The Ant Mosaic Distribution of *Oecophylla smaragdina* and Dominant Ant Species: Effects on Ants Communities in Agroforestry in Tarakan Island

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Abstract. Agroforestry system enhanced ant biodiversity. Ant structure in the ecosystem has been driven by many factors, e.g., competition and predation among species. Dominant species and predator may give impact to species diversity in the ecosystem. We had field research to examine the interactions among dominant ant species, predator *Oecophylla smaragdina*, and other ants in Tarakan, North Kalimantan. In agroforestry system as the study site, ants and other insects on 66 crop trees were collected by sweeping and beating. The obtained number of two species *Tapinoma melanocephalum* and *Oecophylla smaragdina* occupied more than 60% of all collected ants. Two dominant ants tended to be separately distributed. The community structure may be ant mosaic pattern. Furthermore, the densities of the two dominant ants were higher, but their diversities in the tree were lower than dominant species and predator absence. Probably, the tendency seems to be active on the distribution of other ants.
Keywords: Agroforestry System, *O. smaragdina,* Interaction, Ant Mosaic

1. Introduction

Agroforestry systems are a set of land-use systems [1-2]. Plants were grown as crops and other crops animals in some forms of spatial arrangement or temporal sequence [1-4]. In Indonesia, it is consist of traditional cultivars, such as coffee, cacao, and banana, are a part of ancient knowledge and practice [1,3]. They are sustained by various biological components in addition to artificial process because many plants and animals are mutually interacting in the agroforestry ecosystems [4-7,8]. Although increased plant diversity in agroforestry is expected to grow beneficial arthropods, variety by itself may not reduce pests [9]. Also, intensive agroforestry can influence ant species composition, promoting invasive tramp ant species [10].

Ant is one of the insects giving a heavy impact on the ecosystems as predators, preys and symbionts [11-13]. *Oecophylla smaragdina* is one of an important predator on a tropical island. Weaver ant *O. smaragdina* found from South-East Asia and North-Australia [14]. It lives on trees (arboreal insect) and a major predator in the food web of rainforest [11]. So, it may be useful material to establish the agricultural methods with the control of insects [11,15-18]. *Oecophylla* as a biological agent has been widely reported. It was control pests in citrus [15,18], mango [19,20], cashew [21], mahogany [22], palm oil [23], and cacao [24]. In mango tree, using *O. smaragdina* as biocontrol and soft chemical showed insect pest damage, the incidence of mango scab disease and infestation of lenticels lower than using chemical insecticides [19,25]. However, some farmers are reluctant to use weaver ants, since they attack not only pests but also humans [16]. It was repelling of pollinators [26], interfere foraging behavior and parasitism [27,28] and negative impact host-parasitoid interactions on mango [29].

Dominant species also affect ant community structure in the ecosystem. In savanna ecosystem, dominant species can control ant assemblages [30]. *Crematogaster lorteti* and *Tapinoma simrothi* followed by *Tapinoma israele* and *Crematogaster scutellaris* are dominant species that the ants strongly monopolized each tree in Mediterranean forests [31]. In tropical arboreal ants, if dominant ants are present, the other ants are a random subset of the overall community, but where dominant ants are absent, species were distributed nonrandomly across trees [32]

Interaction *O. smaragdina* with other ants were interested in understanding. In horticulture system (cashew and mango tree) plot with abundant weaver ant, *O. smaragdina* had similar or higher canopy arthropod and natural enemy diversity and similar ratios of natural enemies to insect pests, compared with a plot where the weaver ant was absent [33]. Other than that, dominant species competition varied with habitat type [30]. In this study, we want to know whether that the dominant species may seriously influence on ant the community structures in agroforestry system or not. This research was made to answers these questions; (i) how does species composition of ants on trees structure in agroforestry, (ii) does distribution of populations in dominant species influence other ants, (iii) effects of *O. smaragdina* and dominant species on the diversity of ants on trees.

2. Material and methods

2.1 Study sites

From February to August in 2016, field collection was carried out in the mixed tree plantations or agroforestry system (the area: 80 m x 90 m) at Mamburungan village (3016’06.29” N, 117037’12.43” E) on the Tarakan Island in North Kalimantan (figure 1). Tarakan has the highest rainfall in North Kalimantan. During 10 ten years ago, precipitation in February is lower than another month. The mean temperature is 27.50C, and the mean humidity is 75%.

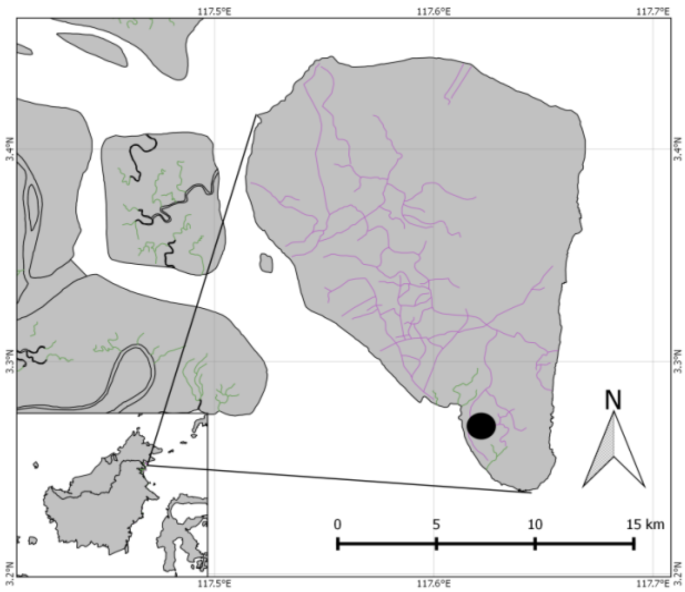


Figure 1. Map of study sites in Tarakan Island, North Kalimantan, Indonesia. *Black dot* represent the study site.

2.2. Collection of ants on the crop trees
In this study, we used durian (*Durio zibethinus*) and Citrus (*Citrus aurantiifolia*) as crop sample. In total 66 crop trees were exploited. These crops composed 44 durians and 22 citruses. We collected ants by beating and sweeping, in 10 branches. Count of individuals in a given unit (branch, leaf, or flower) was 20 branches. All collected samples served with ethanol (99%) specimens. In the laboratory, ants sorted according to their external morphology or morphospecies [34]. We were recorded and identified. Ant specimens identified to genus level by the key of identification guide to the ant genera of the world [35]. Furthermore, we were recognized ants to species by other resources (e.g., electronic funds)

2.3. Data analysis
Species composition of ants on trees and tree in the site were summarized. The diversity of ants was analyzed using the Shannon-Wiener diversity index (HI). We examined the distribution of dominant species population for analysis mosaic of ants. Besides, effects of dominant species on the diversity of ants on trees using generalized linear model (GLM) were used to analyze the relationship between ant dominants species and ant diversity.

3. Results

3.1. Species composition of ants on trees
In total, 25 ant species were collected. These species belonged to 5 subfamilies and 15 genera (table 1). The accumulated number of two species *T. melanocephalum* and *O. smaragdina* occupied more than 60% of all collected ants.

Table 1. Species composition of ants in the studied site.

Sub Family	Species	Number	(%)
Ponerinae	*Ponera* sp.1	4	0.01
Dolichoderinae	*Dolichoderus* sp. 1	2	0.001
	Iridomyrmex anceps	3086	5.8
	Iridomyrmex sp. 1	329	0.6
	Iridomyrmex sp. 2	356	0.7
	Philidris sp.1	786	1.5
	Tapinoma melanocephalum	26808	50.5
	Tapinoma sp. 1	288	0.5
	Technomyrmex albipes	1517	2.9
	Technomyrmex sp. 1	2428	4.6
Formicinae	*Anoplolepis gracilipes*	2325	4.4
	Oecophylla smaragdina	7750	14.6
	Camponotus sp. 1	57	0.1
	Polyhachis sp. 1	29	0.05
Pseudomyrmicinae	*Tetraponera* sp. 1	325	0.6
	Tetraponera sp. 2	49	0.1
Myrmiciane	*Crematogaster diffromus*	2121	4.0
	Crematogster sp. 1	806	1.5
	Crematogster sp. 2	145	0.3
	Monomorium destructor	2712	5.1
	Monomorium sp. 1	402	0.8
	Monomorium sp. 2	140	0.3
	Tetramorium sp. 1	586	1.1
	Tetramorium sp. 2	32	0.1
	Pheidole sp.1	16	0.03

On a tree, 9-17 species were collected (figure 2) and an average number of workers on branch trees ranged from 1.2 to 10.6 (figure 3). Multiple ant species inhabited in a tree, however only two species were dominant.

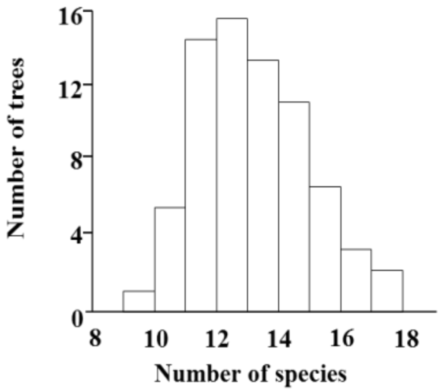


Figure 2. Frequency distribution of species number species in tree

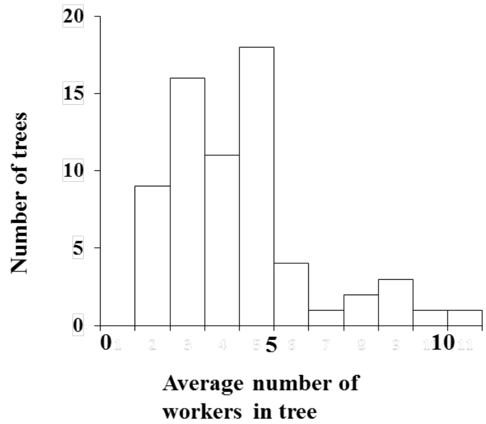


Figure 3. Frequency distribution of average number of ant workers in tree

3.2. Distribution of populations in dominant species

As shown in figure 4, the two species were dominant in the rank of worker densities. The densities of *T. melanocephalum* and *O. smaragdina* occupied more than 60% of all ant densities in 39 and 9 trees, respectively (figure 5). In addition, the spatial distribution of the trees where they were dominant tended not to be overlapped (figure 6), showing the distribution pattern called "ant mosaic." Furthermore, there was a negative correlation between the densities of the two ants in the tree (R^2=0.08, $P<0.05$).

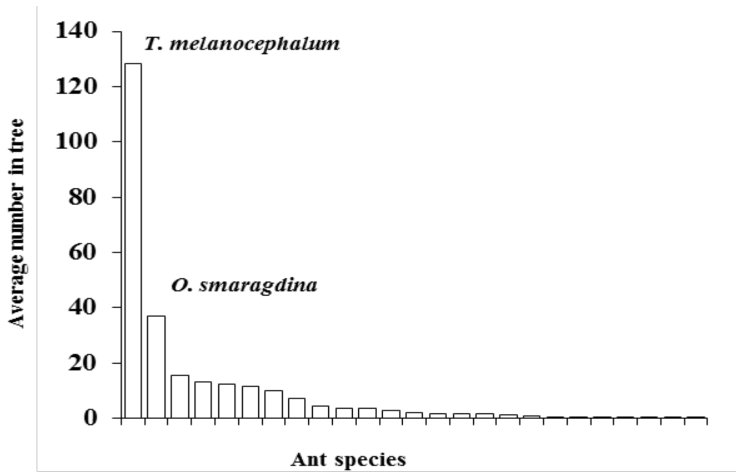


Figure 4. Rank of the worker densities in ant species

3.3 Effects of dominant species on the diversity of ants on trees

The species diversity of ants in trees, described as Shannon's diversity index was negatively correlated with the density of workers in *T. melanocephalum* (figure 7b), although the correlation with the density of *O. smaragdina* was not significant (figure 7a).

The effects of the two species were analyzed in more detail, by model selection using generalized linear model (GLM). As a result, the densities of both two species had adverse effects on ant species diversity (table 2). The crop trees are likely to be monopolized by single ant species. The pattern decreased the species diversity of ants in trees.

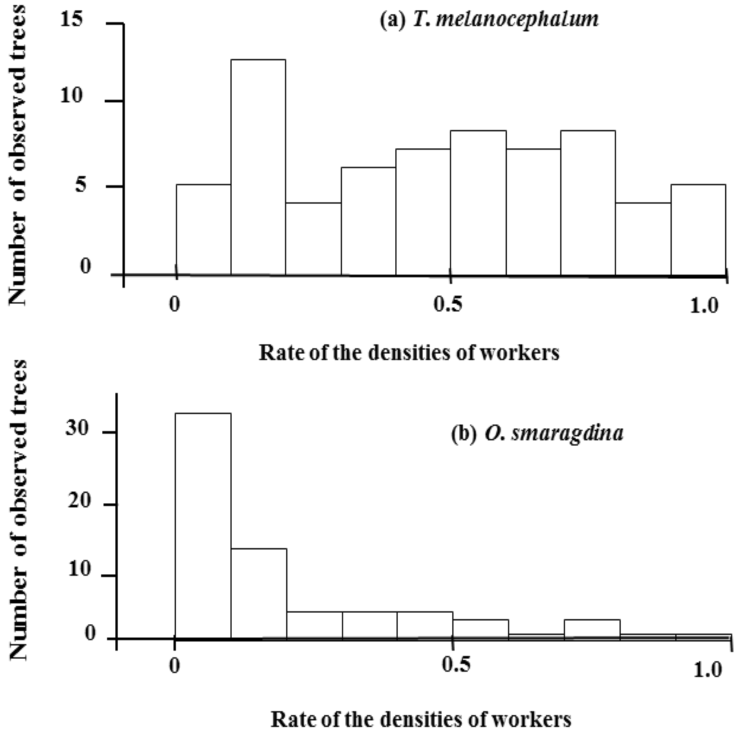
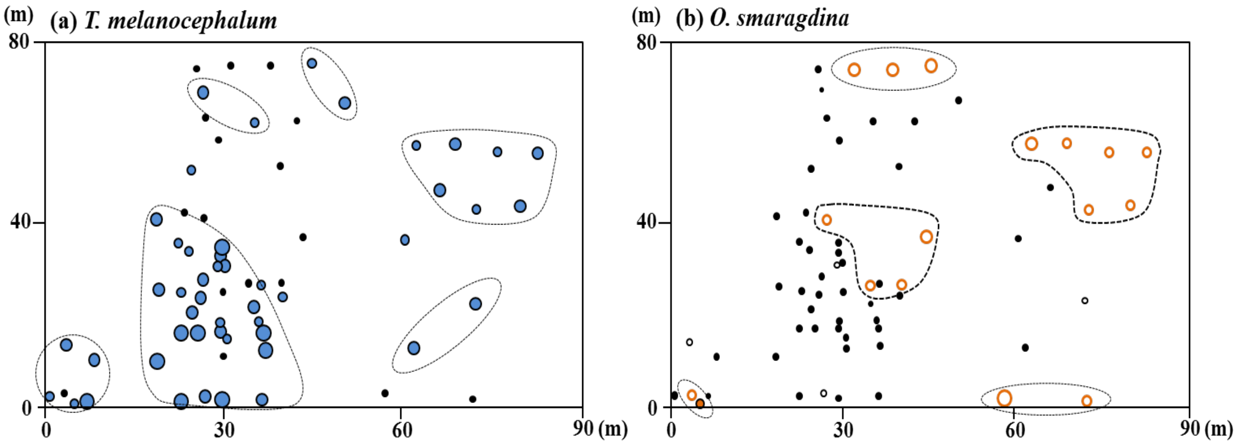


Figure 5. Frequency distribution of the rate of the densities of dominant three species in those of all ant species.

4. Discussion

O. smaragdina and *T. melanocephalum* is species dominant in this research. *O. smaragdina* was 9-10 occupied trees. It species recorded in cacao agroforestry landscapes [36,37] and urban area [38,39]. *O. smaragdina* is an arboreal ant and usually built a nest in a tree. One colony can reach 100 nests. The nests can be scattered over 15 trees or over an area of more than 1000 m^2 [40]. This study, durian and citrus tree supported *O. smaragdina* developed nest. However, the number of nests found in a colony is affected by several factors such as food availability and the degree of disturbance that occurs [11]. Furthermore, *T. melanocephalum* is one of the most ants important in tropical regions of Africa or Asia. In many research *T. melanocephalum* recorded in the urban area on the mainland [38] and small island [39], cacao agroforestry with low precipitation [36,37], and intensive agroforestry practices [10]. *T. melanocephaluma* is tramp species [41] and can be built polydomous colonies [42]. These tramp species are convenient associated with humans and are the most abundant in disturbed habitats, agricultural land and settlements [41,42]. *T. melanocephalum* built a nest and foraging activity in the cavity of a tree, leaf, and another place at the trees. In this study relied on the flowers and tree trunk durian and citrus.

In this study, the two dominant ant species were tended separately distribute at the local area or these 'dominant' ant species in the trees tended not overlap. The distribution these called 'ant mosaic' [43]. Dominant species were maintained colonies by producing abundance and high density and activity. However, it is not related to large numbers, but behavior in aggression and high interferential potential is a form of retaining existing resources from other ants [11,44,45]. Competition between ants can be more stringent [46]. It is mutual exclusion territories, and microhabitat requirement is needed in the competition [43,47]. Food, area, lighting, nests, female, male are competition factor among intraspecific or interspecific species for survival and reproduction [11]. In another case, interaction among ants showed no competition or resulting co-occurrences pattern and species aggregation. However, significant negative interactions detected among large ants in tropical ant communities [48]. Species segregation can be caused by adverse inter-specific interaction, but can also be caused by the influence or filtering of environmental factors [49,50].



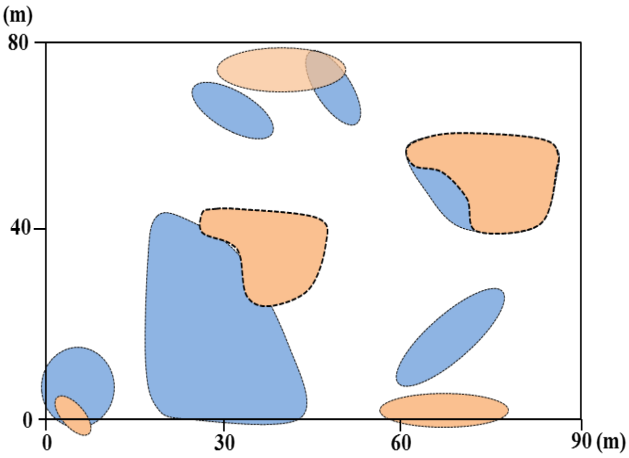
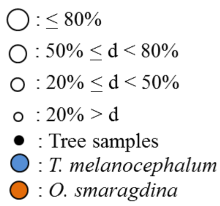


Figure 6. Spatial distribution of trees occupied by two dominant species in the studied site. The size and pattern of the symbol show the rate of worker densities and the existence of *O. smaragdina* nest. Dotted line shows the range of habitat of each species.



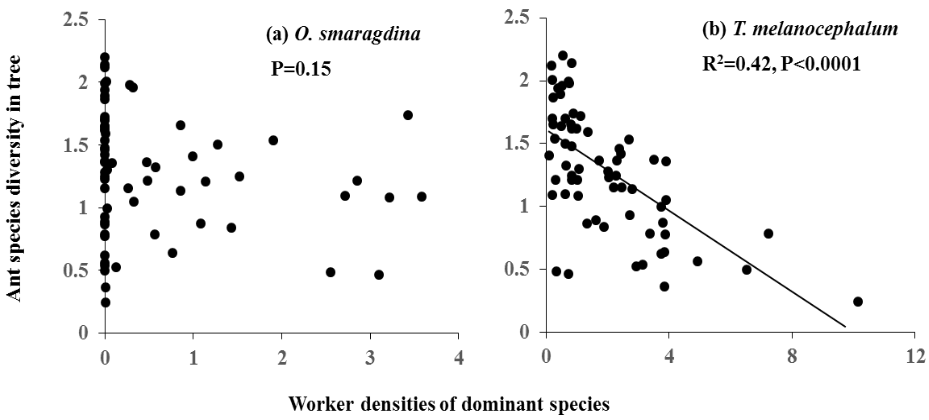


Figure 7. The relationships among the worker densities of the dominant species and the species diversity of ants in tree. The species diversity was shown by the Shannon's diversity index

Table 2. Generalized linear model in the relationships among the worker densities of two dominant ants and the species diversities of ants in tree. The species diversity in tree was described as the Shannon's diversity index.

	Independent variables					
Model	Density of *O. smaragdina*	Density of *T. melanocephalum*	*O. smaragdina* × *T. melanocephalum*	Intercept	AIC	*Δ*
1	-0.2**	-0.2**	-	1.77**	43.2	-
2	-0.2**	-0.2**	0.004	1.77**	45.2	2.0
3	-	-0.16**	-	1.60**	61.0	17.8
4	-0.08	-	-	1.32**	95.2	52.0

*: P<0.005, **: P<0.0001

Dominant species are known to have an impact on the structure of the ant community in the ecosystem. That species influence species richness at the community level [11,50,51] and the effect on other ants species [46,51,52]. In this study, dominant species is *T. melanocephalum* and *O. smaragdina*. Some explanations about the negative relationship between dominant species and ant diversity can be started from the environmental influence of the agroforestry system. Agroforestry supported the existence of species dominant species. Agroforestry allows the availability of food resources such as abundant carbohydrates and proteins. *T. melanocephalum* have symbiosis mutualism with another organism, which was produced sucrose [53]. Carbohydrates and proteins are the primary sources of food for *T. melanocephalum* species. Also, microhabitats such as canopy, flower, and tree trunk allow ants to make more nests. Another factor is the role of farmers in controlling ecosystems facilitating the existence of such ants, for example, pruning. Pruning affects temperature and humidity on the trees. Foraging activities were negatively correlated with ambient temperature but positively correlated with ambient relative humidity [54]. Especially for *O. smaragdina*, disruption of activity, the presence of chemical compounds released by the body and predation of other ants or known as "aggressively" are the factors that cause negative interaction of ant diversity in the ecosystem [26-28,55]. In another case, species dominant Pheidole spp observed aggressively displacing other ants from the baits in all areas [51]. *Iridomyrmex purpureus* were affected ant assemblages depends on microhabitat and resource type [56].

5. Conclusion

In conclusion, plantation using agroforestry supported ant diversity. However, there are dominant species and that species separately distributed in the ecosystem. These dominant species and predator affected the diversity of ants. Through this study, we collected information of ant diversity in an agroforestry system in Tarakan Island, North Kalimantan, and we have illustrated how ants diversity can contribute to the knowledge of species distributions across the potency using the ant as a biological control in agroecosystem plantation. Further research that also, interaction among natural enemies and herbivore species in agroforestry.

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References

[1] Nair P K R 2009 *Agroforestry system* **3** 97-128.
[2] Sardjono M A, Djogo T, Arifin H S and Wijayanto 2003 *Classification and Pattern Combination Component Agroforestry* (Bogor ICRAF) p 38.
[3] Aumeeruddy S B 1994 *Agroforestry Systems* **28** 113-141
[4] Jose S 2012 *Agroforest Syst.* **85** 1–8.
[5] Altieri M A 1999 *Agriculture, Ecosystems and Environment* **74** 19–31.
[6] Sileshi G, Festus K A, Oluyede C A, Sebastian C, Martin K and Matakala P W 2007 *African Journal of Environmental Science and Technology* **1** 68–80
[7] Bhagwat S A, Willis K J, Birks H J B, Whittaker R J 2008 *Trends Ecol. Evol.* **23** 261–267
[8] Tian Y, F Cao and G Wang 2013 *Agroforest Syst* **87** 1201–1210
[9] Rao M R, Singh M P and Day R 2000 *Agroforestry Systems* **50** 243–277
[10] Wara A, Lach L, Majer J D, Heterick B and Didham R K 2015 *Asian Myrmecology* **7** 87 – 104
[11] Hölldobler B and Wilson E O 1990 *The Ants* (Canada: Harvard UnivPr) p 732
[12] Klein A M, Steffan-Dewenter I and Tscharntke T 2002 *Biodiversity and Conservation* **11** 683–693
[13] Philpott S M and Armbrecht I 2006 *Ecol. Entomol*. **31** 369–377
[14] Azuma N K, Ogata T K and S Higashi 2006 *Ecol. Res.* **21** 126–136
[15] Way M J, Khoo KC 1991 *Annu. Rev. Entomol* **37** 479–503.
[16] Offenberg J 2015 *Journal of Applied Ecology* **52** 1197–1205
[17] Mele P V, Cuc N T T, Seguni Z, Camara K and Offenberg J 2009 *Int. J. Agricultural Resources, Governance and Ecology* **8** 484-504
[18] Mele PV 2008 *Agricultural and Forest Entomology* **10** 13–22
[19] Peng R K and Christian K 2005 *International Journal of Pest Management* **51(2)** 149-155
[20] Peng R K and Christian K 2013 *Journal of Economic Entomology* **106 (1)** 299-304
[21] Dwomoh D A, Jakpasu V K A, Joseph B A, Agene V N 2009 *Pest Manag Sci*. **65** 41–46
[22] Peng R, K Christian, D Reilly 2012 *Agricultural and Forest Entomology* **14** 428–433
[23] Pierre E M, Azarae I 2013 *Asian Myrmecology* **5** 163–176
[24] Forbes S J and Northfield T D 2017 *Biotropica* **0** 1-9
[25] Abdulla N R, Rwegasira R M, Jensen K M V, Mwatamala M W, Offenberg J 2016 *J. Appl. Entomol*. **140** 500–506
[26] Tsuji K, Hasyim A, Harlion, Nakamura, K 2004 *Ecological Research* **19** 669–673
[27] Appiah E F, Ekesia S, Afreh-Nuamah K, Obeng-Ofori D and Mohamed S A 2014 *Biological Control* **79** 49–57
[28] Tanga C M, Sunday E, Prem G, Nderitu P W and Samira A M 2016 *Insects* **7** doi:10.3390/insects7010001
[29] Migani V, Sunday E, Merkel K and Hoffmeister T 2017 *Plos One* DOI:10.1371/journal.pone.0170101.
[30] Parr C L 2008 *Journal of Animal Ecology* **77** 1191–1198
[31] Martinez J J I 2015 *Acta Oecologica* **65-66** 11-16
[32] Sanders N J, Gotelli N J, Heller N and Gordon D M 2003 *Proc. Nat. Acad. Sci.***100** 2474–2477
[33] Peng K and Christian K 2013 *J. Appl. Entomol* **137** 711–720
[34] Lattke J E *Specimen processing: building and curating an ant collection* 2000 (In Ants: Standard Methods for Measuring and Monitoring Biodiversity) ed Agosti D, Majer JD, Alonso LE, Schultz TR. (Smithsonian Institution Press: Washington, DC, USA) pp 155–171
[35] Bolton B 1997 *Identification Guide to The Ant Genera of The World* (London: Harvard UnivPr) p 22.
[36] Rizali A, Clough Y, Buchori D, Hosang M L A, Bos M M and Tscharntke T 2013 *Insect Conservation and Diversity* **6** 328–338
[37] Rizali A, Yann C, Buchori D and Tscharntke T 2013 Agroforestry *Diversity* **5** 26-38

[38] Rizali A, Bos M M, Buchori D, Yamane S and Schulze C H 2008 HAYATI *Journal of Biosciences* **15 (2)** 77-84
[39] Rizali A, Rahim A, Sahari B, Prasetyo L B and Buchori D 2011 *Jurnal Biologi Indonesia* **7 (2)** 221-230
[40] Van Mele P and Cuc N T T 2000 *International Journal of Pest Management* **6 (4)** 295- 301
[41] McGlynn T E 1999 *J.Biogeo.* **26** 535-538
[42] Appel A G, Na J P S and Lee C 2004 *Sociobiology* **44** 89–100
[43] Leston D 1973 *ANS* **19** 311–41
[44] Davidson D W 1997 *Biological Journal of the Linnean Society* **61** 153-181.
[45] Arnan X, Gaucherel C and Alan N 2011 *Oecologia* **166** 783–794.
[46] Andersen A N and Patel A D 1994 *Oecologia* **98** 15–24.
[47] Blüthgen N and Nigel E S 2007 *Austral Ecology* **32** 93–104
[48] Elwood M D F, Bluthgen N, Fayle T M and Foster W A 2016 *Acta Oecologica* **75** 24-34
[49] Palmer T D 2003 *Ecology* **84 (**11**)** 2843–2855
[50] Nathan J, Kraft B, Adler P B, Godoy O, Emily C J, Fuller S and Levine J M 2015 *Functional Ecology* **29** 592–599
[51] Parr C L, Brent J S, Alan N A, Kevin J G and Steven L C 2005 *American Naturalist* **165(**4**)** 481-494
[52] Seguni Z S K, Way M J, Mele P V 2011 *Crop Protection* **30** 713-717
[53] Kim-Fung C, Lee C Y 2006 *Sociobiology* **48**(3) 875-883
[54] Zhou A M, Kuang B Q, Gao R and Liang G W 2015 *Florida Entomologist* **98**(4) 1217-1222
[55] Dejean A, Corbara B, Orivel J and Leponce M 2007 *Functional Ecosystem and Communities* **1**(2) 105-120
[56] Gibb H 2005 *Austral Ecology* **30** 856–867