Entomology and Applied Science Letters
Volume 6, Issue 3, Page No: 48-54

Available Online at: www.easletters.com

ISSN No: 2349-2864

Role of two agrosystems (mango and cashew trees orchards) in bees' activity increasing within beehives in Korhogo, Northern Ivory Coast (West Africa)

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ABSTRACT

This work aimed to assess the impact of different agrosystems on bees' activity in beehives. Pan traps (UV-bright yellow, white and blue) were used to sample insects particularly honey bees and wild bees within mango and cashew orchards and compare them with those in unmanaged savanna. Ten beehives were installed in each agrosystem in order to monitor bees' activity. A total of 283 bee specimens were caught during three months. The bee specimens found revealed three families (Apidae, Halictidae and Megachilidae). Halictidae were the most diversified family with 8 ± 0.01 species. A total of 33 species assigned to 17 genera were found. According to data analysis, the average bee richness and the average bee abundance were greater in mango and cashew orchards. Bees' activity was also more intense in beehives installed in mango and cashew orchards. It evolves with temperature up to a threshold and inversely with relative humidity. It is maximum between 11am and 2pm at temperatures between 34°C and 35°C and with a relative humidity between 56% and 65%. This study highlights the role of cashew and mango orchards in the conservation of bee populations, in particular honey bees ''Apis mellifera'' (dominant species), mainly responsible for honey production and associated products (eg. wax, propolis and royal jelly) in our regions. The positive impact of these agrosystems on bees' activity is beneficial for beekeepers and even, could help to provide pollination service in agricultural areas, effectively.

Keywords: *Activity, Agrosystems, Beehives, Beekeeping, Bees, Honey.*

HOW TO CITE THIS ARTICLE: Yalamoussa Tuo, Drissa Coulibaly*, Tenon Coulibaly, Soualiho Bakayoko, Kouakou Hervé Koua; Role of two agrosystems (mango and cashew trees orchards) in bees' activity increasing within beehives in Korhogo, Northern Ivory Coast (West Africa), Entomol Appl Sci Lett, 2019, 6 (3): 48-54.

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Received: 11/03/2019
Accepted: 04/07/2019

INTRODUCTION

Bees play an important role in balancing ecosystems because they ensure the conservation of biological diversity of plant species (cultivated and wild plants) through pollination services [1]. By visiting flowers for their food needs, they pollinate the plants allowing many fruits production. Approximately, 90% of angiosperm plant species depend on animals for pollination and sexual reproduction [2]. As much as 75% of agricultural crop species are, to some degree, dependent on animal pollination [3]. Pollination, in particular by bees improves seed and fruit quality in ca. 30% of the crops [4]. Beyond their pollinating activity, bees provide honey and associated products such as wax, propolis, and royal jelly indispensable to life [5-7]. In addition, honey contributes greatly to improve the socio-economic conditions of populations. The importance of honey has favored beekeeping practice worldwide, particularly in Sub-Saharan Africa, where people's incomes in rural areas have improved, considerably [8]. According to the FAO report in 2010, small-scale honey production has contributed significantly to securing the livelihoods of rural people. In Ivory Coast, several development projects have been implemented to intensify beekeeping to improve farmers' living conditions [9]. Unfortunately, beekeeping sector is still less developed in this country. Even if there are small-scale initiatives, such as the United Nations Development Program (UNDP), the beekeeping industry has never got enough investment to develop. Honey production is still rather low in Ivory Coast, as 95% of its honey is imported from Europe. As proof, the National Federation of Beekeepers (FENAPCI) in Ivory Coast estimated honey production in 2015 at about twenty tons, only. Despite this lackluster decor, beekeeping in Ivory Coast augurs interesting prospects. Unfortunately, from ancient times, the bee population especially honey bees, responsible for honey production, has been declining. This decline is due to climatic disturbances, the appearance of new viruses and pathogens such as mites (varroa destructor), parasites (nosema ceranae), but especially due to the disappearance of many natural habitats and agrosystems [10]. What could be the consequence of agrosystems' disturbance or disappearance on bee populations and therefore on bees' activity in beehives? To answer this question, this study has been initiated to assess the impact of agrosystems on bees' activity in beehives. Specifically, it consisted (i) to assess the diversity and abundance of bees in the studied agrosystems, (ii) to study the impact of agrosystems on bees' activity in beehives, (iii) to establish a relationship between bees' activity and weather parameters (temperature and relative humidity).

METHODS

Study area and study sites

This study was carried out in Korhogo (9°27'41'' N and 5°38'19'' W) in northern Ivory Coast. Located to 635 km from Abidjan (the economic capital), Korhogo is the chief-place of Savannah Region and Poro Region. Data were collected in three agrosystems (cashew orchard, mango orchard, and the protected area of the University) (Figure 1). *Anacardium occidentale* L. and *Magnifiera indica* are naturally more representative in the cashew and mango orchards, respectively, in contrast to the protected area where several woody species are found. In each agrosystem, fifteen pan traps (UV-light, yellow, blue, and white), were placed at a distance of five meters from each other with alternating colors, and an apiary of ten beehives was installed.

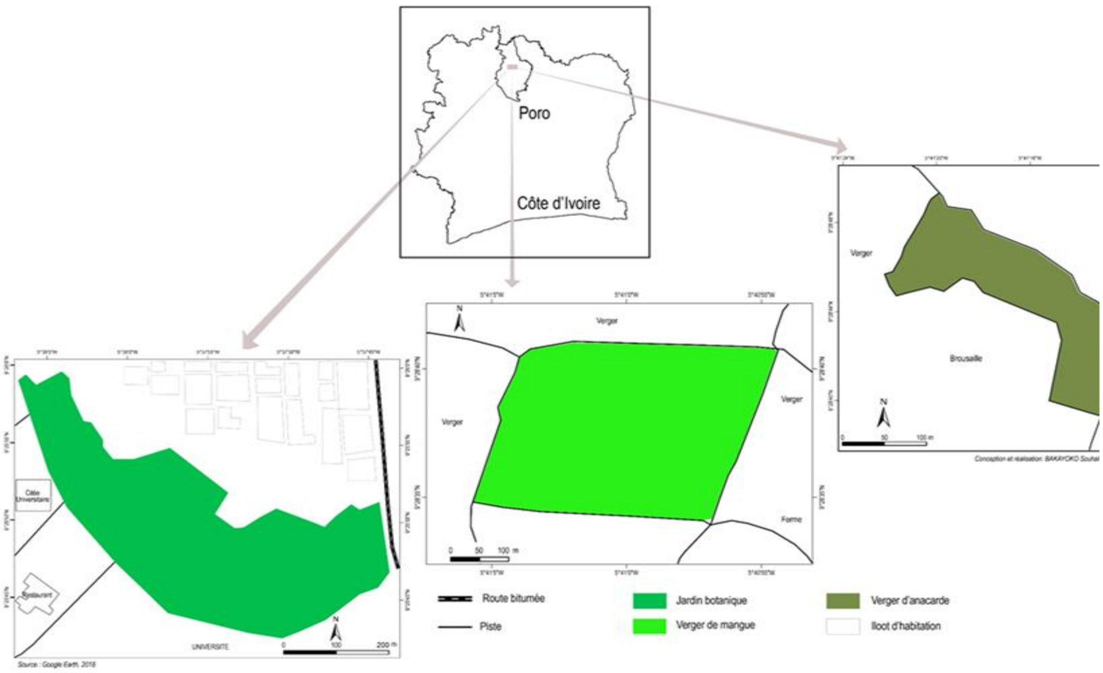


Figure 1: Sampling sites (Cissé, 2018)

Data collection

Capture and identification of bees

Bees were caught using pan traps (UV-light yellow, blue, and white plastic bowl) for three months. Each bowl was filled with salt (NaCl) saturated water and a small drop of detergent (liquid soap). Indeed, the detergent eliminates the surface tension on the water surface and the insects sink to the bottom, while salt allows insect conservation. The traps were activated twice a month and were left activated for 72 hr during each sampling turn. Bee specimens were collected, stored in ethyl alcohol, and thereafter pinned and identified to genus or species if possible.

Monitoring bees' activity in beehives

Beehives were mainly smoked with beef dung, slathered with beeswax and placed on trees to attract and shelter bees. After the colonization of beehives, the daily bees' activity was recorded for 10 minutes each one hour, between 6 am and 6 pm, using binoculars. The meteorological parameters (temperature and relative humidity) were recorded through a hygrometer. Indeed, the binoculars used made it easy to detect and count the entries and exits of bees from beehives at a rate of ten minutes per hour.

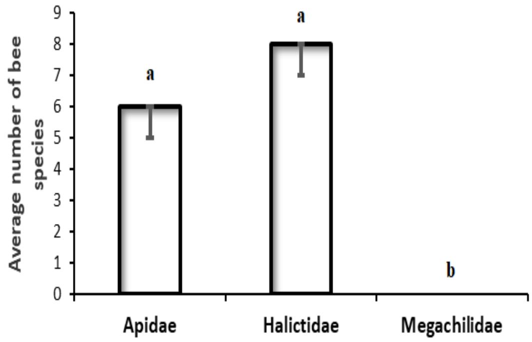
Data analysis

Using EstimateS software (version 7.0), specific richness (S) and biodiversity indices including Shannon diversity index (H') [11] and Pielou's evenness index E [12] were calculated to evaluate bee diversity for each habitat. Bee specimens were counted to determine the abundance (N). Abundance (N) is the total number of bee specimens collected for each species. Analysis of variance (ANOVA) and the least significant difference (Duncan tests) post hoc comparison ($p < 0.05$) were performed using STATISTICA software (version 7.0) [13]. These analyses were used to compare the diversity and abundance of bees between habitats.

RESULTS

Bee specific richness according to family

A total of 33 bee species were identified assigned to three families (Apidae, Halictidae, and Megachilidae) and 17 genera. Halictidae was the most diverse family with 20 species followed by Apidae (11 species) and Megachilidae (2 species), respectively. According to the statistical analysis, there was no significant difference between the average specific richness of Halictidae (8 ± 0.01) and of Apidae (6 ± 1.65). However, the difference was significant compared to the family of Megachilidae (0.67 ± 0.15) (Figure 2).

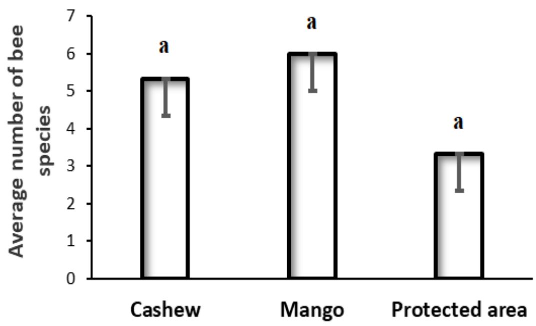


(Standard errors followed by the same letter are not significantly different at the level of 5% (test of Duncan)

Figure 2: Bee specific richness by family

Bee specific richness according to agrosystem types

The mango and cashew orchards with respectively 18 and 16 bee species were the most diverse habitats compared to the protected area with 10 species. The bee species identified in the cashew orchard and protected area belonged to two families (Apidae and Halictidae). As for bees identified in mango tree orchard, they belonged to three families (Apidae, Halictidae, and Megachilidae). However, according to the statistical analysis, there was no significant difference between the average bee specific richness in the three agrosystems: cashew orchard (5.33 ± 0.73), mango orchard (6 ± 0.46), and protected area (3.33 ± 0.51) (Figure 3).



(Standard errors followed by the same letter are not significantly different at the level of 5% (test of Duncan)

Figure 3: Bee specific richness in different agrosystems

Comparison of biological diversity

Shannon index values were relatively low in the mango orchard (H' = 1.76) and cashew trees (H' = 1.93) but were higher in the protected area of the university (H' = 2.70) (Table 1). These values indicated that although the protected area is less rich in bee species (10 species), it appeared to be more diverse. Pielou's evenness index (E = 0.85) varied in the same direction with the Shannon index. This shows a fair distribution of bee species in the natural area. On the other hand, in the other two agrosystems, bee abundance was dominated by the specimens of the honeybees (*Apis mellifera*). If mango and cashew orchards are able to attract a large population of honey bees, their role in the management of beekeeping practices will occupy a prominent place. Because honey production is mainly provided by honeybees.

Table 1: Indices of biological diversity

Indices	Cashew	Mango	Protected area
Specific richness (S)	16	18	10
Shannon index (H')	1.93	1.76	**2.70**
Pielou's evenness index (E)	0.48	0.42	**0.85**

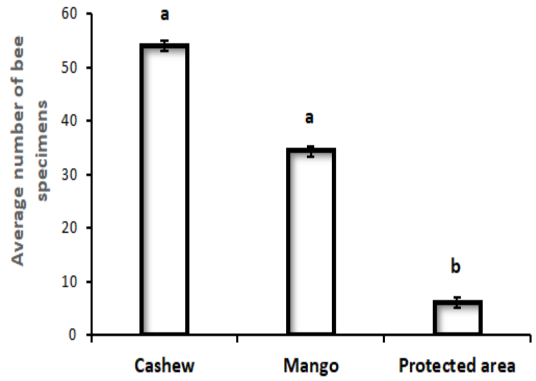
Bee abundance

A total of 283 bee specimens were caught through pan traps during the three-month sampling period. The Apidae family, with 218 specimens caught, was the most abundant, followed by Halictidae (63 specimens) and Megachilidae (2 specimens). Among all species identified, *Apis mellifera* (190 specimens), was the most representative (more than 67% of bee specimens) (Table 2). This result is very relevant for beekeepers because *Apis mellifera* is the main bee species, responsible for producing honey in large quantities in our regions.

Table 2: Distribution of bee specimens

	Apis mellifera	others Apidae	Halictidae	Megachilidae	Total
Number of specimens	**190**	28	63	2	283
Percentage (%)	**67.14**	9.89	22.26	0.71	100

The largest number of bee specimens were recorded in cashew orchard (162 specimens), mango orchard (103 specimens), and the protected area (18 specimens), respectively. There was no significant difference between the average number of bee specimens caught in cashew orchard (54 ± 1.60) and mango orchard (34.33 ± 1.14). However, there was a significant difference between the average numbers of bee specimens caught in the two previous agrosystems compared to the protected area (6 ± 0.19). (Figure 4).



Standard errors followed by the same letter are not significantly different at the level of 5% (test of **Duncan)**

Figure 4: Bee abundance in different agrosystems

Monitoring bees' activity

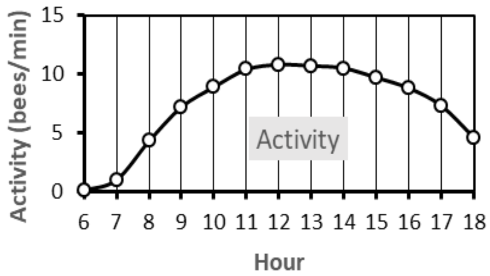
The number of beehives colonized by bees varied from one area to another. On 10 beehives installed in each habitat type, only one beehive was colonized by bees in the protected area. However, the cashew orchard and the mango orchard had the highest number of beehives colonized with 5 beehives and 3 beehives respectively colonized by bees. Only the honey bees *Apis mellifera* were observed at the entrance and exit of each beehive. The cashew and mango orchards had the highest average abundances of bees (*Apis mellifera*) per beehive with 1588 and 879 specimens respectively. However, the average abundance of bees per beehive in the protected area (276 specimens) was low. Bees' activity was greatest in the mango orchard where bees went out or entered the beehives at an average rate of 12 bees/minute. In the cashew orchard, the activity was estimated at an average of 7 bees/minute. The lowest activity was recorded in the protected area with a rate of 2 bees per minute. These results show that mango and cashew orchards are more likely to colonize beehives (Table 3).

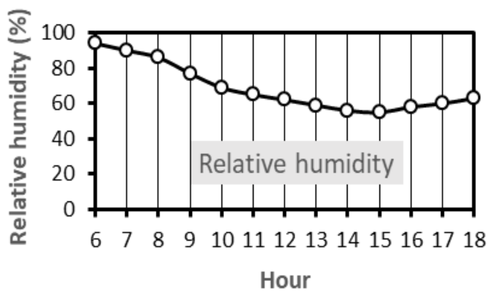
Table 3: Bees' activity within beehives

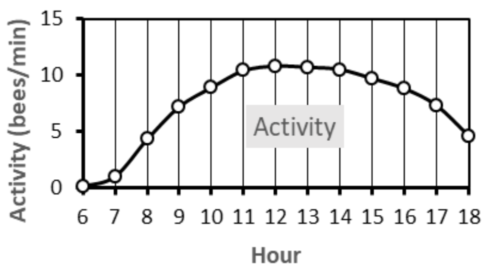
Agrosystems types	Number of colonized beehives	Average number of bees recorded/beehive	Observation time (min)	Bees' activity (bees/min)
Cashew	5	879	130	7 bees/min
Mango	3	1588	130	12 bees/min
Protected area	1	276	130	2 bees/min

Variation of bees' activity according to weather parameters

The curve of the bees' activity was similar to that of temperatures. In other words, bees' activity within beehives increased with temperature and decreased with relative humidity. From 6 am, the bees' activity increased gradually to reach a maximum from 11 am to 2 pm and then decreased again. The maximum activity corresponded to a temperature between 34°C and 35°C, and relative humidity ranging from 56% to 65% (Figure 5).







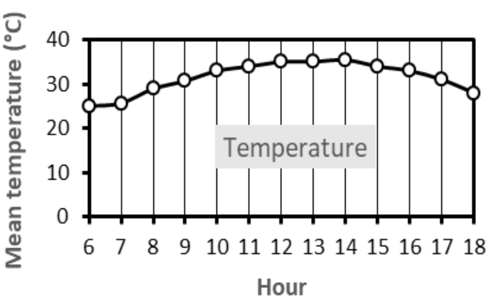


Figure 5: Variation of bees' activity according to meteorological data.

DISCUSSION

The greatest specific richness has been recorded in the Halictidae family. This is in accordance with a similar study conducted by Pauly and collaborators in West Africa [14]. This study showed that Halictidae are the most diversified bee family in Sub-Saharan Africa. Indeed, Apidae represented by Meliponini tribe and honey bees are very polytrophic; Megachilidae are limited in their choice by the accessibility of stamens to the movements of their ventral brush; Colletidae are represented only by two genera, they are more frequent in dry season (Hylaeus, devoid of Scopa, collects pollen through the mouth), while Halictidae as a whole, have a fairly wide choice for plants [15]. This expanded choice for plants could explain their great diversity especially, in areas where vegetation is quite heterogeneous. The high values of the Shannon index and Pielou's evenness index in the protected area reflect the fact that this environment is the most diversified with a more equitable distribution of bee species within it. That could be explained by the strong heterogeneity of this environment in the floral sources. Because the diversity of bees in a given ecosystem is strongly correlated with its floral richness [16]. In fact, to collect nectar and pollen, bees have a preference for certain plants, although, for the most part, they are polylectic. This assertion has been confirmed by the results of a study conducted by Meurgey's [17]. According to this study, honey bees observed on 70 different plant species, behaved opportunistically, while other species of Megachile were strictly subservient to a single family of a plant (Fabaceae). The diversity of environments, especially the richness of plant communities (structure, composition, and specific richness) is important for the diversity of Apiformes communities and constitutes a challenge for their conservation [18-20]. Otherwise, the low values of Pielou's evenness index in mango and cashew orchards reflect the fact that bee abundance within these agrosystems is related to the strong presence of a single bee species (*Apis mellifera*). Honeybees caught by pan traps within these agrosystems represent more than half of all bee species. That could be due to a large number of colonized beehives in these two habitats. Therefore, from this study, it seems that honeybees are attracted by mango and cashew trees flowers compared to other wild plant species. Bee abundance was much higher in cashew and mango orchards compared to the protected area. That could be explained by the fact that the protected area was more covered and shadier, whereas the majority of bees, such as *Apis mellifera*, prefer more or less lit environments compared to dark environments. Bee abundance in mango and cashew orchards was strongly related to the high number of honeybees due to the presence of several colonized beehives. If cashew and mango trees are among the most attractive melliferous plants of many bee species, their role in biological diversity conservation of bees and their utility in the good management of beekeeping practices will occupy a prominent place. The gradual increase in bees' activity from 6 am to 11 am could be explained by the fact that at this time of the day a large number of bees leave beehives for foraging. The lowering of bees' activity was observed from 2 pm when the majority of bees left beehives. A study achieved by Marceau and collaborators established a relationship between bees' activity and daily beehives output that clearly indicates the importance of bees' activity on honey production level [21]. According to these authors, the minimum value of activity to obtain a positive daily production was around 14,000 bees/hour (about 233 bees/min). For an average hourly activity below this value, the mass of beehive decreased gradually because the bees consumed the accumulated reserves. In our study, the values of bees' activity in mango and cashew orchards are therefore relatively lower at the minimum value estimated by these authors. However, it is already important that bees' activity in these agrosystems is not zero.

CONCLUSION

This study aimed first, to assess bees diversity and abundance in different agrosystems; second, to study the influence of these agrosystems on bees' activity in beehives and third, to establish the relationship between bees' activity and weather parameters (temperature and relative humidity). The results showed that bees' richness and abundance are higher in cashew and mango orchards. However, the distribution of individuals between bee species was more equitable in the protected area. Bees' activity in beehives was also more intense in cashew and mango orchards. These results showed the importance of agrosystems, in particular, mango and cashew orchards and their likely involvement in the good beekeeping practices.

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