

Ant Species Diversity in Coffee Plantation in Chiang Mai Province, Northern Thailand

Yuka Onishi^{1,3,*}, Weeyawat Jaitrong², Piyawan Suttiprapan¹,
Sawai Buranapanichpan¹, Yaowaluk Chanbang¹ and Fuminori Ito³

¹ Department of Entomology and Plant Pathology, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200 Thailand

² Thailand Natural History Museum, National Science Museum, Technopolis, Khlong 5, Khlong Luang, Pathum Thani, 12120 Thailand

³ Faculty of Agriculture, Kagawa University, Ikenobe, Miki, 761-0795 Japan

ABSTRACT:- Some coffee plantations in Thailand suffer problems caused by the coffee berry borer, *Hypothenemus hampei* (CBB). Recently, the effects of ants on CBB have been intensively investigated in South America, however it does not investigate in Thailand. As a first step for evaluating ant effects on the CBB in Thailand, the ant species diversity was investigated in two coffee plantations, Pa Miang village, Doi Saket district, and Highland Research and Training Station Khun Chang Kian Site A, in Chiang Mai province, northern Thailand. Ants were collected by two quantitative sampling methods, collection on coffee tree trunks and collection by using a hand sifter during both the dry and rainy season in Pa Miang, and during the rainy season only in Khun Chang Kian. In Pa Miang, the number of ant species collected in the dry and the rainy season was 64 and 58, respectively, while in Khun Chang Kian, 44 species were collected in the rainy season. In total, 121 species of ants were obtained from the two coffee plantations. Ant species diversity in these coffee plantations is comparable to that in the other land use types in and around Chiang Mai. The head width of these 121 ant species were measured to determine which ant species are able to enter galleries inhabited by CBB. Among the ant species collected in two coffee plantations, 67 species had smaller head width than the CBB body width.

KEYWORDS: ant species diversity, arabica coffee plantations, northern Thailand, coffee berry borer, *Hypothenemus hampei*

INTRODUCTION

The coffee berry borer (CBB), *Hypothenemus hampei*, is one of the most damaging pests of commercial coffee in all producer countries of the world (Jaramillo *et al.*, 2011; Jiménez-Soto *et al.*, 2013; Le Pelley, 1968; Tribble and Carroll, 2014; Vega *et al.*, 2009). Females of CBB bore galleries into the coffee berries to lay eggs, after which the larvae

feed on and destroy the coffee beans (Schmutterer, 1990). Borer infestation reduces the quality of the coffee crops. In northern Thailand, where arabica coffee (*Coffea arabica*) is produced, damage by the CBB has been serious since the 1990's. The main control method for CBB in Thailand is the use of pesticides (Pongsiri, 2013). However, the pesticides are not always effective against the CBB, because the CBB spends most of

*Corresponding author.

E-mail: lakritsi923@yahoo.co.jp

its life inside coffee berries. Furthermore, the CBB has developed resistance to insecticides (Gonthier *et al.*, 2013). Effective biological control agents such as the parasitoid wasp *Cephalonomia stephanoderis*, the fungus *Beauveria bassiana* and predators, such as birds, thrips and ants have been reported in Central and South America (Vega *et al.*, 2009). Recently, the effects of ants on CBB have been intensively investigated in South America, especially in Mexico and Colombia (Jiménez-Soto *et al.*, 2013; Perfecto and Vandermeer, 2006). It has been reported that the myrmicine ant *Pheidole synanthropica* carries the CBB to their nests, and the dolichoderine ant *Azteca instabilis* expels the CBB to maintain honeydew from scale insects (Jiménez-Soto *et al.*, 2013). In Thailand, too, it is possible that some ant species play an important role for controlling the CBB, however, no studies of ant effects on the CBB have been carried out to date. Furthermore, the ant fauna in coffee plantations in Thailand has been rarely studied so far. Research of ant effects on the CBB is indispensable for the establishment of integrated management of the CBB in Thailand. As a first step for evaluating ant effects on the CBB, we investigated the ant species diversity in coffee plantations in northern Thailand.

MATERIALS AND METHODS

Ant species diversity was investigated in two coffee plantations in Chiang Mai province. One is located in Pa Miang village, Doi Saket district (910m alt., 18°59'N, 99°20'E, hereafter PM), the other is in the Highland Research and Training Station Khun Chang Kian Site A (1280m alt., 18°48'N, 98°58'E, hereafter KCK). The distance between the two plantations is ca 45 km. In PM, to determine the difference of ant fauna between the dry and rainy seasons, we carried out ant collection at the end of the rainy season (September and November, 2014) and at the

end of the dry season (June, 2015). In the rainy season, fifty coffee plants (height between 1.5 to 2.0 m) in the plantation were chosen randomly. Ants were collected by the following two methods: (1) Searching for ants on coffee tree trunks: foraging ants on tree trunks at 0.5 – 1.5m were collected for 5 min. using an aspirator. During this collection period, we tried to collect as many species of ants as possible. (2) Sifting leaf litter and surface soil: a small quadrat (30 × 30 cm) was set up on the ground near the coffee plant chosen in the above survey, and ants were collected by sifting litter from the quadrat. For the litter sifting, a hand sifter (mesh size 4 × 4 mm) was used on a plate and the dropping ants were collected by an aspirator. The same methods were applied for the 50 trees and 50 quadrats nearby the trees in the dry season. In KCK ants were collected during the rainy season between May and November, 2013. As in PM, 50 coffee trees were chosen, and ants were collected by the same two methods mentioned above.

The expected number of ant species was calculated by Chao2 (Colwell and Coddington, 1994). To compare species richness between the two seasons in PM, and between PM and KCK during the rainy season, we generated sample-based rarefaction curves with EstimateS version 9 (Colwell, 2013).

To determine which ant species can enter the galleries inhabited by CBB, the maximum head width of ant workers was measured under a binocular microscope for all species collected in the two coffee plantations.

The statistical analysis was conducted in R (Team R, 2013).

RESULTS

Ants in Pa Miang

At the end of the rainy season, ants were collected from 45 out of 50 coffee tree trunks. The average number of species per tree was 1.6 ± 1.1 SD (range: 0-5, fig 1). In total, 27 species were collected, 17 of which were from single trees. The expected number of species to be collected by this method is 49.3 ± 14.6 SD. *Technomyrmex yamanei* was exclusively dominant, being found on 32 trees. The other dominant species were *Polyrhachis* (*Myrmhopla*) sp. PM5 (eight trees) and *P. armata* (5 trees). Among 50 quadrats, 44 quadrats harbored ants. The average number of species per quadrat was 2.1 ± 1.2 SD (range: 0-7, fig 1). In total 37 species were collected from litter and surface soil, of which 21 species were collected from single quadrats, and six species were found in two quadrats. The expected number of species to be collected by this method is 60.2 ± 14.0 SD. As in ants collected on tree trunks, *Technomyrmex yamanei* was the most dominant, being found on 27 quadrats. *Trichomyrmex* sp. PM1 was collected from 11 quadrats. The other species were found in less than five quadrats. Combining the results obtained by the two sampling methods, 58 species were recorded at the end of the rainy season.

At the end of the dry season, ants were collected from 47 out of 50 coffee trees. The average number of species per tree was 1.9 ± 1.1 SD (range: 0-6, fig 1). In total, 35 species were collected, of which 15 species were

collected from single trees. The expected number of species to be collected by this method on coffee trees is 45.3 ± 7.1 SD. At the end of the dry season, the most dominant species was *Technomyrmex yamanei* being found in 18 trees. The other dominant species, found in more than five trees, were *Crematogaster* sp. PM2, *Plagiolepis* sp. 3 of WJT, *Camponotus nicobarensis*, and *Tapinoma* sp. PM1. In total 41 species were collected from all 50 quadrats, of which 19 species were collected from single quadrats, and nine species were found in two quadrats. The expected number of species to be collected by this method is 57.8 ± 10.2 SD. *Technomyrmex yamanei* was the most dominant, being found in 19 quadrats. The other dominant species collected from more than 5 quadrats were *Nylanderia* sp. PM2, *Tapinoma* sp. PM1, *Trichomyrmex* sp. PM1, and *Lophomyrmex birmanus*. Among the 41 species collected from litter and surface soil, 12 species were the same as ants collected in coffee trees. Thus, the total number of species recorded at the end of the dry season was 64.

Comparing the two sampling seasons, both the average number of species per coffee tree and per quadrat were not significantly different between the two seasons (t-test, $P = 0.16$ for ants from tree trunks, $P = 0.08$ for ants from quadrats). Species richness of both tree ants and litter ants was not different between both seasons (Fig. 2). However, the



Figure 1. Number of ant species collected per coffee plant and per quadrat in Pa Miag during rainy season (PMR) and dry season (PMD), and in Khun Chang Kian during rainy season (KCK). Average number of species with standard deviation is shown.

species composition between the two seasons was slightly different. Only 37 species were common the both rainy and dry season, and the remaining 48 species were collected in only the dry (27 spp.) or rainy season (21 spp.). Of these 48 species, the majority were “rare” species, to be found on less than three occasions. *Plagiolepis* sp. 3 of WJT and *Camponotus nicobarensis* were exceptional, listed as dominant species but collected in the dry season only. Among the 37 species collected in both seasons, the frequency of occurrence between the two seasons was remarkably different in *Crematogaster* sp. PM2 (Fisher's exact test, $P = 0.01$), which was only once collected during the rainy season while the ants were collected from seven trees and three quadrats in the dry season.

The quantitative sampling in the two seasons yielded 85 ant species in 36 genera of 6 subfamilies in this plantation (Table 1). Myrmicinae (30 spp.) was the most species rich subfamily, followed by Formicinae (25

spp.), Ponerinae (15 spp.) and Dolichoderinae (12 spp.). The most species rich genera were *Polyrhachis* (9 spp.), *Technomyrmex* (6 spp.), *Camponotus* (6 spp.), *Crematogaster* (6 spp.) and *Tetramorium* (5 spp.). Among 85 species, 29 species were collected only once, and 21 species were collected twice. Therefore, further research could increase the cumulative number of ant species (Fig. 2). Remarkable characteristics of the ant fauna in PM is the exclusive dominance of *Technomyrmex yamanei* in both seasons. In addition to the quantitative samplings, we collected three species, *Technomyrmex* sp. PM4, *T. modiglianii*, and *Polyrhachis* (*Myrma*) sp. PM3.

Ants in Khun Chang Kian

Ants were collected from 38 out of 50 coffee tree trunks. The average number of species per tree was 1.3 ± 1.0 SD (range: 0-3, fig 1). In total, 20 species were collected, of which 6 were collected from single trees. The

Table 1. Number of ant species collected by each collection method, each season and each site. T: collected on coffee tree, Q: collected from quadrat

Subfamily	Coffee plantation at Pa Miang village						Khun Chang Kian Site A			
	No. species collected						No. species collected			
	End of rainy season			End of dry season			Total	Rainy season		
	T	Q	Subtotal	T	Q	Subtotal		T	Q	Subtotal
Dolichoderinae	7	5	9	7	6	0	12	4	2	4
Dorylinae	0	0	0	0	0	0	0	0	1	1
Ectatomminae	1	1	1	1	0	1	1	0	0	0
Formicinae	10	4	14	15	8	20	25	9	6	12
Myrmicinae	9	15	22	9	19	23	30	7	20	22
Ponerinae	0	12	12	1	8	8	15	0	4	4
Procerinae	0	0	0	0	0	0	0	0	1	1
Pseudomyrmecinae	0	0	0	2	0	2	2	0	0	0
Total	27	37	58	35	41	64	85	20	34	44

expected number of species to be collected by this method is 21.5 ± 1.90 SD. *Dolichoderus affinis* was the most dominant, being found on 19 trees. One to seven ant species were collected from 42 out of 50 quadrats. The average number of species per quadrat was 2.2 ± 1.7 SD (range: 0-7). In total 36 species were found from litter and surface soil, of which 17 species were collected from only single quadrats, and three species were found in two quadrats. The expected number of species for leaf litter and surface soil is 77.9 ± 27.6 SD (Chao2). The dominant species, found in more than 10 quadrats, were *Brachyponera luteipes*, *Nylanderia* sp. CK2 and *Tetramorium* sp. PM2. The average number of species per coffee tree and per quadrat in KCK was not different from those of PM in the rainy season (t-test, $P = 0.15$ for tree ants, $P = 0.68$ for quadrat ants). The species richness of both tree ants and litter ants was not different from the result obtained in PM during the rainy season. However, the species richness on coffee trees in KCK was

significantly lower than that in PM (Fig. 2).

In total 44 species in 26 genera of 6 subfamilies were collected by the two sampling methods in KCK during the rainy season. Myrmicinae (22 spp.) was the most species rich subfamily, followed by Formicinae (12 spp.), Ponerinae (4 spp.), and Dolichoderinae (4 spp.). The most species rich genera were *Tetramorium* (7 spp.), *Polyrhachis* (5 spp.), and *Pheidole* (4 spp.). Ten out of 44 species were collected by both methods. In addition to the 44 species collected by the two methods, 17 species of ants were collected in November 2012 and May to November 2013. Thus, 61 species have been recorded from KCK.

The head width of ants collected in two coffee plantations

Figure 3 shows the head width distribution of 121 ant species collected in PM and KCK. 67 species of ants have a smaller head width than the body width of the CBB. Among the

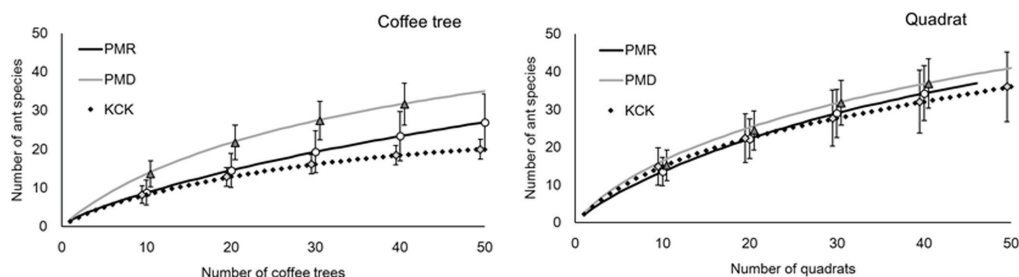


Figure 2. Species accumulation curves for ants on coffee trees and ants in quadrates in Pa Miag during rainy season (PMR) and dry season (PMD), and in Khun Chang Kian during rainy season (KCK). Error bars show 95% confidence intervals and non-overlapping bars show significant differences between study sites and/or sampling seasons.

dominant species listed in Table 2, the following 11 species were included in the 67 species; *Crematogaster* sp. PM2, *Kartidris* sp. PM1, *Lophomyrmex birmanus*, *Nylanderia* sp. PM2, *Nylanderia* sp. CK2, *Oligomyrmex* sp. PM1, *Paraparatrechina* sp. PM1, *Plagiolepis* sp. 3 of WJT, *Tapinoma* sp. PM1,

Tetramorium sp. PM2, and *Trichomyrmex* sp. PM1.

DISCUSSION

In the present study, 88 and 61 ant species were recorded from coffee plantations in PM

and KCK, respectively. Only 28 species were in common between the two sites. Thus, in total 121 ant species were obtained from the two coffee plantations. If we consider the results of our quantitative survey, we recorded 58 species during the rainy season, and 64 species in the dry season in PM, and 44 species during the rainy season in KCK. Ant species diversity in KCK was slightly lower than that in PM. The commonness of species composition calculated by the Nomura-Simpson Index between PM and KCK is 0.46. In West Java, Indonesia, Ito *et al.* (2001) reported that the commonness of ant species composition among three study sites in lowland areas (the Bogor Botanical Gardens, Ujung Kulon National Park, Pangandaran National Park) which are ca 160–370 km apart from each other, is 0.62–0.68. The value between Bogor Botanical Gardens and Purwodadi Botanical Gardens in East Java, that are ca 650 km apart from each other is 0.59 (Ito *et al.*, unpublished). Comparing these values, the commonness between the two coffee plantations in Chiang Mai is slightly lower. Furthermore, the dominant ant species were different between PM and KCK (Fig. 4). *Technomyrmex yamanei* which was

the most dominant species in PM, was not found in KCK. On the other hand, the most dominant ant in KCK, *Dolichoderus affinis*, was collected only twice in PM. *Meranoplus laevis* was commonly collected in KCK but was not found in PM. One of the factors affecting the difference of species diversity and its composition between the two sites is the altitude of the study sites. The altitude of PM and KCK is approximately 910 m and 1280 m above sea level, respectively. In the tropics, ant species diversity is generally highest in lowland forests, and decreases with higher altitude (Malsch *et al.*, 2008, Brühl *et al.*, 1998). In Mt. Kinabalu, for example, species richness of ground ants at 830 m, 1140 m, and 1340 m, was 89 spp., 61 spp., and 25 spp., respectively (Malsch *et al.*, 2008).

Another factor contributing to the difference of species diversity and the composition may be the construction of the plantations. According to the classification of coffee plantations based on vegetational and structural complexity by Moguel and Toledo (1999), PM is of the rustic type where coffee trees are grown on the natural forest floor

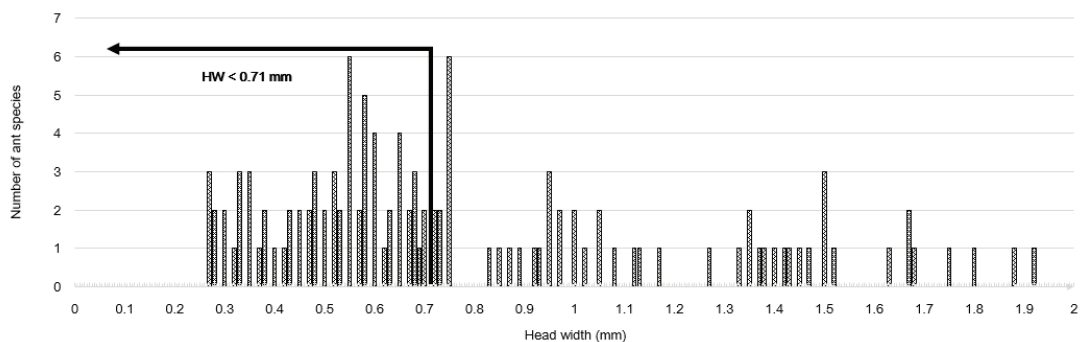


Figure 3. Head width distribution of 121 ant species collected in two coffee plantations in Chiang Mai. Head width of CBB is $0.7 \pm \text{SD } 0.06$ mm. The head width of 67 ant species was smaller than that of CBB.

Table 2. Dominant species collected by each method at two study sites.

Coffee tree					
Coffee plantation at Pa Miang village			Khun Chang Kian Site A		
End of rainy season		End of dry season	Rainy season		
Species name	N	Species name	N	Species name	N
<i>Technomyrmex yamanei</i>	32	<i>Technomymex yamanei</i>	18	<i>Dolichoderus affinis</i>	19
<i>Polyrhachis (Myrmhopla)</i> sp. PM 5	8	<i>Crematogaster</i> sp. PM 2	7	<i>Meranoplus laeviventris</i>	9
<i>Polyrhachis armata</i>	5	<i>Plagiolepis</i> sp. PM 1 = sp.3 of WJT	6	<i>Polyrhachis (Myrmhopla)</i> sp. CK5	5
<i>Paraparatrechina</i> sp. PM 1	3	<i>Camponotus nicobarensis</i>	5	<i>Plagiolepis</i> sp. PM 1 = sp.3 of WJT	5
<i>Gnamptogenys bicolor</i>	3	<i>Tapinoma</i> sp. PM 1	5	<i>Crematogaster</i> sp. CK1	3

Quadrat					
Coffee plantation at Pa Miang village			Khun Chang Kian Site A		
End of rainy season		End of dry season	Rainy season		
Species name	N	Species name	N	Species name	N
<i>Technomyrmex yamanei</i>	27	<i>Technomyrmex yamanei</i>	19	<i>Brachyponera luteipes</i>	12
<i>Trichomyrmex</i> sp. PM 1	11	<i>Nylanderia</i> sp. PM 1	11	<i>Nylanderia</i> sp. CK2	11
<i>Nylanderia</i> sp. PM 2	4	<i>Tapinoma</i> sp. PM 1	10	<i>Tetramorium</i> sp. PM2	10
<i>Oligomyrmex</i> sp. PM 1	4	<i>Trichomyrmex</i> sp. PM 1	9	<i>Dolichoderus affinis</i>	7
<i>Kartidris</i> sp. PM 1	3	<i>Lophomyrmex birmanus</i>	8	<i>Meranoplus laeviventris</i>	7

while KCK is of the traditional polyculture type where coffee trees are planted alongside several useful plants. Although both PM and KCK are surrounded by taller trees and coffee trees are shaded by these trees, the density of the taller trees in PM is higher than that in KCK, providing more shade for coffee trees in PM. KCK is a nature park, visited by many tourists, and therefore is well-managed. Taking this into consideration, PM may have a lot of the forest species, while KCK may have the forest edge – open land species. However, we still do not know the definite reason because the knowledge of habitat preference of each ant species is still lacking at present.

In Southeast Asia, the ant fauna in coffee plantations has been investigated in Sumatra, Indonesia (Philpott *et al.* 2008). Philpott *et al.* (2008) report the occurrence of 136 morphospecies from three coffee plantations inside the Bukit Barisan Selatan National Park and 125 morphospecies from three coffee plantations outside this park. In total, 165 ant species were recorded from six coffee plantations in and around this national park. Despite the fact that species numbers are not given for each plantation, the coffee plantations in Chiang Mai (121 species from two plantations) seems to have a comparable species number to the result obtained in Sumatra.

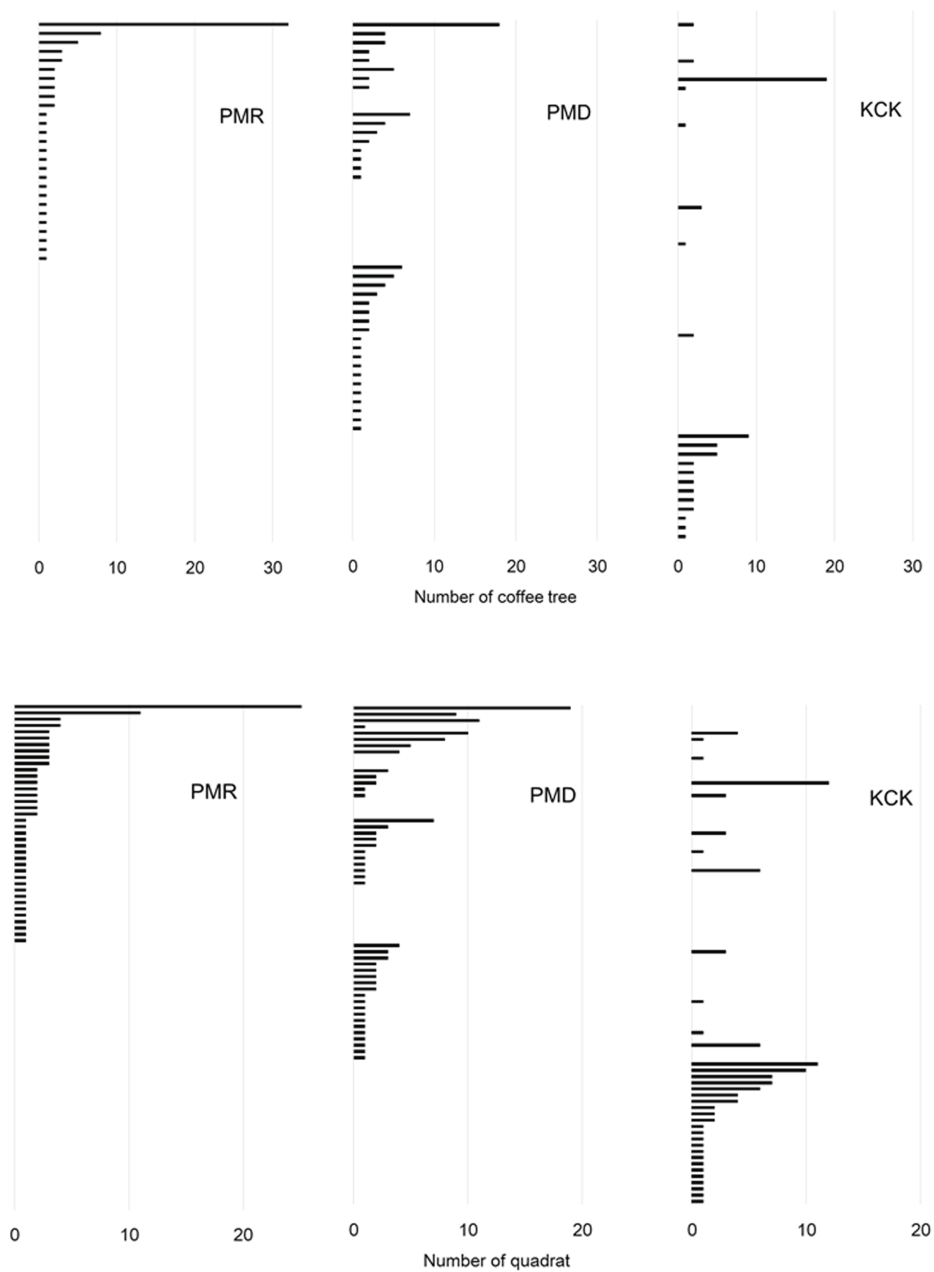


Figure 4. Comparison of ant fauna between rainy (PMR) and dry seasons (PMD) in Pa Miang and rainy season in Khun Chang Kian (KCK) with matched abundance plot. In the left side of the figure, the order of abundance for species is plotted with the most abundant species at the top. The middle and right side show the corresponding abundance for all the species shown in the left side. Abundance of species not found in the left side was also shown with descending order of abundance in the middle and right side of figures.

Sakchoowong *et al.* (2008) conducted an investigation of the ant fauna by litter sifting in five different land use types (montane forest, jungle tea, forest fallow for one year and eight years, and annual cabbage crop site) in Chiang Mai province, and found 43 to 89 species per type. Montane forests had the highest species diversity, 89 species being recorded from five plots. Because the sampling method employed for this research is different from the present study, direct comparison of species number does not seem meaningful. However, the occurrence of 121 species in our study indicates that ant species diversity in these coffee plantations is quite high among several forest types in Chiang Mai province.

The most dominant species at PM, *Technomyrmex yamanei*, attended the scale insect, *Coccus viridis*, to obtain honeydew. This scale insect shows outbreaks on coffee trees during the rainy season. *Technomyrmex yamanei* was abundant both in the rainy and dry season. However, the frequency of its occurrence in the rainy season was higher than that in the dry season, probably because the scale insects may attract many workers of *T. yamanei* during the rainy season. Scale insects are generally known as pest insects of agricultural products. However, the previous study indicated that the mutualistic relationship between ants and scale insects has a positive effect on the coffee plant by attacking the CBB (Perfecto and Vandermeer, 2006).

According to the head width of workers, at least 67 species of ants are able to enter the gallery of CBB on the coffee berries, enabling them to attack and predate the colonies of CBB. Gonthier *et al.* (2013) and Perfecto and Vandermeer (2013) reported that very small ants could be predators of CBB. After harvesting coffee berries, infested berries which turn black, are left on the branches.

Therefore, small ant species foraging on coffee trees can affect the CBB throughout year. The small ant species foraging on the ground may also have a chance to attack the CBB in the old berries fallen to the ground (Perfecto and Vandermeer, 2006). In our study site, *Nylanderia* sp. PM2, *Oligomyrmex* sp. PM1, *Paraparatrechina* sp. PM1 and *Tapinoma* sp. PM1 were very small species with less than 0.40 mm head width of workers. They might have a higher potential as predator of the CBB than other ant species in PM and KCK. Actually, one species of *Tapinoma* was reported as a predator of CBB in Mexico; the workers forage inside fruits and predate on borers (Infante *et al.*, 2003). Regardless of the body size, ant species that show aggression against the CBB, can affect the CBB during its dispersal from old berries to new berries. The CBB takes more than one hour to make a hole on a berry, hence, ants on coffee trees may be able to attack and expel the CBB from the branch or transport it to their nest (Perfecto and Vandermeer, 2006). Thus, there may be many possible candidates of ant species for biological control agents of the CBB. Further detailed observations of ant behavior against the CBB will be necessary for evaluating the effectiveness of ants for controlling the important pest insects of coffee.

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Appendix. List of ants collected at the coffee plantations in Pa Miang and Kun Chang Khian Site A. The number of coffee trees (T) or quadrats (Q) with each ant species was shown for each sampling season at two study sites. Asterisks indicate the size of head width of each ant: *0.60 – 0.71 mm, **0.40 – 0.59 mm, *** < 0.39 mm.

	Coffee plantation at Pa Miang village					Kun Chang Khian Site A		
	End of rainy season		End of dry season		Other	Rainy season		Other
	T	Q	T	Q		T	Q	
Dolichoderinae								
<i>Dolichoderus affinis</i>	2	0	2	0		19	7	
<i>Dolichoderus butteli</i>	0	0	0	0		1	0	
<i>Dolichoderus</i> sp. PM 1*	1	0	3	0		1	0	
<i>Dolichoderus</i> sp. PM 2	0	0	2	0		0	0	
<i>Tapinoma melanocephalum</i> **	2	0	2	2		0	0	
<i>Tapinoma</i> sp. PM 1***	2	3	5	10		2	4	
<i>Tapinoma</i> sp. PM 2***	1	0	0	0		0	0	
<i>Technomyrmex albipes</i> **	0	0	1	0		0	0	+
<i>Technomyrmex modiglianii</i>	0	0	0	0	+	0	0	
<i>Technomyrmex pratensis</i> *	0	1	0	1		0	0	
<i>Technomyrmex yamanei</i>	32	27	18	19		0	0	
<i>Technomyrmex</i> sp. PM 1*	2	3	0	5		0	0	+
<i>Technomyrmex</i> sp. PM 2*	0	1	0	0		0	0	
<i>Technomyrmex</i> sp. PM 3**	0	0	0	1		0	0	
<i>Technomyrmex</i> sp. PM 4*	0	0	0	0	+	0	0	
Dorylinae								
<i>Aenictus watanasiti</i> **	0	0	0	0		0	1	
Ectatomminae								
<i>Gnamptogenys bicolor</i>	3	1	2	0		0	0	
Formicinae								
<i>Anoplolepis gracilipes</i> *	0	0	0	0		0	0	+
<i>Camponotus lasiselene</i>	0	0	1	0		0	0	
<i>Camponotus leonardi</i>	0	0	1	0		0	0	+
<i>Camponotus nicobarensis</i>	0	0	5	0		0	0	
<i>Camponotus</i> (<i>Myrmamblys</i>) sp. PM 1 (= sp.23 of WJT)*	1	0	0	0		1	0	
<i>Camponotus</i> sp. PM 2 (= sp. 57 of WJT)	0	0	1	0		0	0	
<i>Camponotus</i> sp. PM 3	0	0	1	0		0	0	
<i>Myrmoteras binghamii</i>	0	0	0	1		0	0	
<i>Nylanderia</i> sp. PM 1**	0	0	0	2		0	0	
<i>Nylanderia</i> sp. PM 2***	0	4	0	11		0	0	
<i>Nylanderia</i> sp. PM 3**	0	1	0	0		0	0	
<i>Nylanderia</i> sp. PM 4**	0	1	0	1		0	6	

Appendix. (continued)

	Coffee plantation at Pa Miang village					Kun Chang Khian Site A		
	End of rainy season		End of dry season		Other	Rainy season		Other
	T	Q	T	Q		T	Q	
<i>Nylanderia</i> sp.CK1*	0	0	0	0		2	2	
<i>Nylanderia</i> sp.CK2**	0	0	0	0		0	11	
<i>Oecophylla smargdina</i>	0	0	1	2		0	0	
<i>Paraparatrechina opaca</i> ***	0	0	0	0		2	1	
<i>Paraparatrechina</i> sp. PM 1***	3	0	2	2		0	0	
<i>Plagiolepis</i> sp. PM 1 (= sp.3 of WJT)*	0	0	6	1		5	1	
<i>Plagiolepis</i> sp. PM 2**	0	0	2	0		0	0	
<i>Polyrhachis armata</i>	5	0	4	0		0	0	+
<i>Polyrhachis aff. tibialis caligata</i>	0	0	0	0		0	0	+
<i>Polyrhachis dives</i>	1	0	1	0		0	0	
<i>Polyrhachis halidayi</i>	0	0	0	0		2	0	
<i>Polyrhachis laevis</i>	1	0	0	0		0	0	
<i>Polyrhachis</i> (<i>Cryptomyrma</i>) sp.CK1	0	0	0	0		2	0	
<i>Polyrhachis</i> (<i>Myrma</i>) sp. PM 1 (= aff. sp.13 of WJT)	1	0	0	0		0	0	
<i>Polyrhachis</i> (<i>Myrma</i>) sp. PM 2	0	0	1	0		0	0	
<i>Polyrhachis</i> (<i>Myrma</i>) sp. PM 3	0	0	0	0	+	0	0	
<i>Polyrhachis</i> (<i>Myrmhopla</i>) sp. PM 4	1	0	2	0		0	0	
<i>Polyrhachis</i> (<i>Myrmhopla</i>) sp. PM 5	8	0	4	0		2	0	
<i>Polyrhachis</i> (<i>Myrmhopla</i>) sp. PM 6	1	0	0	0		0	0	
<i>Polyrhachis</i> (<i>Myrmhopla</i>) sp.CK2	0	0	0	0		1	0	
<i>Polyrhachis</i> (<i>Myrmhopla</i>) sp.CK4	0	0	0	0		0	0	+
<i>Polyrhachis</i> (<i>Myrmhopla</i>) sp.CK5	0	0	0	0		5	0	
<i>Polyrhachis</i> (<i>Myrmothrinax</i>) sp. PM 7	1	0	1	0		0	0	
<i>Pseudolasius</i> sp. PM 1*	0	1	0	7		0	0	
<i>Pseudolasius</i> sp.CK1 (= sp.3 of WJT)*	0	0	0	0		0	1	
<i>Aphaenogaster</i> sp.CK1	0	0	0	0		0	0	+
<i>Cardiocondyla</i> sp. PM 1***	0	0	1	3		2	3	

Appendix. (continued)

	Coffee plantation at Pa Miang village				Kun Chang Khian Site A			
	End of rainy season		End of dry season		Other	Rainy season		
	T	Q	T	Q		T	Q	Other
Myrmicinae								
<i>Cardiocondyla</i> sp.CK1***	0	0	0	0		0	1	
<i>Carebara affinis**</i>	0	1	0	2		0	3	
<i>Carebara diversus</i>	0	3	1	1		0	1	
<i>Cataulacus granulatus</i>	0	0	1	0		0	0	
<i>Crematogaster rogenhoferi</i>	0	0	0	0		0	0	+
<i>Crematogaster</i> sp. PM 1	1	0	0	0		3	1	
<i>Crematogaster</i> sp. PM 2*	1	0	7	3		0	0	
<i>Crematogaster</i> sp. PM 3*	1	0	0	0		0	0	
<i>Crematogaster</i> sp. PM 4	1	0	0	1		0	0	
<i>Crematogaster</i> sp. PM 5*	0	0	2	0		0	0	
<i>Crematogaster</i> sp. PM 6**	0	0	2	0		0	0	
<i>Kartidris</i> sp. PM 1*	0	3	0	0		0	0	+
<i>Lophomyrmex birmanus*</i>	1	3	1	8		0	1	
<i>Meranoplus laeviventris</i>	0	0	0	0		9	7	
<i>Monomorium</i> sp. PM 1***	0	1	0	2		0	0	
<i>Myrmecina</i> sp. PM 1**	0	0	0	2		0	0	
<i>Oligomyrmex</i> sp. PM 1***	0	4	0	1		0	0	
<i>Pheidole smythiesii</i>	0	0	0	0		2	6	
<i>Pheidole tandjongensis**</i>	0	1	0	1		0	0	
<i>Pheidole</i> sp. PM 1	1	3	4	4		0	0	+
<i>Pheidole</i> sp. PM 2***	0	1	0	1		0	0	
<i>Pheidole</i> sp. PM 3**	0	0	0	1		0	1	
<i>Pheidole</i> sp.CK1**	0	0	0	0		0	1	
<i>Pheidole</i> sp.CK2**	0	0	0	0		0	2	
<i>Recurvidris recurvispinosa***</i>	0	0	0	0		0	1	
<i>Rhopalomastix</i> sp.CK1 (= sp.1 of WJT)**	0	0	0	0		1	0	
<i>Solenopsis</i> sp. PM 1***	0	2	0	1		0	0	
<i>Strumigenys adiastrata**</i>	0	1	0	0		0	0	
<i>Strumigenys</i> sp. PM 1 (= sp.13 of WJT)**	0	1	0	1		0	1	
<i>Strumigenys</i> sp. PM 2 (= sp.19 of WJT)***	0	0	0	1		0	0	
<i>Tetramorium kheperra**</i>	0	0	0	0		0	4	
<i>Tetramorium lanuginosum</i> (= sp.5 of WJT)**	0	0	0	0		0	2	
<i>Tetramorium</i> sp. PM 1	1	0	1	0		0	0	

Appendix. (continued)

	Coffee plantation at Pa Miang village					Kun Chang Khian Site A		
	End of rainy season		End of dry season		Other	Rainy season		Other
	T	Q	T	Q		T	Q	
<i>Tetramorium</i> sp. PM 2*	2	0	0	0		1	10	
<i>Tetramorium</i> sp. PM 3**	0	1	0	0		0	0	
<i>Tetramorium</i> sp. PM 4**	1	0	0	0		0	0	
<i>Tetramorium</i> sp. PM 5**	0	0	0	1		0	0	
<i>Tetramorium</i> sp. CK1**	0	0	0	0		0	1	
<i>Tetramorium</i> sp. CK2*	0	0	0	0		0	1	
<i>Tetramorium</i> sp. CK3**	0	0	0	0		0	1	
<i>Tetramorium</i> sp. CK5	0	0	0	0		2	0	
<i>Trichomyrmex destructor</i> **	0	0	0	0		0	1	
<i>Trichomyrmex</i> sp. PM 1**	0	11	0	9		0	0	
<i>Trichomyrmex</i> sp. PM 2***	0	1	0	3		0	0	
Ponerinae								
<i>Anochetus myops</i>	0	2	0	0		0	0	
<i>Brachyponera chinensis</i>	0	1	0	0		0	0	
<i>Brachyponera luteipes</i>	0	2	0	2		0	12	
<i>Brachyponera nigrita</i>	0	0	0	1		0	6	
<i>Diacamma</i> sp. PM 1 (= aff. sp.10 of WJT)	0	2	0	0		0	0	
<i>Diacamma</i> sp. PM 2	0	0	1	1		0	0	
<i>Diacamma</i> sp. CK1	0	0	0	0		0	0	+
<i>Ectomomyrmex leeuwenhoekii</i>	0	2	0	0		0	0	
<i>Ectomomyrmex</i> sp. CK1 (= aff. sp.18 of WJT)	0	0	0	0		0	4	
<i>Hypoponera</i> sp. PM 1***	0	2	0	1		0	3	
<i>Hypoponera</i> sp. PM 2***	0	1	0	0		0	0	
<i>Hypoponera</i> sp. CK2***	0	0	0	0		0	0	+
<i>Leptogenys</i> sp. <i>diminuta</i> gp (= sp.6 of WJT)	0	1	0	0		0	0	+
<i>Leptogenys kitteli</i>	0	1	0	2		0	0	
<i>Leptogenys</i> sp. PM 1*	0	1	0	1		0	0	
<i>Odontomachus rixosus</i>	0	1	0	0		0	0	
<i>Odontoponera denticulata</i>	0	1	0	3		0	0	+
<i>Ponera</i> sp. PM 1**	0	0	0	4		0	0	
Proceratiinae								
<i>Proceratium</i> sp. CK1**	0	0	0	0		0	1	
Pseudomyrmecinae								
<i>Tetraponera attenuata</i>	0	0	4	0		0	0	+
<i>Tetraponera</i> sp. PM 1**	0	0	3	0		0	0	+

Appendix. (continued)

	Coffee plantation at Pa Miang village					Kun Chang Khian Site A		
	End of rainy season		End of dry season			Rainy season		
	T	Q	T	Q	Other	T	Q	Other
	58 species		64 species			44 species		
Total number of species			88 species			61 species		