Eurasia Specialized Veterinary Publication

Entomology Letters

ISSN:3062-3588

2022, Volume 2, Issue 2, Page No: 19-26

Available online at: www.esvpub.com/

Insect Diversity on Inflorescences of Four Cashew Nut Varieties (*Anacardium occidentale* L.) in Niofoin, Côte d'Ivoire

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ABSTRACT

Cashew nuts are the third most exported agricultural product in Côte d'Ivoire, though the production in the country remains limited, possibly due to factors such as inadequate pollination. This study aimed to evaluate the insects visiting the inflorescences of cashew trees in Niofoin, located in the northern region of Côte d'Ivoire. The study was conducted in a two-hectare cashew orchard, where insects attracted to the inflorescences were captured and identified. Four cashew varieties were studied: Yellow Benin, Costa Rica, Henry, and James. The activity of *Apis mellifera* was monitored by counting the number of visits a bee made to an inflorescence per minute, from 5 a.m. to 6 p.m. In this study, 16 insect families from 7 different orders, with the Apidae family having the highest number (32.15%). *Apis mellifera* was the primary insect to visit the inflorescences, with the highest activity observed in the Yellow Benin and Henry varieties, compared to the James and Costa Rica varieties. Honey bee activity showed two distinct peaks during the day: one between 7 a.m. and 8 a.m., and the other from 5 p.m. to 6 p.m. In addition, bee activity showed a negative correlation with temperature ($P < 0.05$; $r = -0.59$) and a positive correlation with relative humidity ($P < 0.05$; $r = 0.49$). Although this study is preliminary, it provides useful information that could help increase cashew production in northern Côte d'Ivoire by improving the role of pollinators.

Keywords: Pollinators, Insects, Henry, Yellow Benin, Costa Rica, James

Received: 10 September 2022
Revised: 27 November 2022
Accepted: 03 December 2022

How to Cite This Article: Tuo Y, Coulibaly D, Koné M, Traoré S, Koné K, Koua KH. Insect Diversity on Inflorescences of Four Cashew Nut Varieties (*Anacardium occidentale* L.) in Niofoin, Côte d'Ivoire. Entomol Lett. 2022;2(2):19-26.
https://doi.org/10.51847/CNR21Y49HR

Introduction

Cashew cultivation was introduced in northern Côte d'Ivoire in 1960 as part of efforts to combat deforestation and soil erosion [1]. This initiative led to an increase in the income of local populations through the trade of products such as cashew nuts and apples [2]. By 2010, cashew nuts became the third-largest agricultural export of Côte d'Ivoire, following cocoa and rubber [3], propelling the country to the top of the global rankings in cashew nut production and exportation [4]. Despite this success, the yield remains lower than expected, with current production ranging from 350 to 500 kg per hectare, far below the anticipated 1.6 tons per hectare [5]. Research indicates that one of the key factors behind the low productivity of cashew trees is inadequate pollination [6-8]. A study conducted in India revealed that a significant portion (25-72%) of the pistils did not receive proper pollination, largely due to the absence of pollinating insects [6]. This highlights the critical role of insects in cashew tree pollination and how their absence can directly affect fruit yield. While previous studies have suggested wind as a pollination agent for cashew trees [9], there has been limited focus on the crucial role of insects. Given the tree's heavy reliance on pollination for fruit production, it is clear that not all insect visitors contribute equally to pollen transfer. Studies in Brazil and India have aimed to identify the most effective pollinators of cashew trees. In northeastern Brazil, where cashew trees originated, direct observations and pollen grain counts have displayed that the non-native honey bee (*Apis mellifera*) is the most efficient pollinator [7]. In India, research has identified ants and bees as the primary insect visitors to cashew flowers. However, in Côte d'Ivoire, the world's largest producer of cashews, data on the pollinator fauna is scarce. This research aims to address these gaps in knowledge by focusing on the pollination process of cashew trees. Specifically, the objectives are (i) to evaluate the diversity of insects visiting cashew inflorescences, (ii) to assess the impact of different cashew varieties on bee diversity, and (iii) to analyze the activity of *Apis mellifera* on cashew tree inflorescences. The research was conducted on four cashew varieties (Yellow Benin, Costa Rica, Henry, and James) in Korhogo, located in northern Côte d'Ivoire.

Materials and Methods

Study area

The research took place in the Korhogo department during the dry season, aligning with the cashew tree flowering period. The research site, Niofoin, is located in the northern region of Côte d'Ivoire, specifically between 8°26' and 10°27' North latitude and 5°17' and 6°19' West longitude. It lies approximately 600 km from Abidjan, the country's capital. The area falls under the Sudano-Sahelian climate zone, where seasonal patterns are influenced by the movement of the Intertropical Convergence Zone [10]. The climate is characterized by a rainy season from May to October, peaking in September, and a dry season from November to April, with harmattan winds prevailing between December and February. Annual rainfall typically ranges from 1,100 mm to 1,600 millimeters, and the average temperature fluctuates between 25 °C and 35 °C [11].

Field observations

Sampling was conducted on four cashew tree varieties (Yellow Benin, Costa Rica, Henry, and James) spread across a 2-hectare plot. The varieties were categorized based on phenotypic traits, following the method of Touré *et al*. [12] **(Table 1; Figure 1)**. These cashew varieties, distributed unevenly across the plot, were selected for the research due to their widespread use among the local community. For each variety, insect observations were carried out on three randomly selected trees, which were marked with various colored bands for easy identification throughout the study period.

Table 1. Features of the four cashew tree varieties [12]

Varieties	Tree (harbor)	Phenology (fruit setting stage)	Apple		Nut	
			Color	Size	Color	Size
Henry	Bottom with multiple stems and branches	The apple is about three to four times smaller than the nut.	Net yellow	Small	Light gray enameled with purple spots	Small
Yellow Benin	Branched lower section with multiple stems and primary branching	The apple and nut have similar lengths.	Yellow	Large	Greenish speckled with purple on the chin	Large
Costa Rica	Low branches with multiple stems, crown spreading out in a parasol shape	The apples and nuts are of comparable size.	Yellowish	Large	Light gray with black speckles	Large
James	Low branching with multiple stems and a spreading growth pattern	The apple is smaller compared to 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, and d) James

Insects' survey

Insects were monitored on the inflorescences of the four cashew tree varieties or collected using a sweep net. Each variety was observed over two consecutive months, with observations conducted 4 days per week. The observation period spanned from 5 a.m. to 6 p.m. Data was recorded by time slot, and each selected inflorescence (ten per tree; n = 10) was observed for ten minutes. Insects were either identified on-site or captured and preserved in 70% alcohol, then transported to the laboratory for further identification using a binocular magnifier. Specimens were classified up to the family level, with those from the Apidae family being identified to the species level, as they were the most abundant.

The activity of the honey bee

Honey bee activity was measured by counting the number of flowers visited by the bee within a one-minute time frame. Each insect was counted for only one visit per inflorescence. A visit was deemed successful if the bee made contact with the flower's anthers, while it was considered unsuccessful if no contact occurred. Over two consecutive months, with observations made 4 days per week from 5 a.m. to 6 p.m., bee activity was recorded. For each time slot, ten-minute observation periods were allocated to monitor the inflorescences of each cashew tree variety. Additionally, relative humidity and average temperature were recorded throughout the study period.

Data analysis

To compare the relative abundances of various taxa, a one-way analysis of variance (ANOVA) was conducted. The relationship between abiotic factors and bee activity was examined using Pearson's correlation test. All data were analyzed using Statistica software, version 7.1.

Results and Discussion

Global diversity of insects

A total of 705 insect specimens were collected from the observed inflorescences. These insects were classified into 16 families and seven orders: Coleoptera, Homoptera, Lepidoptera, Neuroptera, Hymenoptera, Heteroptera, and Diptera. The most diverse orders were Heteroptera (5 families), Hymenoptera (4 families), and Diptera (3 families), while the remaining orders each contained only a single family **(Table 2)**. In terms of relative abundance, Hymenoptera (49.6%), Diptera (16.4%), Homoptera (15.2%), and Heteroptera (11.9%) were the most prevalent, whereas Neuroptera (0.8%) and Coleoptera (0.1%) were present in much lower numbers. Statistical analysis showed a significant difference in the relative abundance of different insect orders ($P = 0.000001$; $F = 7.121$) **(Table 2)**. Within the families, Apidae (32.15%) was the most abundant, followed by Polyphagidae (15.16%) and Syrphidae (15.01%), which were moderately abundant. Other families, including Formicidae, Vespidae, Melittidae, Asilidae, Sarcophagidae, Alydidae, Coreidae, Miridae, Pentatomidae, Pyrrhocoridae, Noctuidae, Chrysopidae, and Chrysomelidae, were found in lower numbers. A one-way analysis of variance, followed by the Newman-Keuls test, indicated a significant difference in the relative abundance of insect 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''

A total of twelve insect families from six orders were recorded on the "Yellow Benin" inflorescences. Hymenoptera (four families), Diptera (three families), and Heteroptera (two families) were the orders with the highest number of families, respectively. Hymenoptera showed a notably higher relative abundance compared to the other orders ($P = 0.000001$; $F = 11.174$). Among the families, Apidae and Polyphagidae were significantly more abundant than the rest ($P = 0.000001$; $F = 11.335$).

Variety ''Henry''

Thirteen insect families across six orders were recorded on the "Henry" inflorescences. The orders Hymenoptera, Heteroptera, and Diptera were the most diverse, with Hymenoptera consisting of four families, Heteroptera four families, and Diptera two families. Hymenoptera had a notably higher relative abundance than the other orders ($P = 0.00000$; $F = 5.175$). When considering family abundance, Apidae and Polyphagidae stood out as significantly more abundant than the other families ($P = 0.00000$; $F = 12.376$).

Variety ''James''

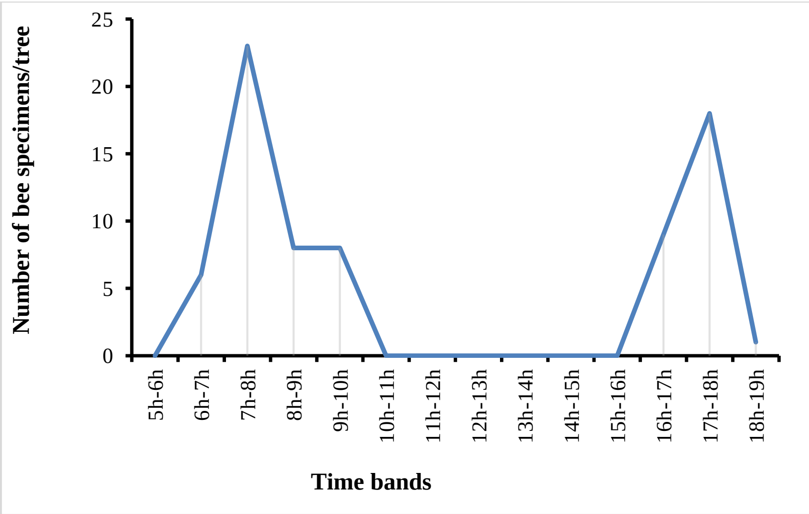
Twelve insect families from five orders were found on the inflorescences of the "James" variety. The most diverse orders were Heteroptera (four families), Hymenoptera (three families), and Diptera (three families). Hymenoptera showed a significantly higher relative abundance compared to the other orders ($P = 0.000$; $F = 4.145$). At the family level, Apidae and Syrphidae exhibited a notably higher abundance than the other families ($P = 0.0000$; $F = 10.319$).

Variety ''Costa Rica''

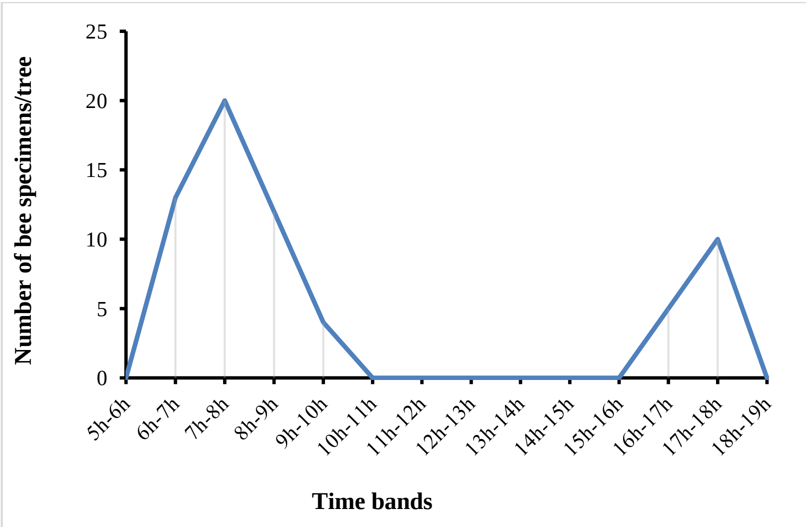
A total of 10 insect families across five orders were recorded. The orders Hymenoptera (with four families) and Heteroptera (with three families) were the most diverse. Hymenoptera showed a significantly higher relative abundance compared to the other orders ($P = 0.00000$; $F = 9.290$). At the family level, Apidae and Syrphidae were the most abundant ($P = 0.0000$; $F = 8.145$).

The activity of the honey bee

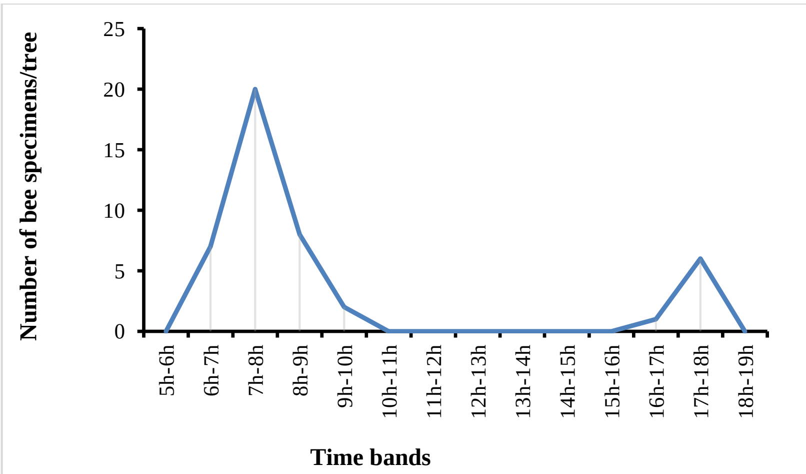
The honey bee visit frequency (F) to the inflorescences varied significantly across different cashew tree varieties ($p < 0.05$). The highest visit rates were recorded on the Henry (F = 30.09%) and Yellow Benin (F = 28.32%) varieties, compared to the Costa Rica (F = 22.12%) and James (F = 19.47%) varieties. The visit rates for the Henry and Yellow Benin varieties were approximately twice as high as those for the Costa Rica and James varieties. Bee activity fluctuated throughout the day. For each variety, no visits were recorded between 5 a.m. and 6 a.m., but the frequency of visits increased rapidly after that, peaking between 7 a.m. and 8 a.m. It then declined gradually, reaching its lowest point around 11 a.m. Activity picked up again toward the late afternoon, with a noticeable increase between 3 p.m. and 4 p.m. and another peak between 5 p.m. and 6 p.m. **(Figure 2**).



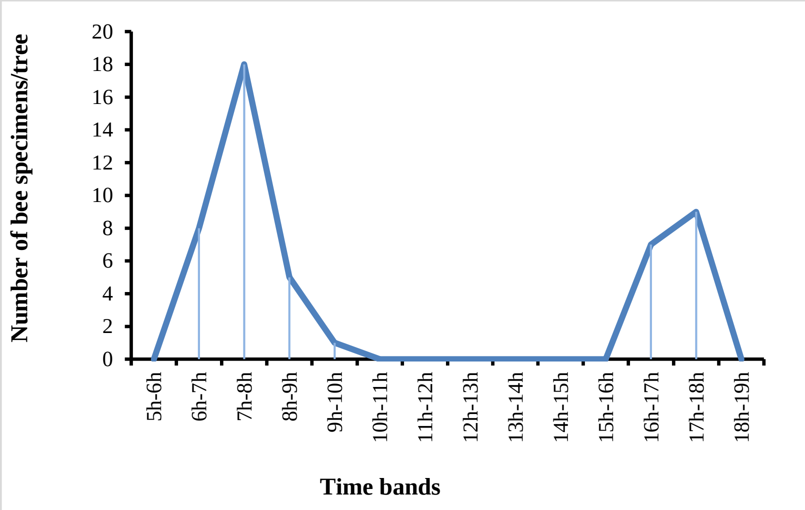
a)



b)



c)

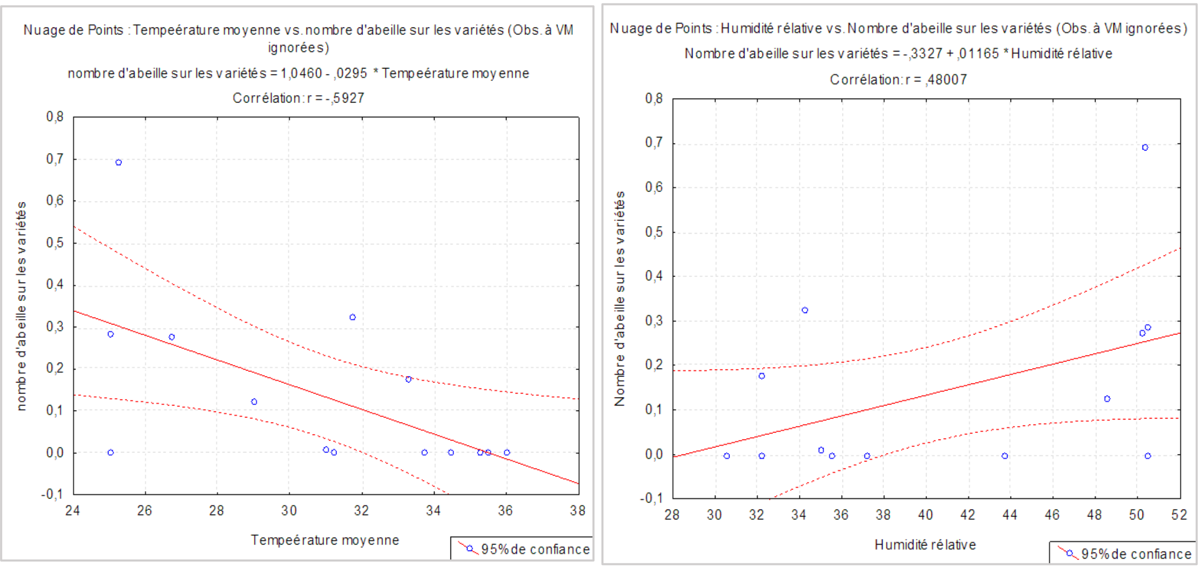


d)

Figure 2. Variation of *Apis mellifera* activity on the different cashew tree varieties' inflorescences. a) Yellow Benin, b) Henry, c) James, d) Costa Rica.

Influence of abiotic factors on honey bee activity

The correlation analysis between abiotic factors and honey bee activity across the four cashew tree varieties' inflorescences revealed that bee activity was significantly impacted by temperature. A negative correlation was observed between temperature and bee activity ($P < 0.05$; $r = -0.59$), indicating an inverse relationship: as temperature decreases to a threshold of 25 °C, bee activity increases, and when temperature rises, bee activity declines **(Figure 3)**. In contrast, relative humidity showed a positive correlation with bee activity ($P < 0.05$; $r = 0.49$), with activity increasing as relative humidity rose, up to a threshold of 50% **(Figure 3)**.



a) b)

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

The analysis of the data revealed a high level of insect diversity. This considerable variety of insects on the cashew tree's inflorescences could be attributed to the fact that the tree's flowering period, which occurs between December and February, coincides with the dry season when food resources for insects (especially bees) are limited. The presence of insects on flowers is not random; it is driven by the search for nourishment. While some insects are attracted to flowers for nectar and pollen, others are drawn to feed on different insects. The attraction is typically due to the color or fragrance of the flowers. As noted by Arnaud *et al*. [13], when an insect moves through its environment, it encounters a range of chemical signals that can alter its behavior or physiology, either attracting or repelling it. Bee diversity tends to be higher during the dry season, as most Apoidea species favor dry climates over humid ones [14]. Some species prefer the dry season specifically because it offers more suitable conditions for nesting, such as fewer issues with mold. Honey bees are the primary visitors to the inflorescences, likely due to their colony-based lifestyle and the presence of numerous beehives near the cashew orchards. A single honey bee colony can contain up to 25,000 individuals, which significantly influences the number of bees visiting nearby crops [15]. Similar studies by Freitas and Paxton have shown that honey bees are the most efficient pollinators of cashew trees in northeastern Brazil [7]. The activity of honey bees peaks in the morning and late afternoon, coinciding with the availability of nectar and pollen. Djonwangwe *et al*. [16] also found that honey bee activity on *Vitellaria paradoxa* inflorescences peaked between 7 a.m. and 8 a.m., a time when the plant species released more pollen and nectar. The increased bee activity in the morning aligns with the peak nectar secretion time [17]. Bees tend to forage more often on flowers that have a higher sugar content in their nectar [18]. Tuo's study on oil palm inflorescences also found that insect activity was highest between 9 a.m. and 1 p.m., peaking at 11 a.m. on the first and second days of anthesis, likely due to the stronger release of anise scent from the flowers at this time [19]. Moreover, factors such as time of day, flower age, and weather conditions can influence the production and quality of nectar [20]. Relative humidity and temperature play a crucial role in flower functioning, which likely explains their correlation with bee activity. Previous research on *P. palinuri* showed that both high temperatures and humidity affected the pollen of this species [21]. Kropacova and Haslbachova [22] also found a negative correlation between temperature and nectar secretion in Trifolium repens. High relative humidity has a positive effect on bee biology. According to Human *et al*. [23], it is particularly important for the development of brood. Similar findings were reported by Koné *et al*. [24], who showed that the highest number of bee visits to zucchini flowers occurred under low temperatures and high relative humidity.

Conclusion

This research aimed to evaluate insect activity on cashew tree inflorescences in northern Côte d'Ivoire. During this initial phase, an inventory of insect species was conducted on four cashew tree varieties: Yellow Benin, Costa Rica, Henry, and James. Findings indicate that Hymenoptera was the most diverse order, while Apidae was the most abundant family. Furthermore, honey bees (*Apis mellifera*) showed a stronger preference for the Yellow Benin and Henry varieties. Future studies will focus on identifying the most effective pollinators for each cashew tree variety.

Acknowledgments: The authors extend their gratitude to the residents of Niofoin for their valuable cooperation during the fieldwork. Appreciation is also expressed to Colleague Hubert Larba Balima from the University of Ouagadougou (Burkina Faso) for their insightful contributions, which helped improve the quality of this article.

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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(3):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(4):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: Pesson P, Louveaux J, eds. Pollinisation et production végétale. Paris: INRA; 1984. p. 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.