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Diversity of Insects on Four Cashew Nut Varieties Inflorescences "*Anacardium occidentale* L." in Niofoin "Côte d'Ivoire"

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ABSTRACT

Cashew nut represents the third most exported agricultural product of Côte d'Ivoire. However, the yield production of cashew is still low likely due to many factors including under-pollination. This study aims to identify the insects visiting cashew tree inflorescences at Niofoin in northern Côte d'Ivoire. Observations were made in a cashew orchard measuring two hectares. Insects visiting the inflorescences were captured and identified. A total of four cashew nut varieties (Yellow Benin, Henry, Costa Rica, and James) were observed. The daily activity of honey bee *Apis mellifera*, considered here as the number of flower visits made by a bee in one minute to an inflorescence, was evaluated on the inflorescences from 5 a.m. to 6 p.m. The findings showed 16 families belonging to 7 orders. Among the insect families, Apidae emerged as the most abundant family (32.15%). *Apis mellifera* (Apidae) was the main visitor of cashew tree inflorescences. His activity was stronger on "Yellow Benin" and "Henry" varieties compared to "James" and "Costa Rica" varieties. For all varieties of cashew trees, honey bee activity varied throughout the day with two peaks, one between 7 a.m. and 8 a.m. and the other between 5 p.m. and 6 p.m. It was inversely proportional to temperature ($p < 0.05$; $r = -0.59$) and evolved in the same direction with relative humidity ($p < 0.05$; $r = 0.49$). This study, although preliminary, remains quite relevant because it will help to boost cashew production in northern Côte d'Ivoire through the pollinators' involvement.

Keywords: Insects, Yellow benin, Henry, Costa rica, James, Pollinators.

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INTRODUCTION

The cultivation of cashew nut has been introduced in the North of Côte d'Ivoire in 1960 to slow down deforestation and fight against soil erosion [1]. This enabled to increase population incomes through the associated traded products such as apple and cashew nut [2]. In 2010, the cashew nut became the third exported agricultural product from Côte d'Ivoire after cocoa and rubber [3]. This performance ranked the country the first among cashew-nut producing and exporting countries in the world [4]. However, despite the recorded gains, the current yield production of cashew (350-500 kg per hectare) is still low compared to forecasts, estimated to be 1.6 t/ha [5]. Several studies attributed partly the low productivity of cashew trees to under-pollination [6-8]. A study from India showed that 25% to 72% of pistil was not pollinated due to the lack of pollinator insects [6]. These findings support that insects are essential pollinators for cashew tree production and that their absence could therefore directly impact yield production. Past studies have suggested that wind is a pollinating agent of cashew trees [9]. Yet, up to date, very few studies highlighted the essential role of insects in cashew pollination.

However, since the cashew tree is highly dependent on pollination to produce fruit, not all insects that visit its flowers participate equally in the pollen transfer. Thus, various studies, particularly in Brazil and India, have sought to determine which insects are the most efficient in pollinating the cashew tree flower. In Brazil, where the cashew tree originated, direct observations of insects visiting flowers and counting pollen grains have shown that honey bee (*Apis mellifera*), although not native, is the most efficient pollinator of cashew tree in northeastern Brazil [7]. In India, the observations have shown that the insects which visit cashew trees' flowers are ants and bees, mainly. Moreover, in Ivory Coast, the first country producer of cashew, very little data exists on the pollinating fauna of this speculation. This study aims to fill these knowledge gaps on cashew pollination. The global objective was to know the *entomofauna* of cashew tree inflorescences. Specifically, this study aims (i) to assess the diversity of insects visiting the cashew inflorescences (ii) to assess the impact of cashew varieties on bee diversity, and (iii) to assess the activity of *Apis mellifera* on the cashew tree inflorescences. The study was carried out on four cashew trees varieties (Yellow Benin, Henry, Costa Rica, and James) in Korhogo, northern Côte d'Ivoire.

MATERIALS AND METHODS

Study area

This study was carried out in the department of Korhogo during the dry season. The dry season was chosen as it corresponds to the flowering period of cashew trees. The study site (Niofoin) is located between 8°26 - 10°27 LN; 5°17 - 6°19 LW in the North of Côte d'Ivoire. The department is situated 600 km away from Abidjan, the capital of Côte d'Ivoire. It belongs to the Sudano-Sahelian climate whose rhythm of seasons is regulated by Intertropical Front displacement [10]. The climate is characterized by a rainy season from May to October (max. precipitation in September) and a dry season from November to April, characterized by the harmattan from December to February. The average annual rainfall varies between 1100 mm and 1600 mm and the average annual temperature varies between 25° C and 35° C [11].

Field observations

Data sampling was carried out on four varieties of cashew trees (Yellow Benin, Henry, Costa Rica, and James) grown over an area of 2 ha. These varieties were identified according to the model of Touré *et al.*, based on phenotypic characters [12] **(Table 1 and Figure 1)**. Distributed heterogeneously within the cultivated area, the four varieties of cashew trees were selected for the study due to their greater use by the local population. For each variety, the insects were observed on three trees chosen at random. During the study period, these trees were marked with different colored bands to facilitate their identification.

Table 1. Characteristics of the four cashew trees varieties [12]

Varieties	Tree (harbor)	Phenology (fruit setting stage)	Apple		Nut	
			Color	Size	Color	Size
Henry	Multi-stemmed branched bottom	The apple is 3 to 4 times smaller in size than the nut	Net yellow	Small	Light gray enameled with purple spots	Small
Yellow Benin	Branched bottom with multi-stemmed and basic branching	Apple and nut are relatively the same lengths	Yellow	Large	Greenish speckled with purple on the chin	Large
Costa Rica	Multi-stemmed low branch, multi-stemmed crown spreading out like a parasol	Apple and nut are relatively balanced	Yellowish	Large	Light gray with black speckles	Large
James	Low branched multi-stem with spreading habit	The apple is smaller than the nut	Red to bright red	Small	Gray, chin spotted with black	Medium to small

a) b) c) d)

Figure 1. Illustration of the four cashew trees' apple varieties (A: Yellow Benin; B: Henry; C: Costa Rica; D: James)

Insects' survey

The insects were observed on the four cashew trees varieties' inflorescences, or captured using a reappearing net. Simultaneously, each variety was observed for two consecutive months (four days per week). The observations were made between 5 a.m. and 6 p.m. All data was recorded by time slot and each selected inflorescence (ten inflorescences per tree; n = 10) was observed for ten minutes. The observed insects were identified immediately, or captured and stored in alcohol (70%) then convoyed to the laboratory for identification with a binocular magnifying glass. For this study, all specimens were identified until to "family" level. Only, specimens belonging to the family of Apidae were identified up to the species. It was more representative in the number of specimens observed.

The activity of the honey bee

The activity of the honey bee was evaluated by taking into account the number of the visited flower by the bee for a given time (one minute for our study). Only one visit per inflorescence was counted for each insect. The visit was considered positive when there was a contact between the bee with the flower anthers, and negative if there was no contact. For two consecutive months (four days per week), from 5 a.m. to 6 p.m., bee activity was assessed. For each time slot, ten minutes was devoted to observing the cashew trees' variety inflorescences. The parameters such as average temperature and relative humidity were recorded during the study period.

Data analysis

A one-way analysis of variances (ANOVA) was performed to compare the relative abundances of different taxa. Pearson's correlation test was used to analyze the relationships between abiotic parameters and bee activity, a Pearson correlation test was used. All the data were processed using Statistica software version 7.1.

RESULTS AND DISCUSSION

Global diversity of insects

A total of 705 insect specimens were recorded from all the observed inflorescences. These insects belong to 16 families and have 7 orders (Coleoptera, Homoptera, Lepidoptera, Neuroptera, Hymenoptera, Heteroptera, and Diptera). Heteroptera (5 families), Hymenoptera (4 families), and Diptera (3 families) were the most diverse orders. Each of the other orders was composed of a single family **(Table 2)**. On the other hand, the relative abundance of Hymenoptera (49.6%), Diptera (16.4%), Homoptera (15.2%), and Heteroptera (11.9%) was higher, respectively. The relative abundance of Neuroptera (0.8%) and Coleoptera (0.1%) was very low. The analysis of variances revealed a significant difference between the relative abundance of different insect orders (P = 0.000001; F = 7.121) **(Table 2)**. Regarding the families, Apidae (32.15%) was more abundant compared to the other families. Polyphagidae (15.16%) and Syrphidae (15.01%) were moderately abundant. The other families (Formicidae, Vespidae, Melittidae, Asilidae, Sarcophagidae, Alydidae, Coreidae, Miridae, Pentatomidae, Pyrrhocoridae, Noctuidae, Chrysopidae, and Chrysomelidae) were considered to have a low abundance. A one-way analysis of variance followed by the Newman-Keuls test revealed a significant difference between the relative abundance of families (P = 0.000001; F = 10.301) **(Table 2)**.

Table 2. Diversity of insects on cashew trees inflorescences

Orders	Relative abundance (%)	Families	Relative abundance (%)
Hymenoptera (4 families)	**49,6 ^{a}**	**Apidae**	**32,15 ^{a}**
		Formicidae	8,78 ^{cd}

		Vespidae	6,8^{cd}
		Melittidae	2,12^{d}
Diptera (3 families)	16,4^{b}	**Syrphidae**	15,01^{bc}
		Asilidae	0,71^{d}
		Sarcophagidae	0,71^{d}
Homoptera (1 family)	15,2^{bc}	**Polyphagidae**	15,16^{b}
Heteroptera (5 families)	11,9^{bc}	Alydidae	0,28^{d}
		Coreidae	7,37^{cd}
		Miridae	0,71^{d}
		Pentatomidae	2,55^{d}
		Pyrrhocoridae	1,13^{d}
Lepidoptera (1 family)	5,9^{cd}	Noctuidae	6,09^{cd}
Nevroptera (1 family)	0,8^{d}	Chrysopidae	0,28^{d}
Coleoptera (1 family)	0,1^{d}	Chrysomellidae	0,14^{d}

Impact of cashew tree varieties on bee diversity

Variety ''Yellow Benin''

The observed insects on "Yellow Benin" inflorescences belonged to twelve families divided into six orders. The orders of Hymenoptera (4 families), Diptera (3 families), and Heteroptera (2 families) included more families, respectively. The relative abundance of Hymenoptera was significantly higher than that of other orders ($P = 0.000001$; $F = 11.174$). Regarding the families, Apidae and Polyphagidae were significantly more abundant than the other families ($P = 0.000001$; $F = 11.335$).

Variety ''Henry''

Thirteen families and six orders of insects have been identified on "Henry" inflorescences. The orders of Hymenoptera (4 families), Heteroptera (4 families), and Diptera (2 families) were more diverse, respectively. The relative abundance of Hymenoptera was significantly higher than that of other orders ($P = 0.00000$; $F = 5.175$). For the family level, Apidae and Polyphagidae were significantly more abundant than the other families ($P = 0.00000$; $F = 12.376$).

Variety ''James''

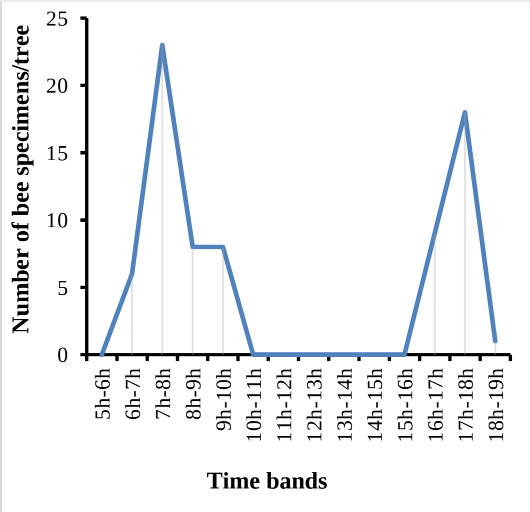
On "James" variety inflorescences, twelve families of insects belonging to five orders were identified. The orders of Heteroptera (4 families), Hymenoptera (3 families), and Diptera (3 families) included more families, respectively. The relative abundance of Hymenoptera was significantly higher than that of other orders ($P = 0.000$; $F = 4.145$). Regarding the families, the relative abundance of Apidae and Syrphidae was significantly higher than that of other families ($P = 0.0000$; $F = 10.319$).

Variety ''Costa Rica''

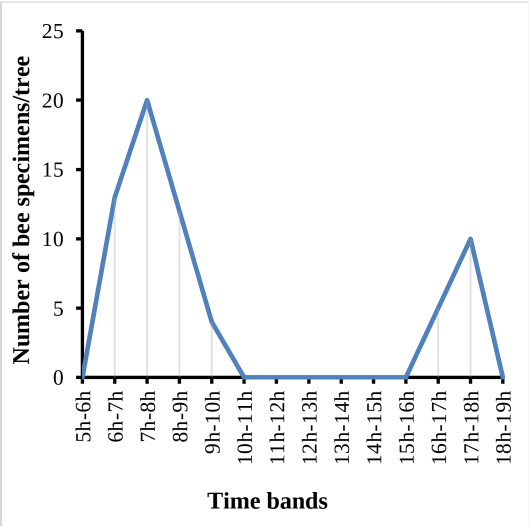
A total of ten families divided into five orders were identified. The orders of Hymenoptera (4 families) and Heteroptera (3 families) included more families, respectively. The relative abundance of Hymenoptera was significantly higher than that of other orders ($P = 0.00000$; $F = 9.290$). For the families, Apidae and Syrphidae were more abundant ($P = 0.0000$; $F = 8.145$).

The activity of the honey bee

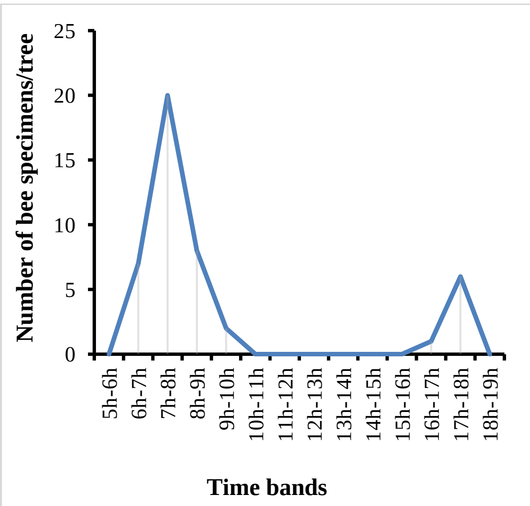
The visit frequency (F) of the honey bee on the inflorescences varied significantly between the cashew trees varieties ($p < 0.05$). It was higher on Henry (F = 30.09%) and Yellow Benin (F = 28.32%) varieties compared to Costa Rica (22.12%) and James (19.47%) varieties. Bees were foraging Henry and Yellow Benin varieties at an average rate twice as high as that of Costa Rica and James varieties. The honey bee's activity varied throughout the day. For each variety, it was zero between 5 a.m. and 6 a.m., and quickly, it increased, reaching its maximum peak between 7 a.m. and 8 a.m. Beyond that, it gradually decreased to cancel out around 11 a.m. A resumption of activity was observed towards the end of the afternoon between 3 p.m. and 4 p.m. with an observed peak between 5 p.m. and 6 p.m. **(Figure 2)**.



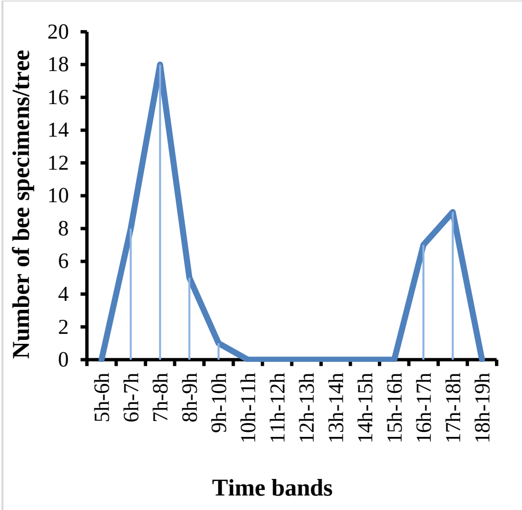
Yellow Benin



Henry



James

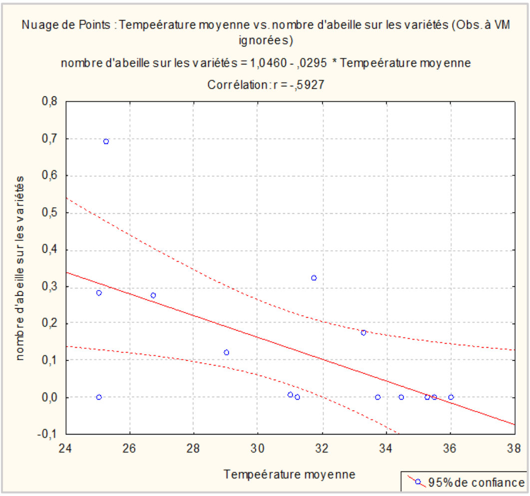


Costa Rica

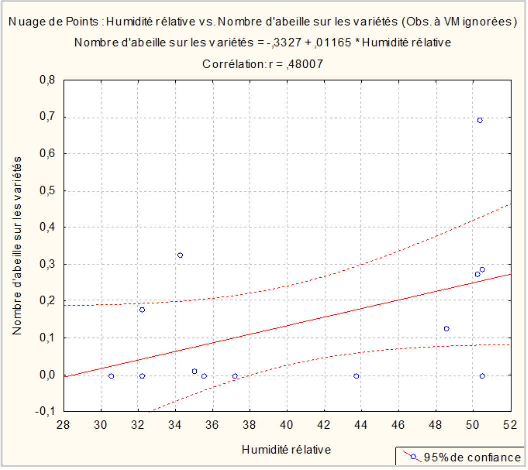
Figure 2. Variation of Apis mellifera activity on the different cashew tree varieties inflorescences

Influence of abiotic factors on honey bee activity

The correlation study between the abiotic factors and honey bee activity on the four cashew trees varieties inflorescences, showed that honey bee activity was influenced by temperature. Indeed, there is a significant negative correlation between these two parameters ($p < 0.05$; $r = -0.59$). In other words, the temperature, and bees' activity change inversely. When the temperature drops to a threshold (25° C), bee activity increases and vice versa **(Figure 3)**. As for relative humidity, it changes with bee activity ($p < 0.05$; $r = 0.49$) up to a threshold (50%). Statistical analyzes revealed a positive and significant correlation between relative humidity and bee activity ($p < 0.05$; $r = 0.49$) **(Figure 3)**.



a)



b)

Figure 3. Correlation between abiotic factors (temperature and humidity) and bee activity

Data analysis revealed a strong diversity of insects. This important diversity of insects on the cashew tree's inflorescences could be explained by the fact that its flowering takes place between December and February which corresponds to the dry season, during which the food resources of insects (bees) become scarce. Indeed, the presence of insects on flowers is never accidental, it is linked to the search for food. Some insects visit flowers for nectar, pollen, and others to feed on certain insects. They are most often attracted to either by the color or the scent of the flowers. According to Arnaud *et al.*, when an insect moves through its environment, it comes into contact with a set of chemical messengers that can modify its behavior or physiology, so the insects are either attracted or repressed [13]. Bee diversity is usually high in the dry season because most of Apoidea prefer areas with a dry climate rather than areas with a humid climate [14]. Some species, not all, prefer the dry season, in particular, because the nesting conditions are more favorable (fewer mold problems in the nests). The honey bee is the main visitor of inflorescences probably due to the life of the honey bee in a colony and the implementation of many beehives nearby to the cashew orchards. Indeed, honey bees can form colonies of 25,000 individuals which can directly affect the number of individuals visiting neighboring crops [15]. Similar work by Freitas and Paxton showed that the honey bee is still the most efficient pollinator of cashew trees in northeastern Brazil [7]. The activity of honey bees in the morning and the day end would coincide with the time of pollen or nectar availability. In another study, Djonwangwe *et al.* showed that the peak of activity for the honey bee on *Vitellaria paradoxa* inflorescences was between 7 a.m. and 8 a.m., period during which, this plant species offered more pollen and nectar [16]. Indeed, the strong activity of bees in the morning is synchronized with a maximum secretion of nectar [17]. Bees forage frequently on the flowers with a relatively high sugar concentration in the nectar [18]. A study conducted by Tuo showed that most insect activity on oil palm inflorescences was observed between 9 a.m. and 1 p.m. with a peak at 11 a.m., the first and the second day of anthesis [19]. This period coincided certainly with that during which the anise scent released by the flower was more intense. In addition, several parameters such as hour, age of flower, and weather conditions, could influence the nectar production and quality [20]. Temperature and relative humidity would have an impact on how flowers function; which would explain their correlations with bee activity. In a previous study on *P. palinuri*, the authors showed that the pollen of *P. palinuri* is affected by both high temperature and humidity [21]. Kropacova and Haslbachova showed that there is a negative correlation between temperature and nectar secretion in Trifolium repens [22]. High relative humidity impacts positively bee biology. Indeed, according to Human *et al.*, high relative humidity is mainly required for brood development [23]. Similar results were obtained by Koné *et al.* [24]. In fact, in their study on zucchini, the authors showed that the greatest number of bee visits to flowers was obtained at low temperatures and high relative humidity.

CONCLUSION

This study was carried out in order to assess the insects visiting cashew trees inflorescences in the north of Côte d'Ivoire. This preliminary phase made it possible to make an inventory of insects on four varieties (Yellow Benin, Henry, Costa Rica, and James). It appears that the order of Hymenoptera is the most diverse and the family of Apidae is the most abundant. In addition, "Yellow Benin" and "Henry" varieties are more attractive to the honey bee (*Apis mellifera*). In perspective, the effective pollinators for each cashew trees variety will be identified.

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REFERENCES

1. Goujon P, Lefèbvre A, Leturcq P, Marcellesi AP, Praloran JC. Etudes sur l'anacardier. Régions écologiques favorables à la culture de l'anacardier en Afrique francophone de l'Ouest. Fruits. 1973;28(3):217-25.
2. Agboton C, Onzo A, Ouessou FI, Goergen G, Vidal S, Tamo M. Insect Fauna Associated with Anacardium occidentale (Sapindales: Anacardiaceae) in Benin, West Africa. J Insect Sci. 2014;14(1):229.
3. Koné M. Analyse de la chaîne de valeur du secteur anacarde de la Côte d'Ivoire. Initiative du Cajou Africain; 2010. 76 p.
4. Diop M. Côte d'Ivoire: Premier producteur mondial de noix de cajou; 2016. 1 p.
5. Djaha JB, N'guessan AK, Ballo CK, Aké S. Germination des semences de deux variétés d'anacardiers (Anacardium occidentale L.) élites destinées à servir de porte-greffe en Côte d'Ivoire. J Appl Biosci. 2010;32:1995-2001.
6. Reddi EU. Under-pollination a major constraint of cashew production. InProc. Indian Nat Sci Acad. 1987;B53:249-52.
7. Freitas BM, Paxton RJ. The role of wind and insects in cashew (Anacardium occidentale) pollination in NE Brazil. J Agric Sci. 1996;126(3):319-26.
8. Bhattacharya A. Flowers visitors and fruitset of Anacardium occidentale, pdf. Annales Botanici Fennici. 2004;41:385-92.
9. Freitas BM, Pacheco Filho AJ, Andrade PB, Lemos CQ, Rocha EE, Pereira NO, et al. Forest remnants enhance wild pollinator visits to cashew flowers and mitigate pollination deficit in NE Brazil. J Pollinat Ecol. 2014;12:22-30.
10. Jourda JP, Saley MB, Djagoua EV, Kouamé KJ, Biémi J, Razack M. Utilisation des données ETM+ de Landsat et d'un SIG pour l'évaluation du potentiel en eau souterraine dans le milieu fissuré précambrien de la région de Korhogo (Nord de la Côte d'Ivoire): Approche par analyse multicritère et test de validation. Télédétection. 2006;5(4):339-57.
11. Kouakou E, Koné B, N'go A, Gueladio C, Savane I. Impact of Rainfall Variability on the Groundwater Resources of the White Bandama Bassin (Northern CÔTE D'Ivoire). J Water Clim Chang; 2012. 85 p.
12. Mamoudou Abdoul T, Elhadji F, Ramatoulaye G. Réponse de quatre variétés de Anacardium occidentale L. aux techniques de greffage horticole en pépinière. Vertigo-la revue électronique en sciences de l'environnement. 2017;1-13.
13. Arnaud L, Detrain C, Gaspar C, Haubruge E. Insectes et communication. J Des Ing. 2003;87:25-8.
14. Michener CD. Biogeography of the bees. Ann Mo Bot Gard. 1979;66(3):277-347.
15. Walters SA, Taylor BH. Effects of honey bee pollination on pumpkin fruit and seed yield. HortScience. 2006;41(2):370-3.
16. Djonwangwe D, Fohouo FN, Messi J, Bruckner D. Impact de l'activité de butinage de Apis mellifera adansonii Latreille (Hymenoptera: Apidae) sur la pollinisation et la chute des jeunes fruits du karité Vitellaria paradoxa (Sapotaceae) à Ngaoundéré (Cameroun). Int J Biol Chem Sci. 2011;5(4):1538-51.
17. Cervancia CR, Bergonia EA. Insect pollination of cucumber (Cucumis sativus L.) in the Philippines. Acta Hortic. 1991;288:278-82.
18. Philippe JM, Philippe JM. La pollinisation par les abeilles: pose de colonies dans les cultures en floraison en vue d'accroître les rendements des productions végétales. Edisud; 1991. 160 p.
19. Tuo Y. Etat de l'entomofaune des inflorescences du palmier à huile en Côte d'Ivoire: cas de la station CNRA de LaMé. Thèse de Doctorat de l'Université Félix Houphouët-Boigny, spécialité entomologie

agricole, Laboratoire de zoologie, biologie animale et écologie; 2013. 204 p.
20. Pouvreau A. Cultures tropicales oléagineuses. In: Pollinisation et production végétale (coordonné par Pesson P., Louveaux J.), INRA, Paris; 1984. pp. 331-47.
21. Aronne G, Iovane M, Strumia S. Temperature and humidity affect pollen viability and may trigger distyly disruption in threatened species. Ann Di Bot. 2021;1:77-82.
22. Kropacova S, Haslbachova H. A study of the effect of some climatic factors on nectar secretion in sainfoin (Onobrychis viciaefolia v. sativa Thell.) and white clover (Trifolium repens L.). Acta Univ Agric Ser A. 1970;18(4):613-20.
23. Human H, Nicolson SW, Dietemann V. Do honeybees, Apis mellifera scutellata, regulate humidity in their nest?. Naturwissenschaften. 2006;93(8):397-401.
24. Koné K, Tuo Y, Yapo ML, Traoré D, Soro F, Koua KH. Diversity, abundance and activity of bees in Zucchini (Cucurbita pepo L) crops in northern Côte d'Ivoire. Int J Entomol Res. 2019;4(1):41-5.