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Three Species of Weeds Enhance The Population of Predator and Parasitoid of Coffee Berry Borers

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Abstract

Flowering weeds can serve as refugia for natural enemies. In coffee plantation, they might have the potential to attract predator and parasitoid of Coffee Berry Borer (CBB), *Hypothenemus hampei* Ferr. (Coleoptera: Scolytidae). The aim of this research was to elucidate the influence of weeds to the presence of predator dan parasitoid and their impact to the population of CBB. The research was conducted at Ngantang, Malang Regency and in Laboratory of Entomology, Faculty of Agriculture, Brawijaya University. Three species of weed used were: *Ageratum conyzoides* L. (Asteraceae), *Synedrela nodiflora*(L.) Gaertn. (Asteraceae), and *Arachis pintoi* Krap. & Greg. (Fabaceae). The research consisted of two experiments (1) coffee plot with single species of weed and (2) coffee plot with two species of weeds. The results of experiment I and II showed that *A. conyzoides*, *S. nodiflora, A. pintoi* and its combination in coffee plantation significantly attracted the predator and parasitoid of CBB. The population of CBB was not significantly different between coffee plot with and without weed. The existence of *A. conyzoides, S. nodiflora* and *A. pintoi* in coffee plantations could increase the number of predator and parasitoid of CBB around coffee tree. This result showed that the presence of weeds in coffee plantation is an important factor in maintaining the predator and parasitoid of CBB population.

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INTRODUCTION

Coffee berry borer (CBB), *Hypothenemus hampei* Ferr. (Coleoptera: Scolytidae) is the main pest of coffee. This pest is difficult to control due to its development occur inside the coffee berries. Controlling CBB with the intensive use of insecticide was reported triggering resistance of the pest (Brun *et al*., 1989, Brun & Suckling, 1992). Habitat management, as an implementation of Integrated Pest Management (IPM), may help solving the problems. Managing vegetations diversity as well as weeds might support the natural enemies by providing resources of food, alternative prey or hosts, breeding site, and shelter (Landis, *et al.,* 2000; Norris & Kogan, 2005; Karindah *et al.*, 2011a). Despite the term of weed has a negative conotation, several studies showed that weeds can give advantage by attracting beneficial insects and also act as a ground cover (Araj & Wratten, 2015).

Some research investigated the correlation between the presence of weeds and natural enemies. Parasitoid *Cephalonomia stephanoderis* Betrem (Hymenoptera:Bethylidae) feed on nectar of weeds in coffee plantation such as *Emilia sonchifolia* (L.) DC. var. *sonchifolia* (Asteraceae) (Salazar, 1998 *in* Baker, 1999). Another CBB parasitoid, *Prorops nasuta* Waterston (Hymenoptera: Bethylidae) also feed on nectar of *Euphorbia hirta* L. (euphorbiaceae) (Damon *et al*., 1999). Other adult predators feed on nectar or honeydew for additional nutrition (Nurindah & Indrayani, 2002). Some spiders used weeds in tea plantation such as *Synedrela nodiflora* (L.) Gaertn. (Asteraceae) and *Borreria repens* DC. (rubiaceae) as shelter while coccinelids prefered *Centrosoma pubescens* Benth. (Fabaceae) for shelter (Rohman, 2008).The presence of weeds in plantation related to the population and performance of natural enemies. The population of parasitoids of fruit flies increased when *Ageratum conyzoides* L. (Asteraceae) are around starfruit trees (Karindah *et al*., 2010). The level of parasitization of *Anastatus dasyni* Ferr. (Hymenoptera: Eupelmidae) in pepper plantation with *Arachis pintoi* Krap. & Greg. (Fabaceae) is higher than on cleaned weed pepper plantation (Trisawa *et al.,* 2004). The number and percentage of parasitization of sugarcane stem borer egg parasitoids on sugarcane plantation with wild plants are higher than wild plants free sugarcane plantation (Meidalima, 2014). The higher number of parasitoid on weed strip and selectively weeded in the rice field tended to decrease the presentage of stem borer's attack (Karindah *et al.*, 2011b).

Coffee is largely planted in Ngantang District, Malang Regency, where CBB is concerned as a main pest. Many coffee farmers in Ngantang do not use any insecticide to control CBB, making the possibility of natural enemies of CBB still remain in high diversity and number. However, farmers usually use herbicide to clean weeds in the coffee plantation especially several weeks before and during harvest season. We assumed that the using of herbicide might decrease natural enemies either in the diversity or the population. Van Emden and Williams (1974) stated that herbicide could reduce the diversity of weeds and the population of arthropods up to 50%. However, there is still less information about the influence of weeds in coffee plantation, more often their effect on the presence of predator and parasitoid of CBB. Therefore, we investigated the effect of weeds on species number and population of CBB predators and parasitoids during fruit season. We also studied the population of CBB in coffee plantation related to the existence of predators and parasitoids on weeds. We expected that this study could show the important of some weeds species in coffee plantation to conserve predators and parasitoids of CBB.

METHODS

This research was conducted in coffee plantation at Ngantang District, Malang, East Java and in the Laboratory of Entomology, Faculty of Agriculture, Brawijaya University. Two experiments were conducted on 1445 m^2 of coffee plantation. The field was divided into two blocks for those two experiments. Experiment I was to elucidate the influence of single weed species on the presence and population of natural enemies. Experiment II was to elucidate the influence of combination of two weed species on the presence and population of natural enemies of CBB.Those two experiments were arranged with Randomized Block Design. The selected species of weed based on what mostly grew in the coffee plantation in Ngantang i.e. *A. conyzoides, S. nodiflora*, and flowering plant intentionally planted in several coffee plantation i.e. *A. pintoi*. Hereafter those three plant species referred to as a ground cover. The selected plants were cultivated in polybags filled with soil. Each polybag had one plant of ground cover. After two weeks, the polybags were located according to the treatments. The coffee plantation were clean from weeding before conducting the experiment.

Experiment I comprised of four treatments, i.e. 1) coffee plot with *A. conyzoides, 2*)

coffee plot with *S. nodiflora, 3*) coffee plot with *A. pintoi* and 4) weed free plot. Each treatment was replicated three times. The coffee plot treatment consisted of four coffee trees set in two-dimensional quadrants. Each coffee plot were separated by one row of coffee trees, while replications were spaced by two rows of coffee trees. A hundred polybags of each weed species were placed inthe center of quadrant. Four plant samples were randomly selected from a hundred polybags. Sampling process was conducted eight times.

Experiment II comprised of three treatments i.e. 1) coffee plot with *A. conyzoides* and *A. pintoi,* 2) coffee plot with *S. nodiflora* and *A. pintoi* and 3) weed free plot. Each treatments was replicated three times. The coffee plot treatment also set in in two-dimensional quadrants. Each coffee plot was separated by one row of coffee trees, while replications were spaced by two rows of coffee trees. The treatment was consisted of a hundred polybags divided evenly for each weed species and were placed in the center of quadrant. Four plants out of hundred polybags were randomly selected as the sample unit. Sampling was taken eight times.

Population of predators and parasitoids on ground cover

The insects on the weeds samples were collected by using farmcorp. All of collected insects were killed with ethyl acetate and sent to the laboratory. Identification of the predators and parasitoids were based on morphological characteristics. The first sampling was done at seven days after the placement of ground cover on the coffee plot. The observation interval was five days.

Population of coffee berry borers

One coffee tree was randomly chosen from each coffee plot as a sample. Then, four twigs toward four cardinal directions were chosen randomly. From those four twigs, five of coffee berries with a hole on the surface, indicating the attack by CBB, were picked. The selected coffee berries were sent to laboratory and the coffee bean was dissected with scalpel. The dissected coffee bean was observed under stereo microscope, followed by counting the total population of borers from all stages.

To determine the parasitoid of CBB, infected coffee berries from plot quadrants were collected randomly and taken to the laboratory. Parasitoids that emerged from these coffee berries were assumed as CBB parasitoid.

The effects of ground cover on the presence of predators and parasitoids was analyzed by nonparametric Chi-square test, while the population of the borers was analyzed by F-test.

RESULTS AND DISCUSSION

Experiment I

The results of Experiment I showed that the population of predators and parasitoids on free weed plot with ground cover was significantly higher than on weed free plot (X^2 = 12.266; df = 3; p = 0.000). The predators and parasitoids found belong to Order Coleoptera, Diptera, Hemiptera, Hymenoptera, Orthoptera and Family Lycosidae, Oxyopidae, Salticidae and Araneidae (Table 1). The most abundant collected predators were *Pheilodogeton* sp., *Monomorium* sp., *Anoplesis gracilipes* S., *Polyrachis bicolor* S., *Oecophylla smaragdina* F. dan *Camponotus* sp. Only two ant species i.e. *A. gracilipes* and *O. smaragdina* found in cleaned plot.

The higher population and number of species of predators and parasitoids in coffee plot with ground cover showed that the ground cover attracted the predators and parasitoids as a shelter, supplementary food source or breeding site. This fact indicated that *A. conyzoides, S. nodiflora* and *A. pintoi* in coffee plantation could deliver predators and parasitoid.

Dyndimus had been reported as CBB predator in Indonesia (Kalshoven, 1981), but we did not find it in this study. However, lots of generalist predators were attracted to the ground cover plot. Since there was no specific predator found, we conducted a treatment on the most abundant predator i.e. *Pheilodogeton* sp., *Monomorium* sp., *P. bicolor*, *O.smaragdina, Salticidae* sp. 3 and praying mantises in the laboratory to determine the wether they preyed upon CBB. The result showed that they preyed on CBB either in immature or adult stages. Armbrecht and Gallego (2007) stated that ants are an important predator for CBB. Twig-nesting ants, soil-dwelling ants and/or ants associated with scales has potential in controlling the population of coffee berry borers either inside the berries on the tree or in the fallen berries (Damon, 2000; Bustillo *et al.*, 2002; Perfecto & Vandermeer, 2006; Armbrecht & Gallego, 2007; Larsen & Philpott, 2010; Gonthier *et al.*, 2013). The fallen berries can serve as a source of CBB population for the next season. Therefore, the presence of certain natural enemies could be expected to control the population of CBB on fallen berries. Spiders were found in high number too and some were preyed upon the CBB. However, their response to an increasing number of CBB was slower than ants (Phillpott, 2004) and their

preference to the adult of CBB was low (Henaut *et al.,* 2001). Nevertheless, the predation of CBB in the field was seemed to be influenced by the abundance or diversity of CBB predators (Larsen & Phillpott 2010). Although there was none of specific predator of CBB in this study, but the presence of generalist predators that attracted by the existence of ground cover was important because these generalist predators included CBB in their diet.

Parasitoids were found in a high number on coffee plot with ground cover but only one spesies of bethylid was found as CBB parasitoid. Indonesia had imported the bethylid parasitoids i.e. *C.stephanoderis* and *P. nasuta*, though they did not survive. The discovery of CBB parasitoid in the coffee plantation where we conducted the experiment could be a sign that the parasitoid still survive or perhaps there is a native bethylid parasitized CBB. Damon (2000) reported several native natural enemies had included the exotic pest CBB in their dietary range. This important finding needs a further study.

CBB parasitoid was only found on coffee plot with ground cover. This implied that ground cover attracted parasitoid of CBB. Parasitoid of CBB increased gradually in each coffee plot with ground cover treatments (Figure 1). The absence of parasitoids of CBB in the beginning of the experiment might happened due to the low initial population of the parasitoids and the absence of host which were suitable for the parasitoids. Before the experiment was conducted, local farmer used herbicide to control weeds, followed by the first coffee harvesting. Weeds in coffee plantation will possibly serve as a food source for parasi-

Table 1. The average number of population of predators and parasitoids in coffee plot with and without ground cover in Experiment I

Class	Sub Class/ Order	Family	Mean number of population				Status
			Coffee plot with *A. conyzoides*	Coffee plot with *S. nodiflora*	Coffee plot with *A. pintoi*	Weed free coffee plot	
Arachnida	Araneae	Lycosidae	0.92	0.75	0.42	0.00	Predator
		Oxyopidae	1.00	1.17	0.50	0.00	Predator
		Salticidae	1.25	0.83	1.67	0.17	Predator
		Araneidae	0.08	0.25	0.00	0.08	Predator
Insecta	Coleoptera	Coccinellidae	0.08	0.00	0.00	0.00	Predator
		Cerambycidae	0.08	0.08	0.00	0.00	Predator
		Staphylinidae	0.00	0.00	0.08	0.00	Predator
	Diptera	Chloropidae	0.17	0.00	0.08	0.00	Predator
		Empipidae	0.17	0.17	0.25	0.00	Predator
		Phoridae	0.50	0.08	0.50	0.00	Predator
		Asilidae	0.00	0.00	0.08	0.00	Predator
	Hemiptera	Myridae	0.00	0.08	0.00	0.00	Predator
	Hymenoptera	Bethylidae	0.42	0.33	0.33	0.00	Parasitoid
		Braconidae	2.75	2.25	2.25	0.00	Parasitoid
		Eulopidae	1.00	1.00	1.00	0.00	Parasitoid
		Eupelmidae	0.00	0.00	0.50	0.00	Parasitoid
		Ichneumonidae	0.50	0.50	0.50	0.00	Parasitoid
		Mymaridae	0.00	0.25	0.25	0.00	Parasitoid
		Scelionidae	1.50	1.50	1.75	0.00	Parasitoid
		Formicidae	2.92	3.42	2.75	0.50	Predator
	Orthoptera	Gryllidae	0.33	0.00	0.08	0.00	Predator
		Mantidae	0.17	0.17	0.08	0.08	Predator
		Tettigonidae	0.17	0.00	0.00	0.00	Predator
Total			13.59	12.75	13.07	0.83	

toids. When there was no source of food, parasitoid have to migrate out of the plantation.

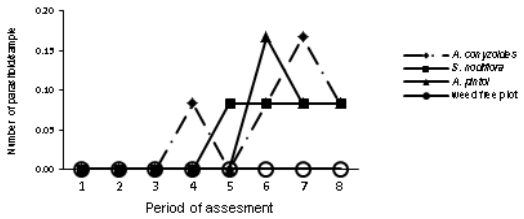

Figure 1. Fluctuation in parasitoids on coffee plot with and without ground cover in Experiment I

We expected that the suitable host for the bethylid parasitoid found in this study was the larva of CBB. This was showed by the existence of parasitoid pupal on the CBB larva inside the berry. During the experiment, the peak population of those host stages was in the middle of the period of sampling. The abundance of host and the existence of flowering ground cover probably attracted parasitoid of CBB to visit coffee plot with ground cover. The close distance between the flowering vegetations as food source and the habitat of the host increased the parasitization of parasitoids (Lewis *et al.*, 1998).

The first coffee harvesting also seemed to cause the parasitoids loosing their host. This happened because the parasitoids inside the coffee berries unintentionally carried together with the harvested berries. Baker (1999) agreed that harvesting often gave parasitoids no chance to emerge. Barrera (1994 *in* Baker, 1999) also suggested that coffee harvesting before the parasitoids succeeded to fully develop could reduce the level of parasitization up to 5% within one or more years after the release of parasitoid *C. stephanoderis* and *P. nasuta*. This caused the population of parasitoids to decrease, contributing to the low initial population of parasitoids in coffee plantation.

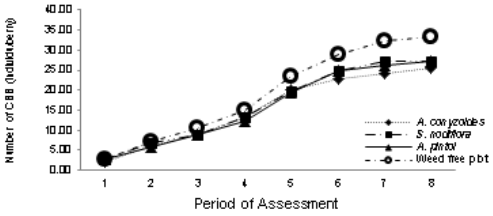

Figure 2. CBB population on coffee plot with and without ground cover in Experiment I

The population of borers in coffee berries on coffee trees with ground cover was not significantly different from those without ground cover ($p = 0.555$). In the beginning of experiment, there was no difference in the average population of CBB in both coffee plot with and without ground cover (Figure 2). However since the middle to the last sampling, it was observed that the population of CBB on coffee plot with ground cover decreased though it was not significant. The higher population and species number of predators and parasitoids of CBB in coffee plot with ground cover seemed to suppress the population CBB. However, the increasing number of predator and parasitoid have not influence CBB population in the berries yet.

Experiment II

The combination of ground cover significantly attracted predators and parasitoids (X^2= 14.329; df = 2; p = 0.000). This indicated that species of ground cover as well as single species ground cover in coffee plantation might attract predators and parasitoids. Forty two species of predators and parasitoids belong to twenty two families were found (Table 2). Two species from Family Cerambycidae and Asilidae were not found in Experiment II, however there was a family and species of predators and parasitoid in Experiment II that were not found in Experiment I, i.e. Syrphidae, Gryllidae sp.1 and Braconidae sp. 4. We did not compare the result from both experiments statistically, however, the result showed that the species number of predators and parasitoids on Experiment II was higher than Experiment I. The combination of weeds might provide the arthropods a direct source of food or a shelter. Indirect trophic interaction or tritrophic interaction (Norris & Kogan, 2000) might also had occured.

We found only one species of parasitoid attacking CBB in Experiment II. This parasitoid also not found on weed free plot. The species of parasitoid of CBB in Experiment II was the same as in the Experiment I. The parasitoid had similiar trend as parasitoid in Experiment I (Figure 3), so we assumed that the cause of the absence of parasitoid in the beginning of experiment was as the same as in the Experiment I.

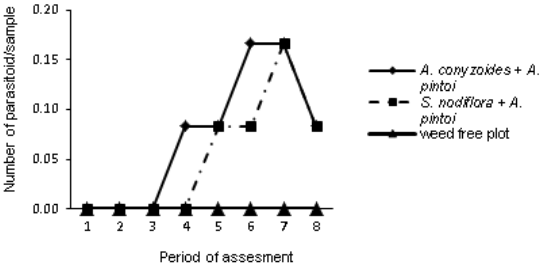

Figure 3. Fluctuation in parasitoids in coffee plot with and without ground cover in Experiment II

Table 2. The average number of population of predators and parasitoids in coffee plot with and without ground cover in Experiment II

Class	Sub Class/ Order	Family	Mean number of population			Status
			Coffee plot with *A. conyzoides* and *A. pintoi*	Coffee plot with *S. nodiflora* and*A. pintoi*	Weed free coffee plot	
Arachnida	Araneae	Lycosidae	0.25	0.08	0.08	Predator
		Oxyopidae	0.25	0.42	0.08	Predator
		Salticidae	1.08	0.42	0.08	Predator
		Araneidae	0.25	0.08	0.08	Predator
Insecta	Coleoptera	Coccinellidae	0.58	0.08	0.00	Predator
		Staphylinidae	0.08	0.25	0.00	Predator
	Diptera	Chloropidae	0.08	0.00	0.00	Predator
		Empipidae	0.17	0.25	0.00	Predator
		Phoridae	0.25	0.25	0.00	Predator
		Syrpidae	0.00	0.08	0.00	Predator
	Hemiptera	Myridae	0.08	0.08	0.00	Predator
	Hymenoptera	Bethylidae	0.58	0.42	0.00	Parasitoid
		Braconidae	3.75	3.75	0.25	Parasitoid
		Eulopidae	1.50	1.00	0.00	Parasitoid
		Eupelmidae	0.25	0.25	0.00	Parasitoid
		Ichneumonidae	0.75	0.00	0.00	Parasitoid
		Mymaridae	0.00	0.25	0.00	Parasitoid
		Scelionidae	2.75	2.75	0.00	Parasitoid
		Formicidae	4.08	4.75	0.25	Predator
	Orthoptera	Gryllidae	0.17	0.25	0.00	Predator
		Mantidae	0.00	0.17	0.00	Predator
		Tettigonidae	0.08	0.17	0.00	Predator
Total			16.98	15.75	0.82	

The species of ground cover which were used in this study have a bright colour flower. This might attract parasitoid of CBB. In addition, *A. conyzoides* has a strong odor that might also attract parasitoid of CBB. In previous research, *A. conyzoides, A. pintoi* and their combination significantly increased the number of fruit fly parasitoid (Meiadi *et al.*, 2015). Parasitoid of CBB seems likely to be the most effective natural enemies to control the population of CBB. However, many factors in plantations that may affect the existence of the parasitoid such as the source of alternative food and the availability of host. The fact that parasitoid of CBB only found in coffee plot with ground cover showed that ground cover in coffee plantation could has the important role to conserve the CBB parasitoid.

There was no significantly different betwen the population of CBB in coffee plot with and without ground cover ($p = 0.147$). Although ground cover significantly affected predator and parasitoid populations, it did not affect the CBB population in the coffee berries. The rate of increase of CBB population on coffee plot with ground cover was lower than weed free plot in the middle to the end of sampling (Figure 4). The lower increasing of CBB population the existence of predators and parasitoids. Small ants could enter and prey upon the CBB inside the berry (Larsen & Philpott, 2010). Parasitoid might had attacked CBB though it could not be measured due to the harvesting after the 8th sampling and also the possibility that the parasitoid have not emerged yet.

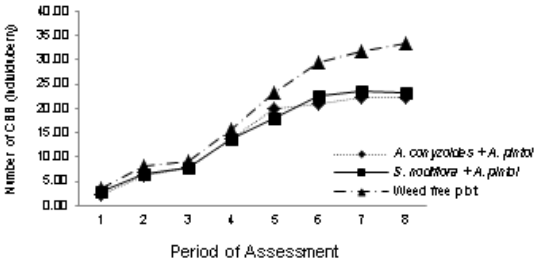

Figure 4. CBB population on coffee plot with and without ground cover in Experiment II

This study indicates the importance of flowering vegetation in influencing the number of predator and parasitoid of CBB. It also highlights that the common weeds in coffee plantation could attract natural enemies of CBB. Their attractiveness is a great potential to maintain the presence of natural enemies in coffee plantation. Therefore, in order to maintain the population of predator and parasitoid of CBB in coffee plantation, the existance of certain species of weed should be considered.

CONCLUSION

The existence of *A. conyzoides, S. nodiflora* and *A. pintoi* or it combination in the field might increase the number of CBB predators and parasitoids though they have not influence the population of CBB. It needs several time to build up the population of predator and parasitoid of CBB.

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