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Nesting Sites of *Apis cerana* Fabr. (Hymenoptera: Apidae) in Two Different Altitutes of Polyculture Plantations in West Sumatera

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Natural cavities in polyculture plantations are important for the conservation of honeybees. This study was aimed to determine the diversity, nest sizes, and fluctuations in the use of sites for nesting by *Apis cerana* Fabr. in polyculture plantations in two altitudes in West Sumatra. A census method was used to obtain the data variables in 10 plantations (five locations for each altitute). Polyculture plantations used as the study sites were dominated by coconut in lowland areas and coffee in highland areas. The results showed that nesting sites of *Apis cerana* were found amongst 18 species of plants belonging to 15 families (12 species in lowlands and seven species in highlands). Most of the nests were placed on *Cocos nucifera* (coconut) trees in lowland sites, and on *Erythria variegata* (dadap) in highland sites. Nests were also found to be located mostly in the cavities of trees with diameter 21-60 cm. Nest entrances were located at 228.31 cm above ground surface (ags) in highland and at 116.04 cm ags in lowlands. The nest entrances in highlands measured 12.21 by 3.73 cm (height and width), and in the lowlands 14.93 by 7.36 cm. The percentage of tree cavities used for nesting was statically higher in lowland (40.73%) compared to high land (17.86%), but it fluctuated very slightly in both high or lowland areas during observation. The percentage of trees with nests decreased in December and January but increased in February, with the same patterns found in both high and lowlands. Our research suggests that higher tree diversity in polyculture plantations promotes increased use by honeybees for nesting. Thus, the more tree diversity in polyculture plantations the better it could conserve natural honey bees populations.

Key words: honeybee, nesting diversity, altitude, colony fluctuation

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INTRODUCTION

Plantations in West Sumatra are generally polycultures, covering an estimated 5.93% of the total land area of West Sumatra. Polyculture crops in lowlands are dominated by commercial plants and fruits such as coconut, areca nut, chocolate, durian, fruit bearing nephelium trees (rambutan), and plumlike fruit (kedondong); while in the highlands crops are dominated by forest products and commercial crops such as coffee, cinnamon and surian (BPS 2012). From an ecological point of view, plantations alter natural landscape and alter established ecosystems. Bee species are highly affected by changes in ecosystems (Steffan-Dewenter 2003). Ecosystem change may have some detrimental effects on bees such as affecting nesting dynamics (Vaudo *et al*. 2011), but on the other hand it may provide benefit for bees by providing increased food sources and nesting sites (Ratnieks & Piery 2004; Coulson *et al*. 2005; Mbah & Amao 2010).

Four species of cavity-nesting honey bees native to Indonesia: *Apis cerana*, *A. koschevnikovi*, *A. nigrocincta,* and *A. nuluensis* (Hadisoesilo 2001). The nesting habits of these are relatively similar to *A. mellifera* (Ruttner 1988). Cavity-nesting honey bees in West Sumatra include *A. cerana* and *A. koschevnikovi*. Between them, *A. cerana* has higher population numbers due to its wide distribution and ability to coexist with humans. However, *A. cerana* has vulnerabilities as well; the species requires relatively large cavities for nesting, and populations are prone abscond in response to environmental stressors.

Apis cerana has been cultured in preservation boxes and in wild. The size of the artificial cavities (box) commonly used for bee rearing are 35 x 31x 25 cm (Kuntadi 2013), where as in nature the volume of cavities is more varied ranging from 22.3-45.9 liters (Inoe *et al*. 1990). Bees exhibit a variety of nesting habits, including tunnelling in bare ground, using pre-existing cavities, excavating dead wood, and constructing nests in side larger cavities in or on trees, in rocks or rodent nests and in active termite nests (Roubik 2006; Kremen *et al*. 2007). Cavities

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found in trees in the wild are used for housing multiple combs, as a shelter from predators and unfavorable weather conditions. A cavity is suitable for nesting if it can be inhabited by a colony of bees for a relatively long period of time.

A. cerana plays an important role as a pollination agent in various types of plantations such as *Coffea canephora* and *Coffea arabica* (Klein *et al*. 2003), apples (Khan & Khan 2004), highbush blueberry (*Vaccinium corymbosum* L.) (Tuell *et al*. 2009), and palm (Emuh & Ofuoku 2011). Due to their importance for commercial crops, studies on the ecology, spatial distribution, diversity, and conservation of this bee and other bees have been gaining pace in recent years (Inoue *et al*. 1990; Baum *et al*. 2005; Caulson *et al*. 2005; Sheffield *et al*. 2008; Murray *et al*. 2009; Vaudo *et al*. 2011). Unfortunately, similar research is rarely conducted in Indonesia, which has resulted in population decline, due to lack of understanding of the ecological role and needs of bees, and lack of pollination management in plantations. Based on these concerns, this study was aimed to investigate nest site diversity, nest size, and fluctuations in the use of sites for nesting by *A. cerana* in polyculture plantations in the tropics, especially in West Sumatra.

MATERIALS AND METHODS

Study Area. The study was conducted in a polyculture plantations in West Sumatra from March 2011 until March 2012. Observations were made at sites at two altitutes: lowland and highlands. Plot criteria were: minimum width 10,000 m^2, presence of trees with minimum stem diameter breast height (dbh) > 20 cm, dominated with cultured plants for the purpose of fruit production, at least there was minimum one colony of *A. cerana* present. Five plots (10,000 m^2/plot) were selected. The lowland site was located in Nagari Parik Malintang, in the sub-district Enam Lingkung, Padang Pariaman District (100027’00” EL and 0050’30” SL). This landscape lies at an altitude of < 100 meters, dominated by the following tree species: *Durio zibetinus* (durian), *Spondias pinnata* Kurz (plumlike fruit), *Areca catecu* (areca nut), *Cocos nucifera* (coconut) and *Theobroma cacao* (chocolate). The average daily temperature during our study was 25.7 ^{o}C and average monthly rainfall was 368.4 mm. The highland location was in Nagari Andaleh Batipuh subdistrict, Tanah Datar District (100022’32” EL and 0023’38” SL). This landscape lies at an; altitude >1000 meters, and is dominated by *Coffea canephora* (coffee) and *Cinnamomum burmanii* (cinnamon). The average daily temperature during our study was 25.0 ^{o}C and average monthly rainfall was 549.00 mm (BPS 2012). Dominant weedys plants found in in the highland location included: *Bidens pilosa* (blackjack) and *Galiansoga parviflora* (yellow weed); while those dominant in the lowlands were *Cynodon dactylon* (bitter grass) and *Mimosa pudica* (sensitive week). All observations were conducted once a month through census of sampling plots, over the course of 13 months.

Diversity of Nesting Sites. All trees with dbh > 10 cm were censused, and the following parameters were measured: species of plants used as nest sites, trunk dbh, and presence of cavities not used for nesting. Trees were categorized as follows: Group I dbh $\leq$ 20 cm, Group II dbh = 21-40 cm, Group III dbh = 41-60 cm, Group IV dbh = 61-80 cm, Group V dbh $\geq$ 81 cm. We also took note of other potential non tree bee nesting sites within observation plots. Tree samples were identified in Plant Systematic Laboratory, Department of Biology, Andalas University, Padang.

Nest Observations. Nest were measured for the following parameters: height of nests from ground surface, entrance height, entrance width, number of entrances in each tree, and total number of nests per sample plot (10,000 m^2).

Fluctuations of Nesting Sites Usage. Total number of tree cavities used by *A. cerana* were observed and measured once per month over a period of 13 months. The measured parameters were the number of cavities occupied by nests, and cavities returned for reuse by bee colonies. Availability of cavities used for nesting is expressed as a percentage (%) of total trees censused in each sample plot.Secondary data like rain fall (mm Hg), relative humidity (%), temperature (^{o}C), wind flow (knots), and photoperiod (% of 24 h) were obtained from Agency for Meterology, Climatology, and Geophysics, station of Padang Panjang (highland) and Sicincin Padang Pariaman (lowland).

RESULTS

Diversity of Nesting Sites. Tree species used for nesting sites by *A. cerana* in polyculture plantations in both locations studied in West Sumatera consisted of 18 species belonging to 15 families; 12 tree species in the lowland and seven tree species in highland (Table 1). Tree species diversity for nesting sites was higher in the lowlands (13 species) compared to the highlands (7 species). In the lowlands nests were mostly placed on trees of the family Arecaceae (3 species). There, the highest number of nests were placed in *Cocos nucifera* (coconut) trees. In the highlands the greatest number of nest were found in *Erythria variegata* (dadap) trees. Nests were mostly found in trees of dbh ranging from 21-40

Table 1. Tree diversity nesting sites, group trunk diameter, and nest size of *A. cerana* in polyculture plantations in West Sumatra

Nesting site scientific/common name	Group of trunk diameter (cm)						Average size of nest (cm)			
	I	II	III	IV	V	Number	Nest height from ground	Entrance height	Entrance width	Number of entrance
A. Highland										
I. Arecaceae										
1. *A. catechu* (areca nut)**	3	0	0	0	0	3	622.87 ± 316.80	2.00	1.00	1 ± 0.0
II. Caesalpinaceae										
2. *E. variegata* (dadap tree)	0	3	4	5	0	12	382.50 ± 247.40	6.50 ± 2.00	4.33 ± 3.76	1.33 ± 0.0
III. Euphorbiaceous										
3. *S. reticulata* (Kepundung hutan tree)	0	1	0	0	0	1	105.00	14.00	7.00	1
IV. Meliaceae										
4. *T. sureni* (Surian tree)	0	1	3	0	0	4	110.00 ± 180.40	6.00 ± 1.30	3.20 ± 3.81	1.25 ± 0.0
V. Rubiaceae										
5. *C. robusta* (coffee)	0	1	0	0	0	1	83.00	30.00	3.00	1
VI. Theaceae										
6. *E. acuminata* (Jirak tee)	0	0	2	0	0	2	125.00 ± 63.64	21.00 ± 0.71	4.50 ± 12.73	1 ± 0.0
VII. Urticaceae										
7. *T. radicans* (nettle)	0	0	1	0	0	1	170.00	6.00	3.00	1
Total number	3	6	10	5	0	24	1598.17	85.50	26,11	8.55
Average							228.31	12.21	3,73	1.02
B. Non-plant										
1. House wall						1	80.00	4.00	2.00	1
C. Lowland										
I. Anacardiaceae										
1. *S. lutea* (plumlike fruit)	0	0	1	1	0	2	90.00 ± 113.14	10.00 ± 0.0	12.00 ± 5.66	1 ± 0.0
II. Arecaceae										
2. *C. nucifera* (coconut)	0	8	2	1	0	11	115.09 ± 121.54	8.94 ± 7.75	6.29 ± 4.61	1.55 ± 0.0
3. *A. catechu** (areca nut)	3	0	0	0	0	3	316.33 ± 107.94	3.67 ± 153	5.67 ± 3.79	1 ± 0.0
4. *C. rumphiana* (sago palm)	0	0	1	0	0	1	15.00	5.00	13.00	1
III. Bombacaceae										
5. *D. zibethinus* (Durian)**	0	0	0	0	2	2	407.50 ± 555.08	5.00	3.00	1 ± 0.0
IV. Guttiferae										
6. *G. mangostana* (mangosteen)	0	2	0	0	0	2	60.00 ± 28.28	28.00 ± 0.71	10.50 ± 2.83	1 ± 0.0
V. Leguminoceae										
7. *P. lithosperma* (Phitocellobium tree)	0	1	1	0	0	2	117.50 ± 45.96	10.50 ± 4.96	11.50 ± 3.54	1 ± 0.0
VI. Meliaceae										
8. *L. domesticum* (Duku)	0	1	0	0	0	1	40.00	50.00	5.00	1
VII. Moraceae										
9. *Arthrocarpus* sp. (berad -tree)	0	0	1	0	0	1	103.00	7.00	5.00	1
VIII. Musaceae										
10. *Musca* sp. (banana)	1	0	0	0	0	1	50.00	33.00	7.00	1
IX. Myrtaceae										
11. *S. aqueum* (Jambu air)	1	0	0	0	0	1	23.00	9.00	5.00	1
X. Verbenaceae										
12. *P. canescens* (Sungkaitree)	0	2	1	0	0	3	55.00 ± 69.31	9.00 ± 2.31	4.33 ± 3.61	1 ± 0.0
Total number	5	15	7	2	2	30	1287.42	165.11	81.29	12.55
Average							107.29	13.76	6.77	1.05
Non-plants										
1. Rodent hole						1	0.00	8.00	8.00	1
2. Old chair						1	40.00	40.00	30.00	1
3. Concrete electric pole						1	30.00	17.00	3.00	1
Total number						3	70.00	65.00	41.00	3
Average							23.33	21.67	13.67	1

cm. Other, non tree sites observed for nesting were: home walls, rodent holes, old chair, and concrete electrical poles.

Nest Size. Nests use by *A. cerana* were placed heights not exceeding 830 cm above ground surface. The nest entrance height and width range from 2-50 and 1-19 cm respectively. There were 1-4 entrances present in each nest (Table 1). On average, nests were placed at height of 228.31 cm above the ground surface in the highlands, while in the lowlands average placement averaged only 116.04 cm from ground surface. The average nest entrance size (height and width) in the lowlands was greater than that found in highlands.

Fluctuations of Nesting Sites Usage. The total number of trees censused in the lowlands was 857 (average 171.4 individuals per 10,000 m^2) with only 8.98% possessing cavities suitable for nesting. By contrast, there was lower tree diversity in the highlands, with 152 plants (on average 30.4 plants per 10,000 m^2). A much higher percentage of these trees (59.87%) possessed cavities suitable for nesting (Table 2). Twenty-four out of 34 nests (70.59%) observed in lowland plantation were found in living trees (as oppossed to dead trees), while only 16 out of 31 nests (51.61%) in the highlands were found in living trees. The number of trees possessing cavities in the highlands was 91 individuals; 31 of the cavities were occupied by nests and 60 cavities were empty. In the lowlands, 77 trees possessed cavities; 34 cavities were occupied by nests and 43 were not.

Availability of trees with cavities in highland polyculture plantations was greater than in lowland plantations. The proportion of plants with cavities utilized for nesting in highland plots ranged from 11.36 to 24.44%, while in the lowland plots the proportion was 28.57 to 47.27% of the total number of available trees with cavities (Figure 1). The use of trees cavities by *A. cerana* fluctuated according to the number of colonies present in each plot, which varied over time. Trees with cavities were mostly used for nesting in June 2011 (47.27% in the highlands; 24.44% in the lowlands) and only few were used in December 2011 and January 2012 (28.57% in lowland; 11.36% in highland).

The variations in the use of trees cavities by *A. cerana* fluctuated according to the number of colonies present in the area in different month. The increase in proportion of trees used for nesting in lowlands polyculture plots occured from January

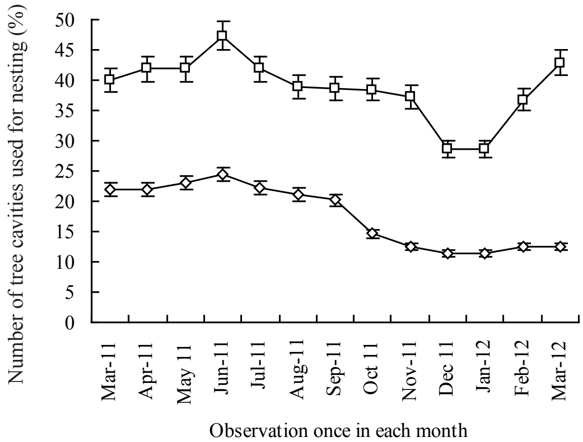

Figure 1. Number of tree cavities used for nesting (%) by *A. cerana* colonies in polyculture plantations in West Sumatra. -◇-: tree cavities in highland, -□-: tree cavities in lowland.

Table 2. Location and number of trees (diameter > 10 cm) in each plot in polyculture plantations in West Sumatra

Locations			Number of trees									
Polyculture plantations	Observation	Altitude (m)	Cavities with nest			Cavities without nest			No cavities			Total
			Live	Stump	Total	Live	Stump	Total	Live	Stump	Total	
Highlands	Plot 1	1050	4	6	10	15	3	18	7	0	7	35
	Plot 2	1050	4	3	7	14	3	17	8	5	13	37
	Plot 3	1300	2	4	6	10	3	13	29	0	42	48
	Plot 4	1450	3	1	4	4	3	7	0	0	7	11
	Plot 5	1450	3	1	4	5	0	5	12	0	17	21
	Total		16	15	31	48	12	60	56	5	61	152
	Average		3.2	3.0	6.2	9.6	2.4	12	11.2	1.0	12.2	30.4
	Stdev		0.84	2.12	2.49	5.03	1.34	5.83	10.85	2.24	14.50	14.48
Lowlands	Plot 1	37	6	2	8	6	0	6	76	0	76	90
	Plot 2	37	3	3	6	2	19	21	212	0	212	239
	Plot 3	55	5	1	6	6	0	6	147	1	148	160
	Plot 4	55	3	2	5	4	1	5	204	0	204	214
	Plot 5	65	7	2	9	4	1	5	140	0	140	154
	Total		24	10	34	22	21	43	779	1	780	857
	Average		4.8	2.0	6.8	4.4	4.2	8.6	155.8	0.2	15.6	171.4
	Stdev		1.79	0.71	1.64	1.67	8.29	6.95	55.17	0.45	55.14	57.97

to February 2012 (28.57%) the month when populations of bees are the highest in the area. In the highland plot, the highest proportion of cavity used for nesting occured May and June 2011 (4.76%) also correlating to the month of highest bee population in the areas. As predicted, a sharp decrease in the proportion of cavity use for nest in highland plots occured from September to October 2011 (27.77%) when bee populations are generally at their lowest. The same pattern was found in lowland plots, where the lowest proportion of use of cavities for nesting occured from November to December 2011 (26.32%) coinciding with period of the lowest bee populations in the region.

In the lowlands, a greater proportion of cavities were used repeatedly for nesting after colonies abscondment than in highland plots. In lowland polyculture plots, nine cavities were found to be used repeatedly (five coconut trees, anareca nut tree, sago tree, jengkol tree, and an electric pole) whereas only one cavity was reused in our highland polycultrure plots (in a dadap tree). The reused cavities were left empty for 1-5 months before they were occupied by new colonies of *A.cerana*. In this study we were unable to ascertain whether colonies occupying previously-used cavities were the same colonies returned to their prior nest, or were new colonies taking advantage of the abandoned space.

DISCUSSION

Diversity of Nesting Sites. The diversity of trees used by honey bees as nesting sites depends on the diversity of tree species available. In our study, we found a higher diversity of tree species used as nesting sites by *A. cerana* in polyculture plantations in West Sumatera, than has been found in earlier studies of *A. cerana* (Inoue *et al*. 1990) or of different species (Baum *et al*. 2005). Inoue *et al*. (1990) found only five tree species (*Cocos nicifera*, *Eugena jamboo*, *Ficus* sp., *Hibiscus similis*, and *Vitex perbescen*) were used by *A. cerana* honey bees for nesting sites in Padang Sarai, Pasir Jambak, and Bungo Pasang Padang. Although in a different ecosystem, Baum *et al.* (2005) also found only five tree species used by feral colonies of honey bee, *Apis mellifera* L. in Welder Wildlife Refuge, San Patricio County, Texas. These were observed in live *Q. virginiana* (oak), *Celtis* spp. (hackberry), *Ehretia anacua* (anacua), *Ulmus crassifolia* (cedar elm), and *Morus rubra* C. Linnaeus (mulberry).

The diversity of tree species used for nesting was greater in lowland polyculture plantations than in the highland plantations (Table 1). Differences in geographic and topographic charateristics represent an important enviromental factor that influences species richness. Species diversity tends to increase as we move toward equator. Systems at lower latitudes tend to have both higher local, or alpha diversity; and higher between system, or beta diversity (Lomolino *et al*. 2006). Out of 42 species of trees planted in Nusakambangan, the most widely planted species were coffee (*Coffea* sp.), orange (*Citrus aurantium* Linn.), sengon (*Paraserianthes falcataria* Back), dadap (*Erythrina lithosperma* Miq.), and petai (*Parkia speciosa* Hassk.) (Abdiani 2008). In the tropics like Indonesia, most people plant coffee, cocoa, coconuts, oil palm, rubber, and tea (Hartemink 2005). All these plants can be used by honey bees for nesting sites and food resources.

In our highland plots, the highest number of *A. cerana* nests (12 out of 24, or 50%) was found in *Erythria variegata*. *A. cerana* may have preference to place nests in this tree because of the availability of multiple cavities in individual trees, and because of the relative abundance of the trees in areas where bee food resources were available. *Erythria variegata* is planted to provide shade for young coffee trees and the shading plants are allowed to grow naturally without interference until dead. *Erythria variegata* has soft stem tissues that easily degrade to produce cavities. Baum *et al*. (2005) reported colony aggregations probably resulted from the high distribution of nesting resources, especially cavities.

In our lowland plots, the highest number of *A. cerana* nests were found in *Cocos nucifera* most likely because this tree is the dominant population in number, found in polyculture plantations in low lands. The species also has relatively more cavities than other species in the area. The structure of the trunk of *C. nucifera* includes a hard outer section, with an inner part that is soft. This condition facilitates the formation of cavities in the softer interior, which are well protected by the hard outer section. Other reason for selection of *C. nucifera* for nesting, is that it produces pollen and nectar throughout the year, therefore acting as a source of food as well as nesting sites. Inoue *et al*. (1990) also found a high proportion of *A. cerana indica* nests in in *C. nucifera* tree cavities in Central Sumatera (13 out of 34 nests). Vaudo *et al*. (2011) compared bee colonies nesting in protected land reserves to those on live stock farms and found that nesting may occur in greater densities in reserves. This supports the idea that higher tree diversity allows for more intensive bee nesting.

In our study we also observed non-tree locations used by *A. cerana* for nest sites. These included concrete electricity pole, rodent holes, old chairs and the space between two layer wall made of wood which acted as alternative nesting sites to tree species (Table 1). The choice of a new nest site is ecologically critical for an insect colony (Visscher 2007). Individual scouts discover potential nest sites and integrate multiple properties of these sites into assessments of their quality. Landscapes characterized by diversity and abundance of early successional flowering plants also provide cavity sites needed by honey bees, as reported by Coulson *et al*. (2005). The Africanized honey bee (Hymenoptera: Apidae) near Tapachula, Chiapas, Mexico, finds natural nest sites in hollow trees, in arboreal termite nests and ground in open areas (Ratnieks & Piery 2004).

Banana stems (*Musa* sp.) were a less common alternative site for nesting by *A. cerana* (Table 1). The nest was placed at the base of the banana tree's dried pseudo-trunk. The combs of the nest were placed in the center of a banana stalk that was dead and decaying. Placement of nests in this unusual spot may have been due to lack of other cavities for nesting sites, since at the lowland location only 10 out of 214 trees had cavities suitable for nesting (Table 2). In this case, the selection of nesting site was determined more by the availability of food resources on the appropriateness of the sites for nesting. The primary food source available throughout the year at this location is coconut. Coconut ranked the second most widely grown plantation commodity in West Sumatra in 2012 (BPS 2012). Plantation management practices and other human activities have altered the landscape and thereby created food and habitat resources suitable for honey bees (Coulson *et al*. 2005). The policies requiring the management of non-cropped farmland to increase floral diversity and abundance are essential to support bee populations (Decourtye *et al*. 2010) and all polinators (Kremen *et al*. 2007). This is especially true in intensively farmed areas. The diversity of insect pollinators can be influenced by the management system applied by farmers, and such effects may have strong impacts on coffee fruit production (Vergara & Badano 2008).

In the lowland sites, most nests of *A. cerana* were placed on trees with diameters of 21-40 cm, while in the highlands they were placed mostly in trees of diameter 41-60 cm (Table 1). This difference was due to the different varieties of plants found in each of the two polyculture plantations. The lowland polyculture plantation was dominated by monocotyledonous plants like palm, with relatively similar diameter across individuals, while the highland location was planted by various dicotyledonous tree species with more diversity in size. Larger trees (diameter 21-60 cm) were preferred by *A. cerana* as nesting sites, as was also reported by Murray *et al*. (2009). In that study, it was shown that larger cavities allowed a colony to establish more combs. In Padang Sarai and Bungo Pasang Padang, Central Sumatra, a range of 3 to 8 combs for *A. cerana* were found in each tree. The nest found in the walls of the house contained 14 combs. The maximum *A. cerana* comb size described in the scientific literature was 52 cm in height and 17 cm in wide (Inoue *et al*. 1990).

Nest Height. Nest entrances were located at 0-800 cm (116.04 ± 121.28 cm) above ground surface (ags) in the lowland polyculture plantations, while in the highlands, they were located at 0-830 cm (228.31 ± 201.53 cm). The average height ags we found for *A. cerana* nests was relatively similar to previous findings on the same or different species of bee (Inoue *et al*. 1990; Baum *et al*. 2005).

We surmise that bees in highland polyculture plantations preferred to place their nest entrances higher than the height of surrounding coffee plants, so that the activity of bees around the nests not to be impeded by coffee branches and twigs. Selection of nest entrance which was higher than ground level may also be related to defense of the colony from highland predators such as reptiles and bears. The choice of a new nest site is ecologically critical for an insect colony (Visscher 2007).

Only a few *A. cerana* nest entrances were observed near the surface of the ground (Table 1). In this study, two colonies were found to have nest entrances lying parallel to the surface of the ground. One was located in kedondong trees (lowlands) and one in asurian tree (highland). Nests located near the ground surface are exposed to many risks, especially from rain. In September 2011 the high rainfall (453 mm Hg) soaked these two nests and the colonies absconded.

Environmental changes have a direct influence on honey bee development (Le Conte & Navajas 2008). The effects of global climate change on other stages in the life cycle of pollinators, such as the larval and migratory stages, must not be overlooked. Temperature constitutes an important factor potentially limiting insect flight and pollen availability, and light intensity, rain and relative humidity also play a role (Chagnon 2008).

The choice of the *A. cerana* nest locations may serve to mitigate some of these environmental factors. The average dimensions of nest entrances of *A. cerana* in highland polyculture plantations (12.69 x 4.15 cm) were narrower than those in the lowlands (15.12 x 7.14 cm). Selection of a narrow entrance helps to protect against the effects of environmental factors such as low temperature and strong wind speeds in the highlands. Average daily temperature in the highlands was 21.98 ^{o}C with wind speeds of 4.25 knots, where as average temperature at lowland plantation sites was 25.3 ^{o}C with wind speeds of 0.94 knots. A small entrance will reduce the cold air and strong wind into the nest, so that the temperature of nest could be maintained. The average nest temperature of *A. cerana* in both locations was 34-37 ^{o}C (Ruttner 1988).

Selection of narrow nest entrance was also related to colony defense against predator attack. Guard bees would find it easier to protect a nest with small nest entrance compared to a larger one. In addition, a smaller entrance also prevents the entry of large predators such as lizards, ikard, mice, or birds. Smaller bee pests, like bee lice, hive beetles, mites, ants, birds, rodents and mammals can occasionally become serious pests in a particular situation (Gulati & Kaushik 2004).

The average number of entrances per nest *A. cerana* were similar in highland and lowland polyculture plantations. The average number of entrances in highlands was 1.46 and 1.27 in lowlands (Table 1). The highest number of nest entrances were observed on coconut trees (lowland) and on dadap (highland), with 4 four entrances observed in each nest on those trees. These findings did not corroborate the hypothesis that the number of entrances would be minimized in the colder uplands, to maintain nest temperature. Instead, nests found in the highlands, and lowlands had the same number of entrances. In our study, it seems that the number of *A. cerana* nest entrances was largely determined by the presence and number of cavities available on a tree. The number of entrances in nests of the same species of bees in Central Sumatera were observed to be 1-3 (Inoue *et al*. 1990), while *A. mellifera* in wildlife Welder Refuge (San Patricio Country Texas) were 1.15 (Baum *et al.* 2005).

Fluctuations of Nesting Sites Usage. The percentage of trees with cavities used for nesting by *A. cerana* in polyculture plantations increased from March to June 2011, in both the highland and the lowland locations. The highest percentage was found in June (Figure 1). This is due to the increased number of bee colonies observed in the research area, which occurred through swarming and immigration. March is generally the start of dry season after a long rainy season in West Sumatera. March to June was also a blooming season for local plants, which provided abundant food sources for bees. Abundance of food sources would support the production of new queens which in turn leads to swarming. In addition, abundance of food sources in observed locations would attract colonies to come in as immigrants. Wild plants were part of abundance of food sources which could increase honey production, thus the wild plants need to be identified and cultivated to supply food sources for honey production (Mbah & Amao 2010).

The highest decrease in percentage use of trees with cavities in the highlands occured from September to October 2011 (27.77%). This was primarily due to human activities such as use of herbicides in the plantations. The use of herbicides caused four bee colonies to abscond from coffee plantations in the highlands. The use of pesticides in agriculture is well documented as a cause of pollinator declines, especially where spraying time coincides with flowering time (Nicholls & Altieri 2012). Insecticides pose a major threat to pollinators, and pesticide-induced declines in bee abundance are reported yearly in many countries of the world. Technical advances and intensive farming practices have had a negative impact on crop pollination and bee populations (Richards & Kevan 2002). The dangers presented by pesticides, especially insecticides, to pollinators are well documented and understood, especially with regard to the honey bee.

The decreased percentage use of tree cavities in the lowlands occurred later than in the highlands, mostly from November to December 2011 (26.32%). Environmental factors such as high rainfall (853.2 mm Hg) is the dominant cause of decreased use of tree cavities for nesting by honey bees. The high rain caused the cavities to be soaked that they could not be used by honey bees. Climate change has had negative effects on other stages in the life cycle of pollinators, including the larval and migratory stages (Chagnon 2008). When environmental conditions deteriorate, bees stop brood-rearing and prepare to abscond. All bees, along with their queens, migrate to an alternative seasonal nesting site (Woyke *et al.* 2012).

The lowest proportion of available tree cavities were used for nesting in December 2011 and January 2012 in both highlands and lowlands (Figure 1). This due to seasonal abscondment (McGlynn 2012) which is common characteristic of all tropical honey bees (Ruttner 1988). An exiting colony merely flies away from its previous nest to a new nest location. In India, Nepal, and Bhutan, the migratory open-air nesting *Apis dorsata* and *Apis laboriosa* honeybees migrate at least twice a year. After all of the brood have emerged, the entire population of bees in such colonies abscond during the swarming period. Thus, data on nest abandonment are encompassed within our results for total bee out-swarming. The swarms do not migrate directly to the seasonal alternative nesting sites, but establish new colonies in the surrounding nearby areas. After environmental conditions deteriorate, all the bees with their queens abscond and migrate to the alternate seasonal nesting sites. The next season, the swarms do not return to their original reproductive natal sites, but to those sites they occupied most recently, from which they absconded (Woyke *et al*. 2012).

Other factors were in play during the months where percentage of tree cavities used for nesting was at its lowest. Specifically, there was significant disruption by wax moths, *Galeria mellonella*, and ants (personal observation). Gulati and Kaushikm (2004) reported that honeybee enemies are among the most important of several limiting factors for honeybee nesting. Wax moths and wasps cause heavy losses to beekeepers throughout the world, constitute a vexing problem for beekeepers and wild honey bee colonies around the globe (Ellis *et al*. 2013). Ants are not usually serious pests in honeybee colonies. Ants are typically found between the inner and outer layers of the hive, and in pollen traps. The small red household ant, *Dorylus labiatus* and small black ants, *Monomorium indicum*, *M. destructor* are some of the ant species which visit bee colony to seek food (Gulati & Kaushik 2004).

In the lowland polycuture plantations, a greater proportion of cavities were reused for nesting after previous abscondment, than in the highland plantations. One cavity was used repeatedly, apparently because of the limited number of cavities available. The presence of comb debris in cavities and availability of food resources near the nest function as stimuli to encourage the scout bees for renesting. With limited cavities available, many cavities were reused by next colony. During our study we did not mark and track specific colonies, so we were not able to discern whether the comb debris in cavities became stimuli for the same or different scout bees colonies. The goal of our study was to determine whether food resource abundance plays a role in the use and reuse of cavities for nesting by *A. cerana*. The role of remnant nest combs and the stimulation of scout bees in nest selection is outside the scope of our study and should be the subject of future research.

The presence of honey bees in coffee plantations could increase coffee fruit production (Klein *et al*. 2003; Vergara & Badano 2008). In the highlands of West Sumatera, people usually plant coffee using dadap (*E. variegata*) trees as protective plants. Our study showed that *A. cerana* used dadap trees as nesting sites and food resource. Whether there is any correlation between the presence of dadap trees and the increased production of coffee fruits due to increased presence of honeybees needs to be resolved in future study.

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