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The Potency of Honey Bee Forage on Beekeeping of *Apis cerana* F. in Wanagama Education Forest, Gunungkidul, Yogyakarta

Potensi Tanaman Sumber Pakan pada Budidaya Lebah Madu (Apis cerana F.) Hutan Pendidikan Wanagama, Gunungkidul, Yogyakarta

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RESEARCH ARTICLE

ABSTRACT

Apis cerana became a common species for beekeeping activities in Indonesia. The sustainability of beekeeping activities depended on the availability of feeds in forests with various plant species, which served as honey bee forage. Therefore, this study aimed to determine the forage plant diversity for A. cerana beekeeping in Wanagama Education Forest, Gunungkidul, from November 2018 to April 2019. Data collection was done through the inventory of trees and understorey plant species around the apiary locations to measure their abundance, flowering conditions, and the number of honey bees on the flower. The analysis indicated that 20 species (10 families) of trees and 60 species (19 families) of understorey plants had potential forage. The observation revealed that honey bees collected nectar and pollen from seven species of trees and 12 species of understorey plants. The highest visitation intensity was in the morning from two trees (Acacia mangium and Eucalyptus grandis) and three understoreys (Oxalis barrelieri, Passiflora suberosa, and Zea mays). Information on potential plant species for honey bee forage could improve beekeeping development in Wanagama Education Forest.

INTISARI

Budidaya lebah madu di Indonesia dilakukan dengan jenis Apis cerana. Faktor penting penentu kelestarian budidaya lebah madu adalah ketersediaan pakan yang salah satu sumbernya dapat berasal dari hutan yang tersusun atas berbagai jenis tumbuhan. Penelitian bertujuan untuk mengetahui keragaman jenis tanaman sumber pakan bagi budidaya lebah madu A. cerana di Hutan Pendidikan Wanagama, Gunungkidul dari bulan November 2018 sampai dengan April 2019. Pengumpulan data dilakukan melalui inventarisasi jenis tanaman berkayu dan tumbuhan bawah di sekitar lokasi apiari untuk mengukur kelimpahan jenis tanaman, kondisi pembungaan, dan jumlah lebah madu yang mengunjungi bunga. Hasil penelitian menunjukkan bahwa di sekitar apiari ditemukan 20 jenis (10 famili) tanaman berkayu dan 60 jenis (19 famili) tumbuhan bawah yang berpotensi sebagai sumber pakan lebah madu. Lebah madu mengumpulkan nektar dan polen dari 7 jenis tanaman berkayu dan 12 jenis tumbuhan bawah. Intensitas kunjungan lebah madu tertinggi di pagi hari terutama pada tanaman kayu Acacia mangium dan Eucalyptus grandis, serta tumbuhan bawah Oxalis barrelieri, Passiflora suberosa, dan Zea mays. Informasi jenis tanaman potensial sumber pakan dapat dijadikan sebagai salah satu rujukan dalam pengembangan budidaya lebah madu di Hutan Pendidikan Wanagama.

KATA KUNCI
Apis cerana, budidaya lebah, hutan, tanaman pakan

Introduction

Beekeeping (apiculture) is one of the non-timber forest products (NTFPs) production activities using planted trees as a source of honey bee forage. Apart from producing wood, this system also produces honey, which has high economic value. Traditionally, beekeepers in Indonesian archipelagos use the *Apis cerana* species (Schouten et al. 2019) in local honey production (Engel 2012; Schouten et al. 2019). Although its honey production is lower than *A. mellifera, A. cerana* is more resistant to pathogens and varroa destructor mites (Koetz 2013; Lin et al. 2016). Pudasaini (2018) stated that beekeeping with the *A. mellifera* species requires initial capital investment and lower colony management costs than *A. mellifera*. The beekeeping of *A. cerana* in Indonesia is a small-medium scale business and stationary beekeeping in an area without moving the bee hives/boxes. This practice is common in rural areas, forests, and surrounding regions. Agricultures, plantations, and forest areas provide forage sources for honey bees from various types of plants. Forests consist of trees and shrubs as sources of feed (Mensah et al. 2017) which are crucial to sustaining beekeeping practice (Priya & Raichal 2018). Schouten et al. (2019) stated that the scarcity of feed became the main factor for the absconding of *A. cerana* colonies, while the abundance of feed would increase honey production (Nugroho & Soesilohadi 2014).

Plants produce pollen and nectar, which provide nutrition for the honey bee colonies. Pollen is a source of protein, while nectar becomes the energy source. Furthermore, they are vital for larvae development and adult honey bees. Bees become natural pollinators for plants while collecting pollen and nectar (Koetz 2013). There are three categories of forage sources, nectar, pollen, and nectar-pollen producing plants (Bhalchandra et al. 2014). Some flowering plants are not the source of forage. Hence information on the forage plants is crucial to be studied as a reference in beekeeping.

Wanagama Education Forest is an area that has been practicing beekeeping for an extended period. Communities in Banaran Village, Playen, Gunungkidul are members of the Sumber Rejeki honey bee forest farmer group (KTH) and have used the area for *A. cerana* stationary beekeeping. The availability of various plants as forage sources around the apiary is substantial to sustain the beekeeping practice. Therefore, this study aims to determine the diversity of plant species that potentially become the forage source for *A. cerana* in Wanagama Education Forest.

Materials and Methods

Time and Location

This study was conducted at three apiary locations from November 2018 to April 2019 in Wanagama Education Forest, Gunungkidul (7°54' 0.84" S, 110°32' 7.98" E). Wanagama Education Forest was a plantation forest that experienced ecosystem succession since its establishment in 1964. Oyo River flowed over its hilly landscape at 120 meters above sea level. The forest soil was formed from limestone, and the dominant soil types were Vertisol, Rendzina, and the Mediterranean, with a pH that ranged from 6.5 to 7.5. Most of the area was composed of very shallow solum of <10-20 cm depth, and only several areas had deep solum of >70 cm (Supriyo 2004). Schmidt and Ferguson revealed that the forest area was in a type C climate, with an average rainfall of 2,000-2,200 mm/year, with the highest average rainfall in December-February. The rainy season was from October to April, while the dry season lasted for four to six months every year. The air temperature was from 23.2 to 32.4°C with an average of 27.7°C. The relative humidity was between 80-90%, with the highest in January-March and the lowest in August-September (Ernawati 2016).

Research Stages

Sampling Design

The sample plots were purposively placed based on the preference of the flying radius of *A. cerana* from the nest, which was 200-500 m (Koetz 2013) and the flight directions were east, west, north, and south. Each apiary location had nine nested square sample plots with a 150 m distance. The measurement of trees was done in a 20 x 20 m² plot, while the measurement of understorey was in five 1 x 1 m² plots, as shown in Figure 1.

Visit of A. cerana

The observations of *A. cerana* visits on flowering plants were carried out every two weeks for six months. This activity was performed three times in each plot, namely, in the morning (07.00 am-09.00 am), noon (11.00 am-01.00 pm), and afternoon (03.00 pm-05.00 pm). The observation parameters included the types of plants, flowering conditions, number of flowering and non-flowering plants, and the number of *A. cerana* that visited the flowers for approximately five minutes. Furthermore, the type of forage was determined based on the activity of *A. cerana* on the flowers. Bees collecting nectar were honey bees that perched quietly and extended the sucker (proboscis) into the flower or sucked nectar from the extrafloral. Bees collecting pollen were those that moved hyperactively on the flowers and got pollen on their bodies or hind legs (pollen basket) (Pande & Ramkrushna 2018).

Forage Source Identification

This research identified pollen or nectar-producing plants using the method proposed by Agussalim et al. (2017), which involved observation of the availability of pollen in the anthers of one or two flowers. The pollen could be in the form of flour or powder with a dark yellow to light yellow color. The assessment of nectar availability was carried out by opening the flower crown and observing the presence or absence of nectar in the base. A literature study supported the identification if the plant did not flower during the observation period.

Data Analysis

Data on plants that were potential sources of forage for *A. cerana* were grouped based on their species, family, flowering conditions (flowering or non-flowering), and status of forage sources (nectar,
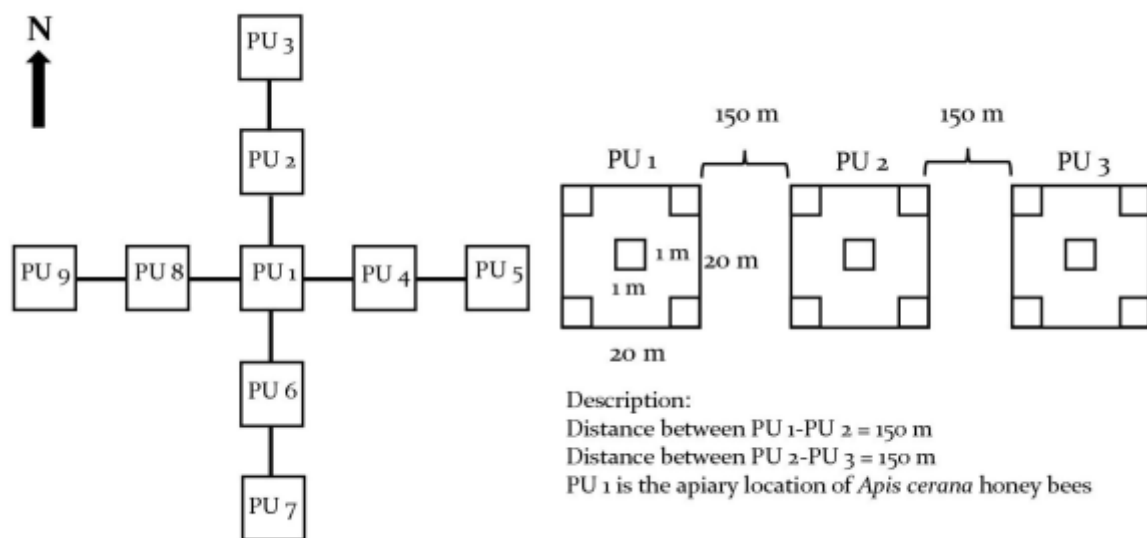
Figure 1. The plot design for the inventory of woody plants and understorey

pollen, or extrafloral). Ayansola and Davies (2012) suggested three visit intensity categories of *A. cerana* on flowering plants, namely, low frequency (+), when the honey bees visited one to two times the same plant species, moderate (++) for three to four times, and high (+++) for more than five times.

Results and Discussion

Potential Woody Plants Forage

Wanagama Education Forest consisted of different pollen and nectar-producing plants for *A. cerana*. In this study, the inventory covered woody and understorey. This research revealed that within a ±300 m radius around the apiary locations, there were 20 species (10 families), dominated by Myrtaceae (seven species) and Fabaceae (five species). These woody plants had various flowering periods. During the observation, only 50% of the plants (10 species) were flowering. *A. cerana* visited only 70% of the flowering woody plants, consisting of Calophyllaceae (one species), Fabaceae (four species), Myrtaceae (one species), and Rutaceae (one species), as shown in Table 1.

These diverse woody plants in the Wanagama Education Forest became the primary food source for *A. cerana* and provided a more optimal landscape for pollinating insects (Donkersley 2019). Myrtaceae consisted mainly of various eucalyptus obtained from tree breeding programs as research materials. Meanwhile, the Fabaceae consisted of fast-growing species planted at the beginning of the forest development for education, study, and community services. These included *Leucaena leucocephala* and *Gliricidia sepium*.

Fabaceae had the highest number of species visited by *A. cerana,* consisting of *A. auriculiformis, A. mangium, B. purpurea,* and *L. leucocephala.* Other plant species included *C. inophyllum, E. grandis,* and *Z. rhetsa*. These results aligned with similar research

in West Sumatra polyculture plantations that found ten species of Fabaceae as *A. cerana* forage (Jasmi 2017). Plants from the family also dominated as pollen and nectar producers for the honey bee *A. mellifera* in the dry savanna of Bauchi, Nigeria (Dukku et al. 2013). Furthermore, the species from Fabaceae were essential food sources for beekeeping (Taha et al. 2019). However, Mensah et al. (2017) stated that the dominant plants, which served as feed for honey bees in the Limpopo forest, South Africa, were from the Rutaceae and Stilbaceae families. Those results suggested that the difference in location could affect the diversity of plant species as forage. Several factors affect vegetation composition at a specific location, such as environmental conditions, climate, soil type, topography, and time of day.

Honey bees had discrimination behavior through the scent-signaling mechanism of nectar or other insects that had visited the flower. They could also use scent cues to tell when a flower had recently been visited by other insects (Reader et al. 2005). These could be the reason that *A. cerana* did not visit eucalyptus (*M. cajuputi*), sandalwood (*S. album*), and teak (*T. grandis*), although they were flowering during the observation period. Other pollinating insects, such as butterflies, might have visited the sandalwood and teak flowers. Furthermore, honey bees were susceptible to the smell of pollen or abundant nectar (O'Toole, 2013). Hence, they tended to visit the flowers of certain types of plants.

Potential Understorey Forage

The understorey in Wanagama Education Forest consisted of 60 species from 19 families. Poaceae had the highest abundance with 15 species, followed by the Asteraceae family with 11 species. Around 85% of the understorey was flowering from November 2018 to April 2019, consisting of 51 species, as shown in Table 2. The observations revealed that *A. cerana* only visited

Table 1. Family and species, flowering conditions, forage sources, and visits of *A. cerana* worker bees on woody plants in Wanagama Education Forest, Gunungkidul, Yogyakarta from November 2018 to April 2019

Family Local name (scientific name)	Flowering conditions	Forage source	Honey bee visit	Status determination	
				Observation	Reference
Calophyllaceae					
1. Nyamplung (*Calophyllum inophyllum*)	B	P	√	√	
Casuarinaceae					
2. Cemara (*Casuarina junghuhniana*)	TB	P	-	-	Ta
Euphorbiaceae					
3. Kemiri (*Aleurites moluccana*)	TB	N	-	-	Ag
Fabaceae (Leguminosae)					
4. Formis (*Acacia auriculiformis*)	B	N, P	√	√	
5. Mangium (*Acacia mangium*)	B	N, P, EF	√	√	
6. Kupu-kupu (*Bauhinia purpurea*)	B	P	√	√	
7. Gamal (*Gliricidia sepium*)	TB	N	-	-	Wa
8. Lamtoro (*Leucaena leucocephala*)	B	P	√	√	
Lamiaceae					
9. Melina (*Gmelina arborea*)	TB	N	-	-	Si
10. Jati (*Tectona grandis*)	B	N, P	-	√	
Meliaceae					
11. Mahoni (*Swietenia macrophylla*)	TB	N	-	-	Ag
Moraceae					
12. Nangka (*Artocarpus heterophyllus*)	TB	P	-	-	Ag
Myrtaceae					
13. Hue (*Eucalyptus alba*)	TB	N, P	-	-	Si
14. Leda (*Eucalyptus deglupta*)	TB	N, P	-	-	Si
15. Eukaliptus (*Eucalyptus grandis*)	B	N, P	√	√	
16. Eukaliptus (*Eucalyptus pellita*)	TB	N, P	-	-	Si
17. Ampupu (*Eucalyptus urophylla*)	TB	N, P	-	-	Si
18. Kayu putih (*Melaleuca cajuputi*)	B	N, P	-	√	
Rutaceae					
19. Panggal buaya (*Zanthoxylum rhetsa*)	B	N	√	√	
Santalaceae					
20. Cendana (*Santalum album*)	B	N	-	√	

Remarks: B= flowering, TB= not flowering, N= nectar, P= pollen, EF= extrafloral, - = none, √= present. Ag= Agussalim et al. (2017), Si= Singh et al. (2016), Ta= Taha et al. (2019), Wa= Waykar and Baviskar (2015)

12 species or 23.5% of the total flowering understorey, which consisted of seven families, namely Asteraceae (two species), Euphorbiaceae (one species), Fabaceae (one species), Malvaceae (one species), Oxalidaceae (one species), Passifloraceae (one species), and Poaceae (five species).

The Poaceae and Asteraceae families had the highest number of plant species. Similar research on seven habitats for pollinating insects on Mount Slamet slopes found the Asteraceae (11 species) and Fabaceae (three species) as dominant families (Widhiono et al. 2016). The Poaceae family in the Wanagama Education Forest consisted of grasses that were planted or naturally grew, as shown in Table 2. The types of grasses planted by villagers in forest areas for fodders included maize (*Z. mays*), bengal grass (*P. maximum*), *suket pahitan* (*P. purpureum*), and

Brachiaria sp. Asteraceae was composed of understorey species with various flower shapes and colors, which lived wildly on the forest floor. Poaceae had a dispersal mechanism with rhizomes and stolons, while wind and water facilitated their seed dispersal. Asteraceae had high growth power and wind facilitated their seed dispersal. Plants from these families could grow and spread quickly (Purnomo et al. 2016).

The *A. cerana* visited five understorey species from the Poaceae family and two plant species from the Asteraceae family, as shown in Table 2. The most pollen collected by *Trigona* sp. in Gunungkidul was from Poaceae (Nugroho & Soesilohadi 2014). Members of Asteraceae generally had attractive flower colors and scents for pollinating insects (Purnomo et al. 2016). Most Asteraceae had small flower sizes with

shades of yellow, purple, and white (Robson 2014).

Understorey species visited by honey bees included *A. hypogaea, A. compressus, Brachiaria* sp., *E. ruderalis, E. heterophylla, I. cylindrica, O. barrelieri, P. suberosa, P. amaura, T. procumbens, W. indica,* and *Z. mays*. Peanut (*A. hypogaea*) and maize (*Z. mays*) were crops that grew under the forest stands as part of intercropping in forest areas. They also had short-term and seasonal flowering. Other understorey plants were wild or grew naturally and became the forage during the peanut and maize off-seasons. Widhiono and Sudiana (2015) stated that 24 wild plant species had a role in 10 types of pollinating insect conservation from the order Hymenoptera. These plants significantly contributed to the availability of food sources for the sustainability of beekeeping (Pande & Ramkrushna 2018). The abundance of

understorey species was helpful as forage for *A. cerana*, mainly during the off-season or short of food sources (famine).

Visit Frequency of *A. cerana*

A. cerana visited woody plants and understorey flowers to collect pollen, nectar, or extrafloral nectar. Within the woody plants, three species produced pollen, one species produced nectar, two species produced pollen and nectar, and one species produced pollen and extrafloral nectar. *A. cerana* visited ten types of pollen-producing and only two types of pollen and nectar-producing understorey flowers. The woody plants visited by honey bees in the morning were seven species, in the noon were five species, and in the afternoon were 11 species. Meanwhile, the honey bees visited 11 species in the morning, seven species in

Table 2. Family and species, flowering conditions, food sources, and visits of *A. cerana* worker bees on understorey in Wanagama Education Forest, Gunungkidul, Yogyakarta during November 2018-April 2019

Family	Flowering conditions	Forage source	Honey bee visit	Status determination	
Local name (scientific name)				Observation	Reference
Apocynaceae					
1. Biduri (*Calotropis gigantea*)	TB	N, P	-	-	Ab
Asteraceae					
2. Bandotan (*Ageratum conyzoides*)	B	N, P	-	√	
3. Ajeran (*Bidens pilosa*)	B	P	-	√	
4. Sembung (*Blumea lacera*)	TB	N, P	-	-	Pa
5. Buyung (*Cyanthillium cinereum*)	B	N	-	√	
6. Tapak liman (*Elephanthus scaber*)	TB	N, P	-	-	Ja
7. Babandotan (*Eleutheranthera ruderalis*)	B	P	√	√	
8. Temu wiyang (*Emilia sonchifolia*)	B	N	-	√	
9. Kerinyu (*Eupatorium odoratum*)	TB	N, P	-	-	Ab
10. Porosa (*Porophyllum ruderale*)	B	P	-	√	
11. Serunen (*Synedrella nodiflora*)	B	N, P	-	√	
12. Sidawala (*Tridax procumbens*)	B	N, P	√	√	
Colchicaceae					
13. Kembang sungsang (*Gloriosa superba*)	B	N	-	√	
Convolvulaceae					
14. Injen (*Ipomoea obscura*)	B	N	-	√	
15. Anggur bel (*Ipomoea triloba*)	B	N	-	√	
Cyperaceae					
16. Rumput belulang (*Fimbristylis* sp.)	B	P	-	√	
17. Rambang (*Scleria levis*)	B	P	-	√	
Euphorbiaceae					
18. *Kate mas* (*Euphorbia heterophylla*)	B	N, P	√	√	
19. Petikan kebo (*Euphorbia hirta*)	B	N, P	-	√	
20. Ketela pohon (*Manihot utilissima*)	TB	N, P	-	-	Ag
Fabaceae					
21. Anjang (*Aeschynomene americana*)	B	P	-	√	
22. Kacang tanah (*Arachis hypogaea*)	B	N, P	√	√	
23. Kacangan (*Centrosema pubescens*)	B	N	-	√	
24. Gatak (*Flemingia* sp.)	TB	N, P	-	-	Ri
25. Jukut borang (*Mimosa diplotricha*)	B	N, P	-	√	

Family Local name (scientific name)	Flowering conditions	Forage source	Honey bee visit	Status determination	
				Observation	Reference
26. *Putri malu* (*Mimosa pudica*)	B	N, P	-	√	
27. Ekor tupai (*Uraria lagopodoides*)	B	P	-	√	
Lamiaceae					
28. Hiptis (*Hyptis capitata*)	B	N	-	√	
29. Gringsingan (*Hyptis suaveolens*)	B	N	-	√	
Linderniaceae					
30. Pimpernel (*Lindernia crustacea*)	B	N, P	-	√	
Loganiaceae					
31. Kemangi cina (*Spigelia anthelmia*)	B	N, P	-	√	
Malvaceae					
32. Sidaguri (*Sida rhombifolia*)	B	N, P	-	√	
33. Pulutan (*Urena lobata*)	TB	N, P	-	-	Jas
34. *Sleepy morning* (*Waltheria indica*)	B	N, P	√	√	
Oxalidaceae					
35. Calincing (*Oxalis barrelieri*)	B	P	√	√	
Passifloraceae					
36. Konyal (*Passiflora suberosa*)	B	P	√	√	
Phyllanthaceae					
37. Kanidei (*Bridelia* sp.)	TB	P	-	-	Ja
38. Meniran (*Phyllanthus urinaria*)	B	P	-	√	
Poaceae (Graminae)					
39. Rumput pahit (*Axonopus compressus*)	B	P	√	√	
40. Rumput malela (*Brachiaria* sp.)	B	P	√	√	
41. Grinting (*Cynodon dactylon*)	B	N, P	-	√	
42. *Deertongue (Dichanthelium clandestinum)*	B	P	-	√	
43. Jampang pait (*Digitaria* sp.)	B	N	-	√	
44. Alang-alang (*Imperata cylindrica*)	B	P	√	√	
45. *Jukut kasuran (Isachne* sp.)	B	P	-	√	
46. Rumput jago (*Oplismenus burmanii*)	B	P	-	√	
47. Rumput benggala (*Panicum maximum*)	B	P	-	√	
48. Rumput kerbau (*Paspalum conjugatum*)	B	P	-	√	
49. Rumput gajah (*Pennisetum purpureum*)	TB	P	-	-	Ab
50. Lamuran (*Polytrias amaura*)	B	P	√	√	
51. Rumput jukut (*Rottboellia* sp.)	B	P	-	√	
52. Rumput merak (*Themeda arguens*)	B	P	-	√	
53. Jagung (*Zea mays*)	B	P	√	√	
Rubiaceae					
54. Hirtus (*Mitracarpus hirtus*)	B	N, P	-	√	
55. Rumput kancing (*Spermacoce laevis*)	B	N, P	-	√	
Solanaceae					
56. *Ciplukan (Physalis angulata*)	B	N, P	-	√	
Taccaceae					
57. Gadung tikus (*Tacca palmata*)	B	N	-	√	
Verbenaceae					
58. Tembelekan (*Lantana camara*)	B	N, P	-	√	
59. Jarong (*Stachytarpheta indica*)	B	P	-	√	
60. Pecut kuda (*Stachytarpheta jamaicensis*)	B	P	-	√	

Remarks: B= flowering, TB= not flowering, N= nectar, P= pollen, EF= extrafloral, - = none, √= present. Ab= Abrol (2010), Agussalim et al. (2017), Ja= Jayadi and Susandarini (2020), Jas= Jasmi (2017), Ri= Rijal et al. (2018), Pa= Pande and Ramkrushna (2018)

the noon, and three species of understoreys in the afternoon (see Table 3).

In the morning, *A. cerana* was more active in collecting pollen and nectar. The diversity of visited woody plants (seven species) and understorey (11 species) in the morning was higher than in the noon and afternoon. The *A. cerana* had a high category visiting activity in the morning for understorey (three species), while those of woody plants were in the morning (three species) and afternoon (one species). The intensity of visiting activity depended on the daily feed production. The morning was the time for the highest nectar and pollen production. The best pollination was in the morning because flowers bloomed, and the stigma was very receptive (Abrol 2012). Therefore, the pollinating insects could actively pollinate as the availability of flowering plants in the morning was higher than in the afternoon. *A. cerana*

Table 3. Frequency of visits by *A. cerana* worker bees on woody plants and understorey in Wanagama Education Forest, Gunungkidul, Yogyakarta during November 2018-April 2019

No	Local name	Scientific name	Flower color	Forage source	Visit intensity		
					Morning	Noon	Afternoon
Woody plant							
1	Formis	*Acacia auriculiformis*	yellow	N, P	++	-	-
2	Mangium	*Acacia mangium*	beige	P, EF	+++	++	+++
3	Pohon kupu-kupu	*Bauhinia purpurea*	pink	P	+	-	-
4	Nyamplung	*Calophyllum inophyllum*	white-yellow	P	++	+	-
5	Eukaliptus	*Eucalyptus grandis*	white	N, P	+++	+	++
6	Lamtoro	*Leucaena leucocephala*	white	P	++	+	-
7	Panggal buaya	*Zanthoxylon rhetsa*	white-beige	N	++	+	+
Understorey plant							
1	Kacang tanah	*Arachis hypogaea*	yellow-orange	N, P	++	-	-
2	Rumput pahit	*Axonopus compressus*	pale yellow	P	+	-	-
3	Rumput malela	*Brachiaria sp.*	light yellow	P	+	-	-
4	Babandotan	*Eleutheranthera ruderalis*	yellow-orange	P	++	+	-
5	Kate mas	*Euphorbia heterophylla*	light yellow	P	-	+	-
6	Alang-alang	*Imperata cylindrica*	light yellow	P	+	+	+
7	Calincing	*Oxalis barrelieri*	pink	P	+++	+	-
8	Konyal	*Passiflora suberosa*	light yellow	P	+++	++	+
9	Lamuran	*Polytrias amaura*	dark yellow	P	+	-	-
10	Sidawala	*Tridax procumbens*	white-yellow	N, P	++	++	-
11	*Sleepy-morning*	*Waltheria indica*	light yellow	P	+	-	-
12	Jagung	*Zea mays*	light yellow	P	+++	+	+

Remarks: N= nectar, P= pollen, EF= extrafloral, - = no bees found, + = bees visit one to two times on the same species, ++ = bees visit three to four times on the same plant species, ++ + = bee visits ≥ five times on the same type of plant. Morning (07.00-09.00 am), noon (11.00 am-01.00 pm), afternoon (03.00 pm-05.00 pm).

also preferred plants that produced high concentrations of nectar with brightly colored flowers, such as white, cream, pink, red, and purple (Tatsuno & Osawa 2016).

The bees' activity searching for food was closely related to the plant community and the climatic conditions. The morning environmental conditions were favorable for honey bees foraging activities. Besides, air temperature, relative humidity, and soil conditions also influenced the nectar of each flower (Muniz et al. 2013). The air temperature increases during the day, which could lead to a decrease in nectar secretion and the attractiveness of flowers to insects (Abrol 2012). Wanagama Education Forest had an average air temperature of 26.20-30.16°C, and light intensity of 11.72-39.71 x 10³ lux with 69.60- 86.67% air humidity between 07.00 am and 09.00 am. Similar research in Yunan, China, revealed that *A. cerana* visited flowers at an air temperature of 11.5-41.0°C with 20.7-96.8% relative humidity (Cui & Corlett 2016). The species could adapt to extreme climatic conditions by

continuously searching for food sources (Theisen-Jones & Bienefeld 2016).

Honey bee *A. cerana* visited *A. mangium* frequently because this species had extrafloral nectar produced from the basal part of the leaf stem. The extrafloral nectar fluid had a sugar content of 60% sucrose, 25% glucose, and 15% fructose and was palatable and favored by ants and bees (Zhang et al. 2012). This extrafloral nectar secretion benefited *A. cerana*, particularly during the flower off-season. Various species from the Acacia genus played an essential role as a forage source for honey bees (Kumar & Sharma 2013). Furthermore, *Apis* spp. and *Trigona* were the primary pollinators of *A. mangium* (Hegde et al. 2013).

Eucalyptus species were the sources of nectar and pollen. This plant produced hexose sugar-rich nectar, which made it attractive to honey bees (Nicolson 2011). The *E. grandis* could produce a very high protein (Crude Protein pollen up to >30%) at the beginning of the flowering season, and its value decreased to <20%

at the end of the season (Invernizzi et al. 2011). In Riau, the *Eucalyptus* sp. and *A. mangium* industrial plantations became the food source for *A. cerana, A. mellifera,* and *T. itama* bees (Pribadi 2016). The existence of mangium and eucalyptus species in Wanagama Education Forest played a critical role in supporting the availability of nectar and pollen sources for current and future apiaries.

A. cerana visits were dominated by pollen collection activities from understorey plants. Honey bees harvested pollen from flowers using a mandible. They collected the pollen on the hind legs in the corbicula or pollen basket (O'Toole 2013). They brought the pollen to their hives in the form of pellets in various colors (yellow, dark yellow, or orange) depending on the pollen's original color. Furthermore, pollen from different plant species had different nutritional values for honey bees. Protein content in crops, wild plants, and weeds varies from 10% to 61% (Pamminger et al. 2019).

The *A. cerana* frequently visited pollen-producing understorey species such as *O. barrelieri*, *P. suberosa*, and maize (*Z. mays*). The *O. barrelieri* was an understorey in the oil palm plantation area of Jambi and a source of bee forage (Siregar et al. 2016). The *P. suberosa* was one of the most visited species by pollinating insects from Hymenoptera, Lepidoptera, and Diptera orders to obtain nectar or pollen (Garcia 2008). Duarte et al. (2013) reported that *P. suberosa* plants flowered in the rainy season, and their flowers were visited by bees and ants.

Maize and other understoreys became a potential pollen source for *A. cerana* honey bees. Villagers planted maize as an inter-cropping during the rainy season in the Wanagama Education Forest. Furthermore, maize was also a feed source for honey bees in Patuk (Agussalim et al. 2017) and Nglipar Sub-Districts (Agussalim et al. 2018) in Gunungkidul Regency, as well in South Africa (Johannsmeier 2016).

Maize produced pollen on each male flower stalk, and many honey bees visited the flowers. Therefore, maize under forest stands substantially supported the availability of forage sources for *A. cerana.*

Conclusion

Forage source plants are crucial for the sustainability of beekeeping. There were 20 species (10 families) of woody plants and 60 species (19 families) of understorey plants within around a ±300 m radius of the apiary in the Wanagama Education Forest. The Myrtaceae (seven species) and Fabaceae (five species) families dominated the woody plant species, while Poaceae (15 species) and Asteraceae (11 species) families dominated the understoreys. The woody plants forage for *A. cerana* honey bees included *A. auriculiformis, A. mangium, B. purpurea, C. inophyllum, E. grandis, L. leucocephala,* and *Z. rhetsa.* The *A. cerana* often visited *A. mangium* because it can produce extrafloral nectar from the basal part of the leaf stem. Hence, it could become a feed source all year long. The understorey on the forest floor such as *A. hypogaea, A. compressus, Brachiaria* sp., *E. ruderalis, E. heterophylla, I. cylindrica, O. barrelieri, P. suberosa, P. amaura, T. procumbens, W. indica,* and *Z. mays* could become the pollen source for honey bees. A permanent beekeeping using *A. cerana* could sustainably run with the support of woody and understorey plant species diversity in Wanagama Education Forest.

Acknowledgment

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