Populationfluctuation of *Apis cerana* Fabr. (Hymenoptera: Apidae) Colonies on Policulture Plantations in West Sumatra

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Abstract: ***Population fluctuation ofApis cerana Fabr. (Hymenoptera: Apidae) colonies on policulture plantations was studied in West Sumatera, Indonesia.Census methode was carried out to determinespecies of plants used as nesting sites and colony population. Data were taken from low (altitude < 100 meter) and high (altitude >1000 meter) lands, each withfive plantations (each 10.000 m^2 width).Multiple regression was used to analiseddata on population density ofcoloniesand their relations with weather factors. Results indicated that 18 species of plants in 15 familieswere used as nesting sites. Colonypopulations of Apis ceranainlowlands were higher(4,06 ± 0,56 colonies per 10.000 m^2) than the one in high lands (3,17 ± 0,54colonies per 10.000 m^2).Colony population densities fluctuated based on ctime, the highest population was found in Juneand the lowest was in December and Januaryy. Weather factors showed more influence on colony population densities in highlands (R^2= 95,03%)compared to lowlands (R^2= 54,97%).***

Keywords: Honeybee,nesting diversity, altitude, colony fluctuation

1. Introduction

Apis cerana is honey bee originated from Asia distributed worldwide [1]. It has some superiorities, i.e, as good polinators for coconut and coffea plants [2,3],easy to be reared [4] and it has organized self defence strategy from hymenopteran predators[5, 6]. This species of bee is still widely distributed in diffrent habitats in West Sumatera[7] with the highest colony population density 22 nests/km^2 [8].

Polyculture plantations play important role in conserving the population of honey bee.They function as a habitat to carry out activities like making nests, foraging for food, and colony multiplications. On the other sides the presence of honey bee is very important to increase plant productions, mainly on *Coffea canephora* and *Coffea arabica*[3], apple [9], highbush blueberry (*Vaccinium corymbosum* L.) [10], and palm [11]. Due their importance, some studies on ecology, spatial distribution, diversity, and conservation of this bee and other bees have been gaining pace in recent years [8, 12, 13, 14, 15,16].

Population colony density of different species of honey beevarries in every habitat [8, 12, 17].The densityis affected byvarious factors such as queen productifity[18],colony migrations[19, 20], food resources[21, 22, 23, 24, 25], pests and diseases [26, 27, 28, 29,30, 31, 33] and environment factors [33].

Polyculture plantations is one of habitats of *Apis cerana*inWest Sumatera[7]. The width of polyculture plantations is the third (5,93%) out of total land esage in West Sumatera[34]. Some good points of polyculture plantations are the presence of various species of plants, various planting dates, low frequency of pesticide applications, very scarce rotation of major plants, and plantations are distributed in all altitutes. Plants diversity and weather factors at different altitutes affect the density of *A. cerana*colony population.This paper reports the diversity of nesting sites,densityand fluctuation ofcolony population of *A. cerana*and the impact of weatherfactors,in tropical polyculture plantations inWest Sumatera, Indonesia

2. Materials and Methods

2.1. Study Sites

The research was conducted inpolyculture plantations inWest Sumatra, from March 2011-March 2012.Observations were conducted in low and highlands (Fig. 1). The lowlands site was in Nagari Parik

Malintang Kec. 2x 11 Enam Lingkung, Kabupaten Padang Pariaman, astronomical position at $100^0 27'$ 00" east longitude and $0^0 50'30"$ south latitude, altitute< 100 m a.s.l., dominatedwith*Durio zibetinus*, *Spondias pinnata* Kurz , *Areca catecu*, *Cocos nucifera* dan *Theobroma cacao*.Average temperature was 25,7^{0}C andmonthly rain fall was 368,4 mm. The high landsobservation was conducted in Nagari Andaleh Kecamatan Batipuh, Kabupaten Tanah Datar, astronomical positionat $100^0 22'$ " east longitude and $0^0 23'38"$ south latitude, altitute>1000 m a.s.l., dominated with*Coffea canephora*and*Cinnamomum burmanii*. Average daily temperature 25,0^{0}C and monthly rain fall was 549,00 mm [34]. The dominant weed species in highlands were *Bidens pilosa*and *Galiansoga parviflora*, while the ones in lowlands were *Cynodon dactylon*and*Mimosa pudica.*

2.2. Colonies Census

The data of *A. cerana*colonies were taken through census.Site criteria were:minimum width 10.000 m^2, there were trees with minimum stem diameter > 20 cm., dominatedwith cultured plants for fruit productions purpose, at least there was minimumone colony of *A. cerana*found.The plot size for every sample point was 100 x 100 m. There were 10 plots, 5 for each lowlands and highlands.All trees with diameter >10 cm were observed. Parameters observedwereplace and species of plants used for nesting sites andnumber of colonies per plot. The species of plants for nesting were identified in Laboratory Plants Taxonomy Andalas University, Padang.

2.3. Colony fluctuation observations

The**o**bservationwas conducted throughcensus. The number of colonies of *A. cerana*was counted once in a month for 13 month periode. Parametersmeasured werecolony numbers (old and new nests) andabsconding colonies.Secondary data like rain fall ($x_{1,}$ mmHg), relative humidity ($x_{2,}$ %), temperature ($x_{3,}$ ^{0}C), wind flow ($x_{4,}$ knot) and photoperiode (x_5, %) were obtained fromAgency for Meterology, Climatology and Geophysics,station of Padang Panjang (highland) and Sicincin Padang Pariaman (lowland).

2.4. Data Analisys

Colonies fluctuations were analised with Mann-Withe test.Correlation between colony population density (Y) with all weather factors, rain fall ($x_{1,}$ mmHg), relative humidity ($x_{2,}$ %), temperature ($x_{3,}$ ^{0}C), wind flow ($x_{4,}$ knot) and photoperiode (x_5, %)is presented in Equation 1. Degree of correlation is expressed as koefisien determination(R) with a rank 0-100 % [35].

$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$................(Equation 1)

3. Result

3.1. Nesting Sites Diversity

Nesting sites of *A. cerana*were found in 18 species of plants (15 families) inpolyculture plantations in West Sumatera. Fifty five colonies of*A. cerana*were found in tree cavities,12 coloniesin*Erythria variegata* (Dadap), 11 coloniesin*Cocos nucifera* (coconut), 6coloniesin*Areca catechu* (Pinang), 4coloniesin*Toona sureni* (Surian), 3coloniesin*Peronema canescens* (Sungkai), 2coloniesin each of the following plants,*Durio zibethinus* (Durian), *E. acuminata* (Jirak), *G. mangostana* (Manggis),*Phithocellobium lithosperma* (Jengkol), *Spondias lutea* (Kedondong), and1colonyineach of the following plants, *Arthrocarpus* sp. (Sukun), *Caryota rumphiana* (Rumbia), *Coffea robusta* (Kopi), *S. reticulata* (Kepundung hutan), *Lansium domesticum* (Duku), *Musca* sp. (Pisang), *Syzygium aqueum*(jambu air) and*Toxicodendronradicans* (Jelatang). Nests were also found in house wall, rat holow, used chair andelectric pool made of cement. There was only one nest found on each of above sites. The highest number of nests were found in *E. variegata* (highland) and*C. nucifera* (lowland).

2.2. Colony Population Density

Average colony population density of *A. cerana* in polyculture plantations in West Sumatera (4,06 ± 0.65colonies per 10.000 m^2). Averagecolony population densityinlowland polyculture plantations was higher(4,06 ± 0,56 colony per 10.000 m^2) than the one in highlands (3,17 ± 0,54colonies per 10.000 m^2).The highest colony population density inlowlands was found in June(5,2 ± 0,84 colonies per 10.000 m^2) and inhighlands in May(4,4 ± 0,55 colonies per 10.000 m^2) (Fig. 2a).

Average density colony population *A. cerana*in polyculture plantations in West Sumatera fluctuated throghout the year(Fig. 2). Colony population density in highlands increasedfrom 4.0 ± 0.71 colonies in April to 4.4 ± 0.55colonies per 10.000 m^2 in June andin lowlands inreased from4.6 ± 0.55 colonies in April to 5.2 ± 0.84colonies per 10.000 m^2 in June.

The significant fluctuation of colony population densityof *A. cerana* in polyculture plantations in highlands (Fig 2a) (p= 0.01) occured from October 2011 (2.6 ± 1.67 colonies per 10.000 m^2) to November 2011 (2.2 ± 1.30 colonies per 10.000 m^2) and March 2012 (2.2 ± 0.84 colonies per 10.000 m^2).Significant fluctuation of colony population density in lowlands (Fig. 2b) (p= 0.01) occured from November (3.8 ± 1.30 colonies per 10.000 m^2) to December 2011 (2.8 ± 0.45 colonies per 10.000 m^2) and January 2012 (2.8 ± 0.84 colonies per 10.000 m^2).

3.3. Correlation between colony population density and weather factors

There was highly significant correlation between colony population density of *A. cerana* and weather factors in highland polyculture plantations (Equation 2) and loose correlation in lowlands (Equation 3). Interaction ofweather factors inhigh lands (R^2= 95.03%) determined*A. cerana* colonies density more than the one in lowlands (R^2= 54.97%). The difference of determination coeffecient between the two locations due to different altitutes. The highlands were located >1000 meter a.s.l. and low lands < 100 meter a.s.l. Different altitute caused different weather conditions in the two locations (Table 1).

$Y= 47.814 + 0.007x_1–0.664x_2 + 1.425 x_3–4.365x_4 +0.236 x_5$($R^2$= 0.95).......... (Equation 2)
$Y = 87.807 – 0.0005x_1 + 1.2776x_2 + 1.845x_3 – 1.360x_4 – 0.044x_5$($R^2$= 0.356) .... (Equation 3)

4. Discussion

The diversity of plant species used as nesting sites of *A. cerana*inpolyculture plantations inWest Sumaterawas higher compared to the past finding either of the same species in Padang Sarai, Pasir Jambak and Bungo Pasang Padang [8] or different species of bee in Kalimantan Selatan [36].The use of *C. nucifera*cavity as nesting sites was also reported by Inoue *et al*. [8]. *Toxicodendron radicans* dan *P. lobatum*were also used as nesting site of *A. koschevnikovi*[36].

The highest number of*A. cerana*nests was found in *Erythria variegata, i.e.*12 out of 24 nests found in high lands. The preference of *A. cerana* to place nests in above tree due to the availability of a lot of cavitieson the trees and due to the abundance of the trees where food resources was available. *Erythriavariegata*is planted as a shading plants for young coffea trees but the shading plants are let to grow naturally until dead. *Erythria variegata* has soft stem tissues easily destroy that produce cavities.According to Baum *et al.* [12] colony aggregations probably resulted from the distribution of resources, especially cavities.

The highest number of *A. cerana*nests found in *Cocos nucifera*due to their dominant number of trees found inpolyculture plantations inlow lands and the have relatively more cavities. The outer part structure of *C. nucifera* is hard while inner parts is soft. This condition fasilitates the formation of cavities well protected by the hard outer parts. Othe reason is *C. nucifera*also produces pollen and nectar thruoghout the year. Inoue *et al*. [8] also found 13 nests of*A. cerana indica* in tree cavity in Central Sumatera. Vaudo *et al*. [16] reported colonies nesting on the reserves may occur in greater densities than those nesting on livestock farms. Donaldson-Matasci & Dornhaus[37] also reported two important characteristics of honey bees' ancestral ecological habitat that could have selected for their unique ability to symbolically communicate resource location. Honey-bees of the genus *Apis* have been recorded as potential pollinators in a few cases such as *Serenoa repens* and in cultivated palms such as *Cocos nucifera*[38].

4.1 Colony population density of*A. cerana*

Averagecolony population density of*A. cerana*inpolyculture plantations inWest Sumatera (4,06 ± 0.65 colonies per 10.000 m^2). This number was higher than the one found by Inoue *et al*. [8] (1990) which was 22 colonies of *A. cerana indica* per km^2 or equal to 2.2 colonies per 10.000 m^2. Baum *et al*. [12] found 12.5 colonies of *A. mellifera*per km^2 inor equal to 1.25 colonies per 10.000 m^2 in coastal prairie landscape. Onhorticultural plants in Tropcal fruit research centre in southeast Thailand it was found2 colonies*A. dorsata*, 5 colonies*A. cerana*, 12 colonies*A. andreniformis* dan 12 colonies*A. florea* per km^2or equal to 0.2 colonies *A. dorsata* , 0.5 colonies *A. cerana*, 1. 2 colonies *A. andreniformis,* 1.2 colonies *A. florea* per 10.000 m^2[17].

Averagecolony populationdensityinlowland polyculture plantations was higherthan the one inhighlands.The higher colonydensityinlowlandswas because of supporting weatherfactors (Table 1). According to Conte and Navajas [33] environmental changes have a direct influence on honey bee development.Chagnon [39] reported the weather conditions have a direct influence on pollinator flight and an indirect effect on pollen and nectar production by the flowers selected by the pollinators for foraging. Temperature constitutes an important factor potentially limiting insect flight and pollen availability, but light intensity, rain and relative humidity also play a role.

Average densitycolony population*A. cerana*in polyculture plantations inWest Sumaterafluctuatedthroghout the year(Fig. 2). Colony population density in highlandsand lowlands increasedfromin April to in June. The increase of colony populationuntil June was assumed that some colonies multiplied in the observed locations.In four months there had bees colonies formed gyna. When a gyna emerged in a colony, thus the colony would swam. Time needed by a colony to form gyna was aroun one month. According to Rhodes *et al*. [40] the survival of honey bee *Apis mellifera* queens to 14 days and 15 weeks after introduction into an established bee colony increases with increasing age of the queen at introduction. Survival rates increased strongly to high levels for queen bees introduced between 7 and 24 days of age and at a slower rate for queens introduced at ages up to 35 days.

The increase of *A. cerana*colony numbers inpolyculture plantations could also due to immigration. During observation periode threecolonies of*A. cerana*was found to moveto observation areas in May. Migration colonywas aimed at looking for new nest sites supported by abundance food sources. The colonyrested on branch or parts of tree waiting for the signal from the guard bees.If guard beesfound suitable cavities they would move to new nests. According to Ruttner [1] seasonal migration of bee colonies is a common characteristic of all tropical honey bee. Woyke *et al*. [20] reported after environmental conditions deteriorate, all the bees with their queens abscond and migrate to alternate seasonal nesting sites. The next season, the swarms do not return to their original reproductive natal sites, but to those sites they occupied the previous season lately, where from they absconded.

The fluctuation of daily temperature followed the weather changes in tropical area.From March to August it is a dry season in tropical areas and the changes are also followed by the increase of daily temperature in the observation areas. The increase in average daily temperature has positive impact on the availability of food either quantity or quality. Quantitatively the plants having blooming periode in dry season would produce more flowers in certain period. Qualitatively the temperature increase would increase the nectar sugar concentration that produce better nectar quality. As a result it would be preferred by bees. Bee colonies would take advantage from the available food sources to increase the qeen productivity and to swarm.According to Kjøhl *et al*. [41] Weather change can be simulated by distributing experimental plots along natural climatic gradients or by creating different climatic conditions in artificial environments such as laboratory or greenhouse experiment. Le Conte dan Navajas [33] reported tropical weathers may evolve towards more distinct seasons with dry periods. In this case, Asian honey bees would need to rapidly step up their honey-harvesting strategy to amass sufficient stores to survive periods without flowers.

The significant fluctuation of colony population densityof *A. cerana*inPolyculture plantations inhigh lands (Fig. 2a)occuredfrom October to November 2011 and March 2012. The significant decrease of average colony population density inhigh landsdue to various things such as man activities, weather condition and problem of pests and diseases.From September until October 2011 four colonies were found absconding because of herbicide apllication inhigh land polyculture plantations. Arzone [42] reported the use of commercial herbicides as recommended by spraying the bees can cause death after 12 hours of use. High toxicity of insecticides besides generally harmfull and also directs selective insect emergence.

Significant fluctuation ofcolony population density inlow lands (Fig. 2b) occuredfrom November to December 2011 and January 2012. Decrease colony population densityin low landsdue to man activities likeburning treecolonies. Kremen *et al.*[43] reported human impacts have modified the landscape through fragmentation, degradation and destruction of natural habitats and the creation of new anthropogenic habitats. Changes in land-use and landscape structure influence pollinators, target plants and their interactions at individual, population and community scales.

Other factordecreasingcolony populationof *A. cerana*in polyculture plantations in December 2011 and January 2012 (Fig. 2) was the presence ofpest, wax moths andants. According to Gulati and Kaushik[26] among several limiting factors, honeybee enemies constitute a major factor. Wax moths and wasps cause heavy losses to beekeepers throughout the world. Ellis *et al*. [32] reported wax moths remain a vexing problem for beekeepers and honey bee colonies around the globe. According to Gulati and Kaushik [26] ants are not usually serious pests in honeybee colonies. Ants are typically found between the inner and outer covers of the hive and in pollen traps. The small red household ant, *Doryluslabiatus* and small black ants, *Monomorium indicum, M. destructor* are some of the other ant species which visit bee colony for food purposes.

4.2 Correlation betweencolony populationdensity andweather factors

Wind was one of weather factors which highly significant influenced and had negative impact on colony population density in highlands(Table 1 andEquation 1). Strong wind broke the branches or the plants mainly the dead ones that caused the colonies to abscond. During observation there were 4 dead trees used for nest inhigh lands andone treein low land that were broken by the strong wind. The strong wind also affected nests directly by shaking them thus it caused the colony to abscond. According to Chagnon [39] a strong wind will also make the flowers sway on the plant rendering access difficult for the pollinators. A wind force greater than six on the Beaufort scale interferes with bumble bee flight.

Besides affecting the nest sites, wind also had negative impact on the activity of *A. cerana* forager and the availability of pollen sources inhigh lands. The strong could chage the flight direction of bees that they could not come back to their nests. The wind caused pollen to dry out and easily blown by wind. The disturbance on forager activity caused direct impact on the amount of stroge available in nests. The short supply of stroke caused the decrease on queen productivity.The limited amount of stroke in nests was one of the cause for colonies to ascond. The same results were reported by Woyke *et al*. [20] on*Apis dorsata* and *Apis laborisa* honey bees in India, Nepal and Bhutan.

Interaction of weather factorsinlow land polyculture plantations determined densitypopulation colony *A. cerana*as 54,97% (Table1 andEquation 3). Besides weather factors other factor affecting colony population density of *A. cerana* was pest such as wax moths *G. mellonella*and ants and human activity. Three colonieswere attacked by pest, wax moths,*Galeria mellonella*and onecolonywas attacked by ants that caused the colony to abscond. According to Gulati and Kaushik[26] among several limiting factors, honeybee enemies constitute a major factor. Wax moths and wasps cause heavy losses to beekeepers throughout the world. Ellis *et al*. [32] reported wax moths remain a vexing problem for beekeepers and honey bee colonies around the globe. According to Gulati and Kaushik [26] ants are not usually serious pests in honeybee colonies. Ants are typically found between the inner and outer covers of the hive and in pollen traps. The small red household ant, *Doryluslabiatus* and small black ants, *Monomorium indicum, M. destructor* are some of the other ant species which visit bee colony for food purposes.

5. Conclusion

Eighteen plant species (15 families) and four other nonplant sites were found to be used by *A. cerana* to place their nests in West Sumatera.Colony population density of *A. cerana*fluctuated throghout the year with an average was 4,06 ± 0.65colonies per 10.000 m^2. The highest colony population density was found in June and lowest was in December and

January. Interaction of weather factors determined colony population density 95.03% in highlands and 54.97% in lowlands

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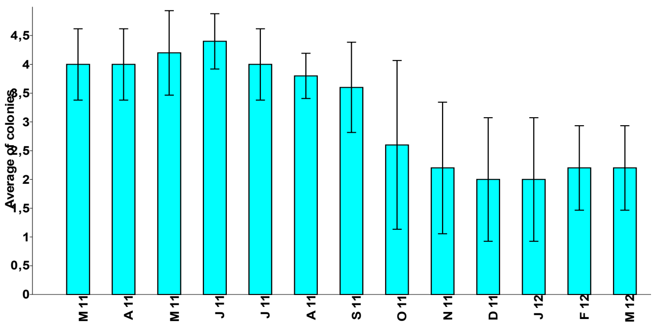
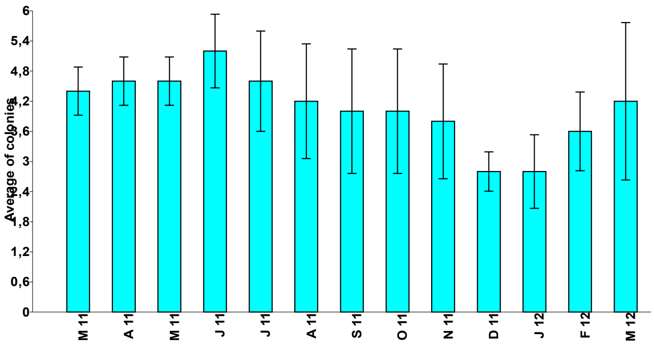


(a)



(b)

Figure 2: Fluctuation of colony populationdensity of *A. cerana*inpolyculture plantations in West Sumatera

a.Highland b.Lowland. M-M= times observation, started from March 2011 to March 2012.

Table 1: Multiple regression analysis on colony population densityand weather factors inpolyculture plantations inWest Sumatera

Variable	*DB*	*Ft (0,05)*	*Ft (0,01)*	*Highlands*	*Lowlands*
Regression	5	2,6	3,86	26,786	0,774
x1	1	4,24	7,77	4,473*	0,004 ^{ns}
x2	1	4,24	7,77	6,040*	2,504 ^{ns}
x3	1	4,24	7,77	1,253 ^{ns}	0,536 ^{ns}
x4	1	4,24	7,77	8,885**	0,021 ^{ns}
x5	1	4,24	7,77	4,170^{ns}	0,153^{ns}
Residu	7	-	-	-	-
Total	12	-	-	-	-
R	-	-	-	0,950	0,356

x_1= rainfall (mmhg), x_2= humidity (%), x_3= temperatur (^{0}c), x_4= wind (knot), x_5= photoperiode (%). ^{ns} = nonsignificant in 5% (α= 0,05) or 1% (α= 0,01).*= significant differen 5% (α= 0,05) and **= significant difference on level of confident 1% (α= 0,01).

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