixed with 2-years old red jabon stands, and a paddy crop. Each plot was approximately 0.25 ha in area.

Observations on parasitoids were performed within 2.5-year-old jabon stands in both a monoculture system and the two agroforestry system that covered white jabon stands, red jabon stands, and a paddy crop. Each plot in the systems measured covered 0.25 ha.

Table 1. Geographical position of the research location in Banyuasin District, South Sumatra Province, Indonesia

Location	South	East
Karang Anyar Village, Banyuasin II Sub-District	$2^0$30’27.068”	$104^0$46’52.186”
Sumber Mekar Mukti Village, Tanjung Lago Sub-District	$2^0$39’17.265”	$104^0$44’02.941”
Tanjung Lago Village, Tanjung Lago Sub-District	$2^0$41’45.297”	$104^0$44’21.693”

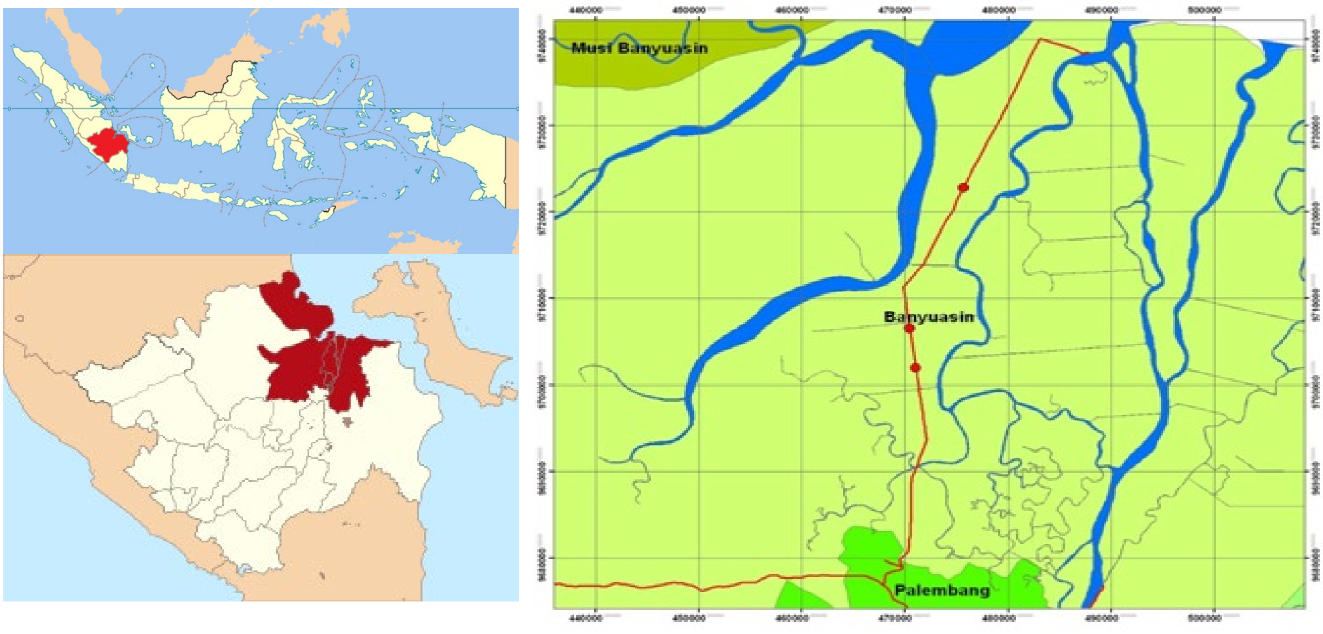

Figure 1. Research location maps in Banyuasin District, South Sumatra Province, Indonesia

Table 2. Average of temperature, humidity, and rainfall in study areas

Time of Observation	Temp. (^{0}C)	Humidity (%)	Rainfall (mm/month)
Rainy season	26.8	85	406
End of rainy season	27.8	81	257
Dry season	28.6	75	24
End of dry season	28.2	78	33

Population dynamics of Arthroschista hilaralis

The population dynamics of *A. hilaralis* in the jabon stands were assessed using a randomized complete block design (RCBD) that implemented factorial patterns. The factors incorporated in the RCBD included the planting systems and observation times. The planting systems consisted of monoculture, Agroforestry System 1, and Agroforestry System 2. Observations on population dynamics were conducted four times. They were at the end of the rainy season (May 2015), at the peak of the dry season (August 2015), at the end of the dry season (November 2015), and at the peak of the rainy season (February 2016). These time points were selected based on data gathered in 2011 until 2014, collected at the Station for Agrometeorology and Climatology in South Sumatra, Indonesia. Climate data collected during the study period included temperature, humidity, and rainfall, and these are presented in Table 2. The average temperature and humidity values were calculated for the observation days. The rainfall data were obtained from the local Station for Agrometeorology and Climatology.

In all sampling time, we determined the presence of *A. hilaralis* by examining the leaves of selected trees. Ten jabon trees were selected for every plot for their leaves, and a total five leaves were harvest from every single stand. The leaves were sampled by cutting off the second upper branch. The leaf samples were placed in a plastic container until further examination to determine the presence of *A. hilaralis*. Larvae found on the sample leaves were counted, and the numbers were recorded. The obtained larvae were then reared in another plastic container box (dimensions: 14 cm × 9 cm × 7 cm). These larvae were fed daily with fresh jabon leaves. Larvae that developed into pupae were then placed in a plastic jar (3-cm diameter and 18 cm high) until moth emergence. Imagoes were fed a honey solution at 20% concentration on moistened cotton. Observations on the emergence of parasitoids were conducted daily, in addition to documenting the number of *A. hilaralis* larvae and pupae parasitized. The rate of parasitization was calculated with the following formula:

Rate of parasitization= × 100%

Observations and identification of parasitoids

Observations of parasitoids were conducted in both jabon monoculture and agroforestry systems that included white jabon stands, red jabon stands, and paddy crop; these jabon stands are heavily attacked by *A. hilaralis*. Every developmental stage of *A. hilaralis* was observed. *A. hilaralis* samples were collected as egg stadia, larval stadia, or pupal stadia from leaves procured from the jabon stands. Eggs were collected by gathering ten jabon leaves, such that there were three groups of eggs on each leaf and every group of eggs consisted of 12-40 eggs, up to 30 larvae per-instar for the larval sample, and up to 25 pupae for the pupal sample. The egg groups were placed in Petri dishes (75-mm diameter and 1.5 cm high). The larvae and pupae were separately placed into plastic containers measuring 14 cm × 9 cm × 7 cm. All *A. hilaralis* stages were observed every day, and any parasitoids that emerged were recorded. Afterwards, parasitoids were identified, and the rate of parasitization was calculated using Equation 1. Insect observations were done using a stereo microscope and a portable microscope (using Dino-Lite AM4113). The books used for the identification of parasitoids were Hymenoptera of The World (Goulet and Huber 1993), A Handbook of The Families of Nearctic Chalcidoidea (Hymenoptera) (Grissell and Schauff 1990), and Manual of the New World Genera of the Family Braconidae (Hymenoptera) (Wharton et al. 1997).

Data analysis

The data on *A. hilaralis* population dynamics were analyzed by an analysis of variance (ANOVA) at a 95% confidence interval, which used the previously described RCBD with a factorial pattern. The data were analyzed using Statistical Analyzes System (SAS, version 9.1).

RESULTS AND DISCUSSION

Population dynamics of *Arthroschista hilaralis*

We found that both planting systems and observation times gave a significant value on the number of *A. hilaralis* that were found in jabon stands (Table 3). By comparing the data from four times of observation, we found that *A. hilaralis* was more abundant in the rainy season than the other observation time. At the end of the rainy season, *A. hilaralis* were still encountered in jabon stands within both the monoculture and agroforestry systems (Table 3). In contrast, no *A. hilaralis* were found in the monoculture or agroforestry system samples at the end of the dry season. No *A. hilaralis* attacks were encountered during the season of forest and land fire (July to September).

Population dynamics of Arthroschista hilaralis *in different jabon plantation settings*

Our results (Table 3) indicate that the planting system significantly affects the abundance of *A. hilaralis*. This pest were more abundant in the monoculture system than the agroforestry system. This finding strongly suggests that monoculture planting is more heavily attacked by *A. hilaralis* than agroforestry systems.

Table 3. Average number of *Arthroschista hilaralis* found in jabon stands within monoculture and agroforestry systems, at four consecutive times of observation

Planting system	Average number of *A. hilaralis*			
	Rainy season	End of rainy season	Dry season	End of dry season
Monoculture	126 ± 4.9a	65 ± 4.5a	4.0 ± 0.9a	0.0 ± 0.0
Agroforestry 1	17 ± 0.6 b	11 ± 0.5 b	0.0 ± 0.0 b	0.0 ± 0.0
Agroforestry 2	85 ± 2.7a	25 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0

Note: Values followed by the same letters in a particular column are not significantly different at a 95% confidence interval

Table 4. Average parasitization rate by parasitoids in *Arthroschista hilaralis* larvae

Planting system	Average parasitization rate			
	Rainy season	End of rainy season	Dry season	End of dry season
Monoculture	17.46 ± 12.71a	15.38 ± 4.71a	25.00 ± 22.36	-
Agroforestry 1	82.35 ± 15.59 b	45.45 ± 7.45 b	-	-
Agroforestry 2	88.24 ± 27.26 b	40.00 ± 0.00 b	-	-

Note: Values followed by the same letters in a particular column are not significantly different at a 95% confidence interval

Several of *A. hilaralis* had been parasitized in the field. Table 4 shows the average rate of parasitization of *A. hilaralis* larvae from the monoculture and agroforestry systems at the four observation time points. ANOVA assessment revealed that the planting systems and observation time points (especially the rainy season compared to the end of the dry season) had a significant effect on the average parasitization rate by *Apanteles* sp. (Table 4). The average parasitization rate in the rainy season was greater than at the end of the rainy season. Regarding the planting system, the highest rate of parasitization was in the agroforestry-2 setting (white jabon stands, red jabon stands, and rice plants), reaching 88.24%. In comparison, the rate parasitization in the agroforestry-1 (white jabon stands, paddy crop, and oil-palm plants) and monoculture systems reached 82.35% and 17.46% respectively (Table 4).

Based on the observed larval population of *A. hilaralis*, the larvae stage and number of larvae were different between the jabon stands of the monoculture and agroforestry systems. There were no *A. hilaralis* attacking jabon in the monoculture at the end of the dry season (Figure 2). During the rainy season, there were some *A. hilaralis* of varying instar stages (the first instar to the fifth instar) (Figure 2).

There were no *A. hilaralis* attacking jabon plants within the agroforestry-1 or agroforestry-2 settings (Figure 3 and 4). Third instars and fourth instar larvae were found on jabon plants within the agroforestry-1 setting, but only fourth instar larvae were found during the rainy season (Figure 3). Figure 4 shows that at the end of the rainy season and during the rainy season, only third instar larvae were found in jabon plants within the agroforestry-2 setting.

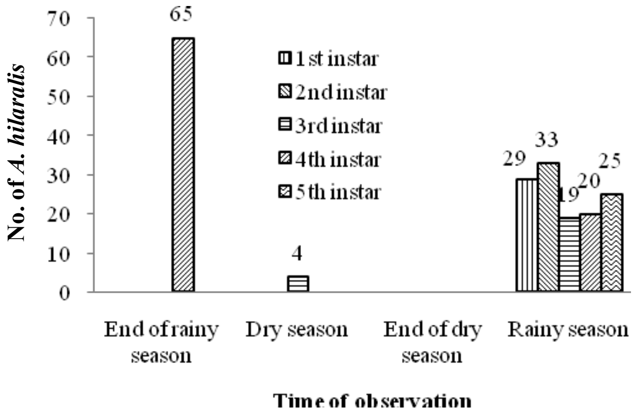

Figure 2. The average number of *Arthroschista hilaralis* in various developmental stages found in jabon stands within monoculture systems, at four consecutive times of observation

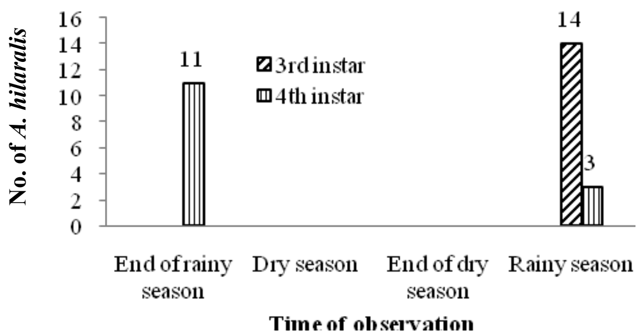

Figure 3. The average number of *Arthroschista hilaralis* in various developmental stages found in jabon stands within agroforestry systems (with 2-years old jabon stands, paddy crop, and oil-palm plants), at four consecutive times of observation

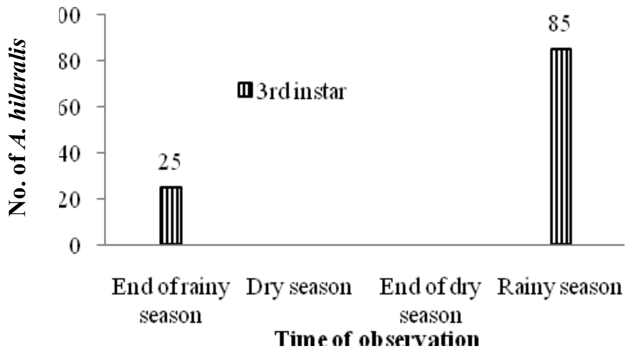

Figure 4. The average number of *Arthroschista hilaralis* in various developmental stages found in jabon stands within agroforestry systems (with 2-years old white jabon stands, 2-years old red jabon stands, and paddy crop), at four consecutive times of observation

Diversity of parasitoids attacking *Arthroschista hilaralis* and the rate of its parasitization

Some of *A. hilaralis* samples obtained from the field including egg stadia, larval stadia, and pupal stadia, had already been parasitized at the time of collection. Three species of parasitoids were identified from the *A. hilaralis* samples: *Phanerotoma* sp., *Apanteles* sp., and *Brachymeria* sp. (Table 5). While in the monoculture system – only larval stadia that had already been parasitized by *Apanteles* sp. In jabon stands within agroforestry system, *Phanerotoma* sp. parasitoids were found to prey on *A. hilaralis* eggs, *Apanteles* sp. parasitoids preyed on *A. hilaralis* larvae, and *Brachymeria* sp. parasitoids preyed on *A. hilaralis* pupae.

Table 6 shows the average parasitization rates of those three species of parasitoids in *A. hilaralis.* The parasitization rate of *A. hilaralis* eggs by *Phanerotoma* sp. was 10.04 %. Approximately five or six *A. hilaralis* eggs per-group were parasitized.

In jabon stands within the monoculture and agroforestry systems, among the larval instar stages, parasitization by *Apanteles* sp. was greatest in the first instar of *A. hilaralis*; there was no parasitization of the fifth instar in jabon plants within the monoculture and agroforestry systems. The average percentage of larval parasitization by *Apanteles* sp. in jabon plants within the agroforestry system was higher than for the monoculture system (Table 6). These findings show that the first instar larval stage is the most suspectable to parasitization. The average percentage of parasitization of *A. hilaralis* pupae by *Brachymeria* sp. was 12% (Table 6).

Table 5. Diversity of parasitoids attacking *Arthroschista hilaralis* in jabon stands within monoculture and agroforestry system

Planting System	Parasitoid was found			
	Species	**Ordo**	**Family**	**Type of Parasitoid**
Monoculture	*Apanteles* sp.	Hymenoptera	Braconidae	Larval Parasitoid
Agroforestry	*Phanerotoma* sp.	Hymenoptera	Braconidae	Egg Parasitoid
	Apanteles sp.	Hymenoptera	Braconidae	Larval Parasitoid
	Brachymeria sp.	Hymenoptera	Chalcididae	Pupal Parasitoid

Table 6. Average parasitization rate of *Arthroschista hilaralis*

Planting system	*A. hilaralis*	Parasitoid	Total number of *A. hilaralis* collected	Parasitized *A. hilaralis*	% parasitization
Monoculture	Egg	-	501	0	0
	Larvae				
	1st instar	*Apanteles* sp.	30	15	50
	2nd instar	*Apanteles* sp.	30	9	30
	3rd instar	*Apanteles* sp.	30	5	16.67
	4th instar	*Apanteles* sp.	30	2	6.67
	5th instar	-	30	0	0
	Pupae	-	25	0	0
Agroforestry	Egg	*Phanerotoma* sp.	448	45	10.04
	Larvae				
	1st instar	*Apanteles* sp.	30	16	53.33
	2nd instar	*Apanteles* sp.	30	10	33.33
	3rd instar	*Apanteles* sp.	30	9	30
	4th instar	*Apanteles* sp.	30	2	6.67
	5th instar	-	30	0	0
	Pupae	*Brachymeria* sp.	25	3	12

Discussion

The population dynamics of *A. hilaralis* were found to vary depending on the time point and seasons of observation. The population of *A. hilaralis* surged during the rainy season. Thapa and Bhandari (1976) also reported that the *A. hilaralis* population in India reached outbreak levels in July-August, while it tended to decline in October. During the season of forest and area fire (July to September), no infestation of *A. hilaralis* were encountered. Smoke from the fire was presumed to disrupt the turgidity and physiology of the plants (i.e., jabon stands). Almost all jabon canopies appeared to be exposed to smoke; thereby becoming coated with dust and soot particles. Consequently, the jabon leaves turned yellow and fell off. Also, elevated temperatures accompanied by low humidity might have inhibited the growth of *A. hilaralis*, leading to no *A. hilaralis* being found on jabon plants in either the monoculture or agroforestry system during this period. Cruz-Vázquez et al. (2004) reported that abiotic factors, such as temperature, affect the turgidity and physiology of plants, which might affect plant resistance against pests.

Husaeni et al. (2006) stated that changes in temperatures might either increase or decrease pest populations, and several other reports have mentioned that temperatures can increase pest populations. Also, Whiting et al. (2010) stated that plants located in a particular place with high temperatures would be vulnerable to pest attacks and diseases. Horn (1998) suggested that enzyme activity inside insects would increase with increasing temperature, thereby increasing their appetite. However, this author also noted that the duration of this increased activity would likely be short because the enzymes would undergo denaturation at high temperatures; furthermore, a hot period that lasted too long might destroy the enzymes. Finally, Bale et al. (2002) asserted that the population dynamics and eating intensity of the pest would increase with increasing environmental temperatures.

Aside from seasonal factors, planting systems have been shown significantly affect the population dynamics of *A. hilaralis*. In the current study, the *A. hilaralis* population was higher in the monoculture system than in the agroforestry systems. The planting of one plant species over a vast area has been shown to induce pest insects to attack those plants because no other choices are available. Damage could be severe if the plants are the main host for the insects, and other factors are present that support the growth of such insects. Within an agroforestry system, however, the sources of food are more limited than in a monoculture system. Also, agroforestry patterns can impart greater biodiversity than a single-species or monoculture forest, thereby promoting a more secure natural balance. Pumariño et al. (2015) reported that pest incidence (describing the population of pest insects indirectly) in agroforestry practices was lower than in a monoculture system because of the interconnection among the involved factors, such as climate, soil nutrition, and water content.

Here, we also made observations of the presence of parasitoids in monoculture jabon stands with endemic heavy attacks by *A. hilaralis* and agroforestry system. Only *Apanteles* sp. was found in those jabon stands, presumably because of the lower variability of plant species associated with the monoculture; whereas three species of parasitoids (*Phanerotoma* sp., *Apanteles* sp., *Brachymeria* sp.) were found in jabon stands within the agroforestry system.

***Phanerotoma* sp.** A parasitoid found attacked *A. hilaralis* egg. *Phanerotoma* sp. is a species of braconid wasps and solitary koinobiont which parasitize the moth of certain Lepidoptera. The wasps oviposit into the lepidopteran eggs, but their larvae do not develop until the caterpillar has hatched. Quicke (2015) reported that *Phanerotoma* sp. has characteristic that reduced epistoma and hypostoma parts, dish-shaped non-papilliform antenna and long, crossing and finely toothed mandibles as showed in Figure 5a.

***Apanteles* sp.** This parasitoid is one of the larval parasitoids of lepidopteran pests. *Apanteles* sp. had been characterized by the absence of vein r-m and therefore was actually a polyphyletic assemblage, with many of the monophyletic units (Figure 5b). While Borror et al. (1992) described that some of these parasitoids had a characteristic in the head having no occipital carina, mandible endodont, and metasoma of the 2nd united with metasoma of the 3rd tergum.

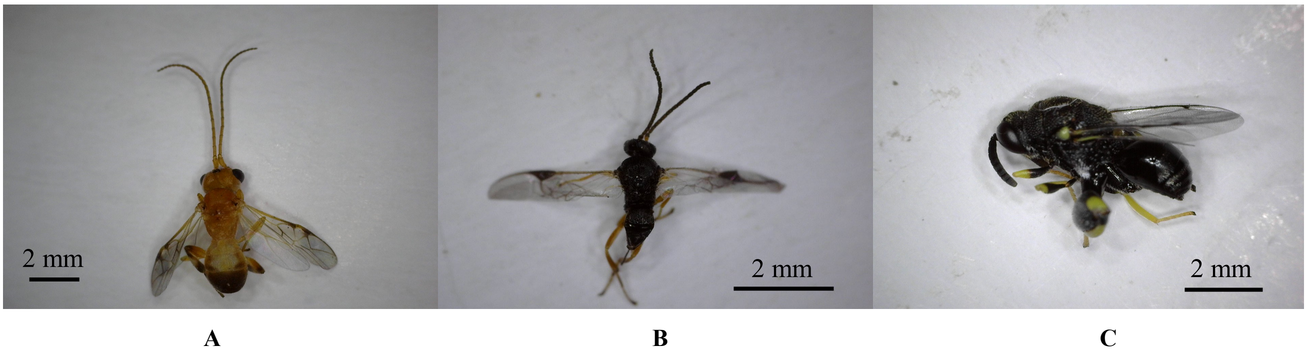

Figure 5. Some species of parasitoid attacking *Arthroschista hilaralis*: (a) *Phanerotoma* sp., (b) *Apanteles* sp., and (c) *Brachymeria* sp.

***Brachymeria* sp.** This parasitoid is a species of parasitic wasps in the family Chalcididae and parasites of insect larvae. It is black with limited yellow markings, and like most chalcidid wasps, it has enlarged hind femora (Figure 5c).

The pupal parasitization percentage by *Brachymeria* sp. preying on *A. hilaralis* reached 12%. These low percentages of parasitization might be due to the relatively low population of *A. hilaralis* pupae. The percentage of parasitization of *A. hilaralis* eggs by *Phanerotoma* sp. was 10.04%; whereas the percentage of larval parasitization by *Apanteles* sp., which was the highest, occurred at the first instar stage (53.33%) (Table 5). Sperber et al. (2004) reported that plant species and microclimate significantly affect the variability of parasitoids and the level of their parasitization of pest insects. Also, Marino and Landis (1999) stated that the parasitization level by parasitoids would increase in a complex landscape. Likewise, Menalled et al. (2003) asserted that the complexity of a landscape affects the parasitization rate and variability of parasitoids.

Because the variability of plants related to planting patterns could also affect the variability of the parasitoids, habitat management should be considered as an important means for dealing with pests. Altieri (1999) and Tscharntke et al. (2005) reported that the structure of the landscape and the management of the habitat have the significant effects on the conservation of parasitoids and other natural enemies in the field. Consequently, increasing the diversity of parasitoids in a monoculture system requires a proper management of the habitat, including the addition of other vegetation, such as the annual plant (trees) (Gámez-Virués et al. 2012). Thus, proper manipulation of the landscape could increase the diversity of parasitoids in monoculture-planted areas.

In conclusion, our data show that the planting of jabon within an agroforestry system provides a useful reduction in *A. hilaralis* populations, as well as an enhancement in parasitoid diversity and the rate of parasitization of the pest. Based on our findings, we propose that habitat management is a sustainable practice for protecting jabon trees from *A. hilaralis*, its principal insect pest in Indonesia.

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