Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2021; 9(4): 01-10

Received: 01-05-2021
Accepted: 03-06-2021

**Dolourou Silué**
Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, BP 28 N'Douci Côte d'Ivoire

**Kolo Yéo**
Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, BP 28 N'Douci Côte d'Ivoire

**Nicodénin A Soro**
Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, BP 28 N'Douci Côte d'Ivoire

**Wouter Dekoninck**
Royal Belgian Institute of Natural Sciences, OD Taxonomy and Phylogeny, Rue Vautier 29, B-1000 Brussels, Belgium

**Lombart MM Kouakou**
Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, BP 28 N'Douci Côte d'Ivoire

**Kaly OUATTARA**
Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, BP 28 N'Douci Côte d'Ivoire

**Seydou Tiho**
Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, BP 28 N'Douci Côte d'Ivoire

**Souleymane Konate**
Nangui Abrogoua University, UFR des Sciences de la Nature, Abidjan, BP 28 N'Douci Côte d'Ivoire

**Corresponding Author:**
**Dolourou SILUÉ**
Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, BP 28 N'Douci Côte d'Ivoire

# Detecting bee's floral preference in cashew orchards: A path towards preservation and management of bee communities and improvement of cashew productivity in Côte d'Ivoire

**Dolourou Silué, Kolo Yéo, Nicodénin A Soro, Wouter Dekoninck, Lombart MM Kouakou, Kaly Ouattara, Seydou Tiho and Souleymane Konaté**

**DOI:** https://doi.org/10.22271/j.ento.2021.v9.i4a.8745

**Abstract**
In spite of the low agronomic performances of Ivorian cashew orchards, Côte d'Ivoire recently became the first worldwide producer and exporter of raw cashew nuts. To maintain this ringleader position, several factors should be understood including the ecological factors supporting this success. Pollination service due to bees was recognized to impact cashew production. Therefore, determining cashew trees that are more attractive to bees can contribute to promote pollination activities. To detect these cashew trees possessing the flowers preferred by bees, two types of investigations were undertaken: (1) a socioeconomic survey in 3167 cashew hectares belonging to 381 producers and (2) an experimental detection of the bees' floral preference. As results, 58 of the 381 interviewed producers had identified the bees' floral preference resulting in a detection of 681 cashew trees. The flowers of the preferred cashew trees were visited 5 times more and they attracted 3 times more bee foragers as compared to non-preferred cashew trees. These findings may be included in research programs focus on: (i) improvement of agronomic performances and (ii) effective management of bees' community.

**Keywords:** bees' floral preference, preferred cashew trees, non-preferred cashew trees

## Introduction
Cashew trees (*Anacardium occidentale* L.), are native to the northeast of Brazil [1]. This plant species contributes to socio-economic development in several African, Asian and South American countries [2, 3]. In Côte d'Ivoire, one variety of cashew plants (Jumbo) was introduced in the north of the country (Korhogo) in 1960s, because of its rapid growth and hardiness in order to combat deforestation, soil erosion and bush fires [4-6]. From 1960 to 2018, this variety of cashew plants was propagated by the smallholders without the assistance of researchers and government funding programs [7-9]. Consequently, the heterogeneous wild seeds were used as vegetal material to propagate cashew plants in Côte d'Ivoire [4]. According to F.I.R.C.A [7] and C.C.A [10] the nuts from these cashew plants became the most important: (i) cash crop in 20 regions out of 31 existing in Côte d'Ivoire; and (ii) source of monetary income for more than 5,000,000 people, including 500,000 smallholders. Presently, the cashew nuts has become a second most export crop after cocoa due to its important weight in the national economy (valued at more than 700 million USD) [11]. Also, the Côte d'Ivoire has become the first worldwide producer and exporter of raw cashew nuts with 25% of the global production and 50% of the world's supply [12-13].
To maintain this ringleader position in cashew production, and to improve its impact on Ivoirian society, it is important to understand the ecological factors supporting this success. Studies have reported that many biotic and abiotic factors may contribute to the success of cashew production [14-16]. Among these ecological factors, ecosystem services delivered by bees might play a major role. Soro [17] and Bhattacharya [18] for example, demonstrated that the reproduction of cashew trees depends on cross-pollination due to bees mainly *Apis mellifera*. Likewise in Vietnam, Brazil, India, Ghana, and Benin studies have revealed that bee pollination is one of the key ecological factors that may increase cashew trees productivity

and fruits quality [14, 19-21]. In these countries, some farmers have linked the cashew farming with beekeeping [20, 22-24]. This association has increased cashew trees productivity and fruits quality (form 10 kg/trees to 25 kg/trees) [22, 23, 25, 26] Hence, bee foraging intensity has become essential for the reproduction of cashew trees [14, 22, 27-29].

Recently, we noted during an empirical investigation in the cashew orchards from Hambol and Bounkani region (Côte d'Ivoire): (i) a few cashew trees with high foraging activity of bees including high yields, and (ii) many cashew trees with low foraging activity including low yields. This important role of bees in cashew reproduction raises a few questions. Firstly, do bees forage equally on the flowers of all the cashew trees in an orchard? Secondly, does attractive capacity of flowers vary from one cashew plant to another in an orchard? In Côte d'Ivoire, studies on bees' communities within cashew agro-systems are lacking [15]. In this study, we hypothesize that bees have some preference among cashew trees which can be shown by their high foraging activity on such trees during flowering periods. The overall goal of this study is to determine cashew trees that are preferred by bees and that may consequently contribute to effective management of bees and to the improvement of cashew production in Côte d'Ivoire.

## Materials and Methods

### Description of study sites

The study was conducted in 16 important cashew producing regions out of the 20 recognized regions in Côte d'Ivoire [13]. The selected regions included Kabadougou, Pôrô, Worodougou, Béré, Marahoué, Folon, Hambol, Gbêkê, N'zi, Indenie, Gountougo, Bafing, Bagoué, Haut-sassandra, Iffou, and Belier region (Fig 1). The natural vegetation in these regions is characterized by savannahs, and semi deciduous forests [30-31] with a dominance of savannahs. In each of the producing regions, we have only one variety of cashew plants (Jumbo) including several wild types that are established with heterogeneous wild seeds [4]. Among the 16 investigated regions, 4 main producing regions were chosen to test experimentally the hypothesis that bees have some floral preference among cashew trees. The chosen regions were Pôrô; Béré; Hambol and Marahoué region (Fig 1).

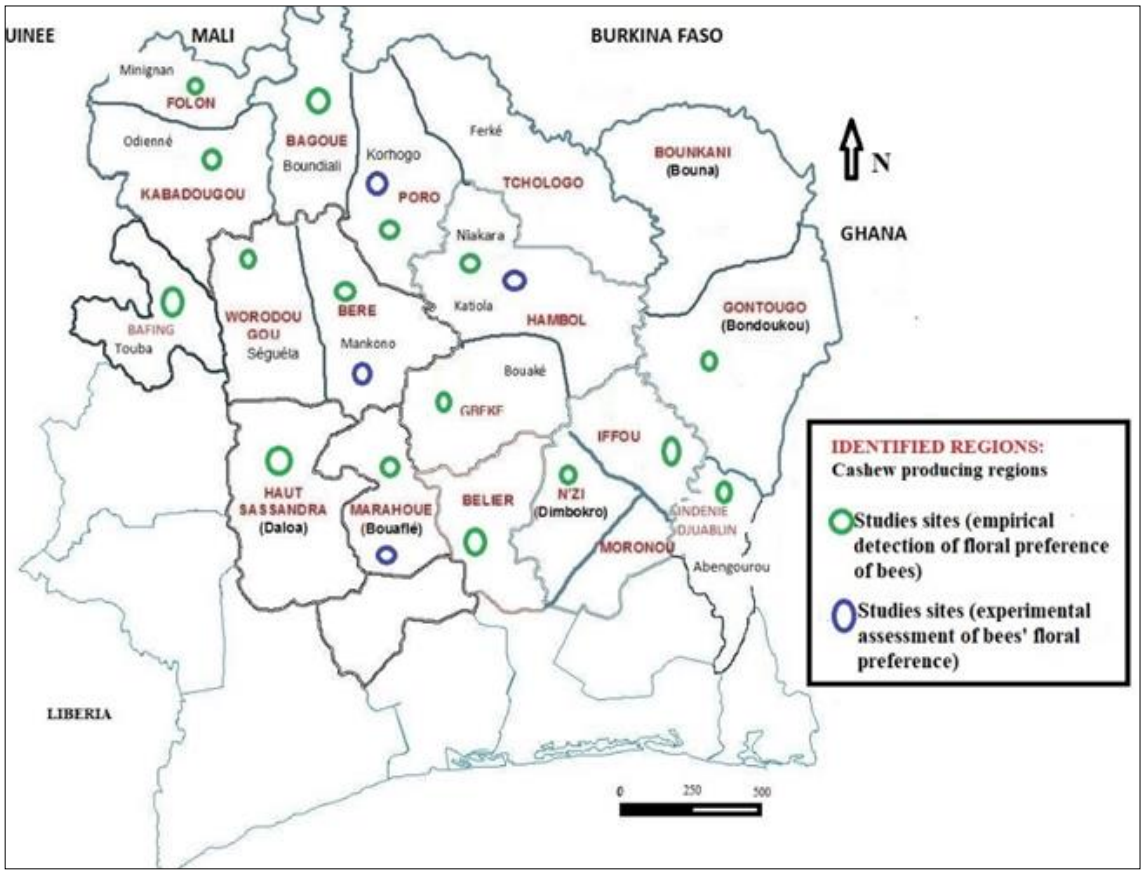



**Fig 1:** Location of studies sites

### Detection of bees' floral preference in cashew orchards

To detect the bees' floral preference in cashew orchards, two types of investigations were undertaken. Firstly, a socioeconomic survey which consisted in interviewing cashew producers to catch their perception during the non-flowering period. Secondly, an experimental assessment of bees' floral preference during the flowering period.

### Assessing the empirical detection of bees' floral preference according to cashew producers' observations

The detection of bees' foraging preference in cashew orchards as perceived by producers, was conducted during non-flowering period using a survey from May to November in 2019. The choice of non-flowering period was due to the necessity that the responses of producers should be independent of flowering season, but rather linked to their individual experience, what they have observed over years in their orchards. This survey was based on a questionnaire (Appendix) which included the following aspects: (i) Famers and orchards identification, and (ii) their knowledge on cashew trees preferred and non-preferred by bees (floral preference of bees).

Cashew trees labeling

To label each category of cashew trees, green paint was used

and the first letter of the: (i) name of region and locality, (ii) number of the orchard investigated in the locality and (iii) number of the tree in the orchard were painted on the trunk. The cashew trees preferred by bees (category A) were marked with capitalize letters while the cashew trees non-preferred by bees (category B) were in small letters.

**Experimental assessment of the bees' floral preference**

In each region, one orchard was selected in which 10 cashew trees of both categories (A and B) were detected. Also, 4 branches were chosen according to the four cardinal directions (North, South, East and West) per selected cashew tree. The main criteria for this choice was the necessity to involve at least 30 inflorescences per selected branch.

**Bees sampling**

The samples were collected during the peak flowering period in February 2020 using two methods namely: (i) direct counting of bee' foragers on the flowers of cashew trees, and (ii) direct capturing using an entomological nets. In practice, during 3 days (3 replicates), samples were collected on each selected branch per cashew tree, at the following times: 7 am, 9 am, 11 am, 1 pm, 3 pm, 5 pm. The sampling duration was 20 minutes split in 5 minutes per branch and per sampling time.

**Data analysis**

**Bees' floral preference according to producers' opinion**

The proportion of producers (Pf) who were able to identify each category of tree was calculated using the formula Pf = (p/Pt) x 100, where p is an individual counting of producers who have identified each category of cashew trees per study region, and Pt is a total number of producers investigated per study region. In each region, the proportion of cashew trees per category (Pc) was calculated using the formula: Pc = (c/Ct) x 100, where c is the individual counting of each category of cashew trees identified per region, Ct is the total number of cashew trees investigated in the region.

**Experimental evaluation of bees' floral preference**

**Identification of bees**

The bees specimens were mounted, labeled and identified using the determination keys of Eardley [32] and Eardley *et al*. [33] under Olympus SZ61 binocular loupe. The reference collection of bees of Côte d'Ivoire housed in the Lamto Scientific Reserve [17, 34, 35] was also used during this work. Voucher specimens of all the identified species are available at the Lamto.

**Bees' foraging activity**

The foraging activity of bees represents the number of flowers that are foraged by the bees per minute [27]. This parameter was determined by individual counting of flowers that are foraged by bees per sampling time.

**Frequency of bees' visits**

The frequency of bees' visits on cashew flowers (F) represents the percentage of bee' abundances that visits the flowers of each category tree [36, 37]. It was calculated using this formula: $F = (n/N) \times 100$. So, n is the bees' abundance on the flowers per category tree; and N is the total abundance of bees in both categories of cashew trees in the orchard. Also, these frequency of bees' visits was classified according to Silveira Neto *et al*. [36] as (i) Very low (0% < Frequency ≤ 25%), (ii) Low (25% < Frequency < 50%), (iii) Medium (Frequency = 50%), (iv) High (50% < Frequency ≤ 75%), (v) Very high (75% < Frequency ≤ 100%).

**Attractive capacity of flowers**

The attractiveness of cashew flowers (A) represents the peak capacity of cashew flowers on bees' species attraction in the orchards [36-37]. It was calculated using this formula: $A = (s/St) \times 100$. So, s is the species richness observed on the flowers per category of tree, and St is the total species on both categories in the orchard. Also, these attractiveness was classified according to Silveira Neto *et al*. [36] as: (i) Very low (0% < Attractiveness ≤ 25%), (ii) Low (25% < Attractiveness < 50%), (iii) Medium (Attractiveness = 50%), (iv) High (50% < Attractiveness ≤ 75%), (v) Very high (75% < Attractiveness ≤ 100%).

**Preference index of flowers**

The preference index of cashew flowers (P) represents the medium capacity of cashew flowers on bees' species attraction in the orchards [36, 37] with modifications. It was calculated using the formula: $P = (s/Sest) \times 100$, where s is the species richness observed on the flowers per category tree; and Sest is the species richness estimated (Chao 2) in the orchard. Also, these preference index was classified according to Silveira Neto *et al*. [36] as: (i) Very low (0% < Preference ≤ 25%), (ii) Low (25% < Preference < 50%), (iii) Medium (Preference = 50%), (iv) High (50% < Preference ≤ 75%), (v) Very high (75% < Preference ≤ 100%).

**Statistical analysis**

The species richness observed (Sobs) was obtained by direct counting of bees' species after identification. The Estimate S software version 9.1 [38] was necessary to obtain the: (i) estimated species richness (Chao 2), (ii) local diversity (Simpson's index), and (iii) evenness. Also, the Jaccard Similarity index was used to compare species composition between the two categories of cashew trees in each region illustrated using a Hierarchical Ascending Classification (H.A.C) performed with Paleontological STatistics (P.A.S.T) version 3.09 [39] at a significance level of 0.05. In this study, all data were analyzed using the Levene's test for homogeneity of variances in order to test for normal distribution of our data before comparison between the different categories of cashew trees. In case of normal distribution the Tukey's pairwise test or one way analysis of variance (ANOVA) on repeated measure was necessary for the multiple comparisons. If not the non-parametric multivariate analysis of variance Kruskal-Wallis or the test U of Mann-Whitney was used for comparison.

**Results and Discussions**

**Empirical detection of bees' floral preference**

Results indicated that, the bee floral preference was detected in the cashew orchards (Table 1 and 2). This result demonstrates probably the important variations (genetics, morphologics and agronomics) of cashew vegetal material from one plant to another within the orchards of Côte d'Ivoire. These important variations of cashew trees, could probably be explained by the: (i) non-adapted agricultural practices such as the use of heterogeneous seeds (nuts) in cashew farming areas since the introduction of this plant in Côte d'Ivoire, (ii) geographic origin of cashew trees (from Brazil to Côte d'Ivoire), and (iii) adaptation of these cashew

plants to the new ecological factors in Côte d'Ivoire [40, 41].

Regarding the: (1) acreage of cashew orchards investigated, (2) proportion of categories cashew trees recorded, (3) proportion of producers who could detect both categories of cashew trees, and (4) producers experience, results reported a few detection bees' floral preference (681 cashew trees out of 3167 hectares). This result could probably explained by the low efficacy of producers' opinion as method to detect the bees' floral preference in the orchards of Côte d'Ivoire. This low efficacy of producers' opinion in the detection of bees' floral preference could probably due to their lack knowledge on the role of bees in the pollination of crops, and therefore explain: (i) the low integration of beekeeping, and (ii) few producers carefully observe their cashew trees and they were able to detect the floral preference of bees in their orchards [42].

Conversely, the table 1 and 2 showed a high distribution of non-preferred trees form an cashew orchard to another (Tukey's pairwise test p = 0.0001). This high distribution of non-preferred trees could probably due to a low heritable characters (attractiveness of flowers, productivity of trees) in the types of seeds that are used by producers, and therefore explain the low yields (500 kg/ha) of cashew orchards in Côte d'Ivoire.

**Table 1:** Bees' floral preference detection by producers and proportion of cashew trees categories per region

| | **Producers' opinions on bees' floral preference** | | **Proportion of producers who were able to detect the categories of cashew** | | **Proportion of cashew trees detected** | |
|---|---|---|---|---|---|---|
| **Regions** | **Detected (%)** | **Not-detected (%)** | **Preferred (%)** | **Non-preferred (%)** | **Preferred (%)** | **Non-preferred (%)** |
| Kabadougou | 82.5 a | 17.5 b | 15 b | 82.5 a | 0.25 b | 87.1 a |
| Folon | 86.66 a | 13.33 b | 16.66 b | 86.66 a | 0.3 b | 80 a |
| Pôrô | 72.1 a | 27.9 b | 11.63 b | 72.1 a | 0.18 b | 63.56 a |
| Bagoué | 87.5 a | 12.5 b | 16.66 b | 87.5 a | 0.24 b | 88.78 a |
| Worodougou | 82.14 a | 17.85 b | 14.3 b | 82.14 a | 0.36 b | 75.75 a |
| Marahoué | 74.1 a | 25.92 b | 22.22 b | 74.1 a | 0.14 b | 74.1 a |
| Béré | 73.1 a | 26.92 b | 11.54 b | 73.1 a | 0.15 b | 80.35 a |
| Gkêkê | 95 a | 5 b | 10 b | 95 a | 0.18 b | 89.47 a |
| Haut-sassandra | 100 a | 0 b | 25 b | 100 a | 0.37 b | 66.66 a |
| N'zi | 100 a | 0 b | 15 b | 100 a | 0.25 b | 66.11 a |
| Gountougo | 94.4 a | 5.55 b | 27.77 b | 94.4 a | 0.34 b | 81.8 a |
| Iffou | 100 a | 0 b | 20 b | 100 a | 0.35 b | 76.84 a |
| Belier | 85.2 a | 14.8 b | 3.7 b | 85.2 a | 0.07 b | 74.1 a |
| Bafing | 100 a | 0 b | 21.43 b | 100 a | 0.16 b | 67.64 a |
| Indenie-Djuablin | 100 a | 0 b | 10 b | 100 a | 0.3 b | 72.22 a |
| Hambol | 100 a | 0 b | 100 a | 100 a | 2 b | 72 a |
| Averages | 89.54 a | 10.35 b | 21.31 b | 89.54 a | 0.353 b | 76.03 a |
| Values of p | p = 0.00012 | | p = 0.00011 | | p = 0.0001 | |

According to the regions, the proportions within the same line followed by the letters (a and b) are significantly different by the Tukey's test ($p < 0.05$)

**Table 2:** Detailed socioeconomic survey

| | **Producers identification** | **Orchards** | **Bees floral preference according to the producers** | **Counting of cashew trees per category** |
|---|---|---|---|---|
| | **a/Number b/Average experience (years)** | **Surface (hectare)** | **a/Detection of preferred trees b/Detection of non-preferred trees c/Not-detected** | **a/Preferred b/Non-preferred c/Absence** |
| Kabadougou | a/40 persons, b/24 | 310 | a/6 persons; b/33 persons; c/7 persons | a/78; b/27000; c/3922 |
| Folon | a/30 persons, b/21 | 225 | a/5 persons; b/26 persons; c/4 persons | a/69; b/18000; c/4431 |
| Pôrô | a/43 persons; b/28 | 472 | a/5 persons; b/31 persons; c/12 persons | a/85; b/30000; c/17115 |
| Bagoué | a/24 persons, b/24 | 214 | a/4 persons; b/21 persons; c/3 persons | a/52; b/19000; c/2348 |
| Worodougou | a/28 persons; b/19 | 132 | a/4 persons; b/23 persons; c/5 persons | a/48; b/10000; c/3152 |
| Marahoué | a/27 person ; b/28 | 243 | a/6 persons; b/20 persons; c/7 persons | a/35; b/18000; c/6265 |
| Béré | a/52 persons, b/20 | 560 | a/6 persons; b/38 persons; c/14 persons | a/88; b/45000; c/10902 |
| Gkêkê | a/20 persons, b/18 | 190 | a/2 persons; b/19 persons, c/1 persons | a/35, b/17000; c/1965 |
| Haut-sassandra | a/12 persons, b/22 | 75 | a/3 persons; b/12 persons; c/0 persons | b/28; b/5000; c/2472 |
| N'zi | a/20 persons; b/25 | 121 | a/3 persons; b/20 persons; c/0 persons | a/30; b/8000; c/4070 |
| Gountougo | a/18 persons; b/24 | 110 | a/5 persons; b/17 persons; c/1 persons | a/38; b/9000; c/1962 |
| Iffou | a/15 persons; b/26 | 95 | a/3 persons; b/15 persons; c/0 persons | a/34; b/7300; c/2166 |
| Belier | a/27 persons; b/27 | 243 | a/1 persons; b/23 persons; c/4 persons | a/18; b/18000; c/6282 |
| Bafing | a/14 persons; b/21 | 136 | a/3 persons; b/14 persons; c/0 persons | a/22; b/9200; c/4378 |
| Indenie Djuablin | a/10 persons; b/18 | 36 | a/1 persons; b/10 persons; c/0 persons | a/11; b/2600; c/989 |
| Hambol | a/1 person; b/25 | 5 | a/1 persons; b/1 persons; c/0 persons | a/10; b/360; c/130 |
| Total | a/381 persons; b/22.6 | 3167 | a/58 persons; b/320 persons; c/60 persons | a/681; b/243460, c/72559 |

**Experimental assessment of bees' floral preference in cashew orchards**

**Bees' abundance, their foraging activities and frequency of visits**

The table 3 shows a comparison of floral preference parameters including (1) bees' abundance, (2) foraging intensity and (3) frequency of visits. This comparison revealed a significant difference between the two categories of cashew trees (Mann Whitney U test, respectively for these parameters in table 3, p = 0.0021, p =0.0036; p = 0.0021). Results revealed also the preferred cashew trees are visited 5 times more by bees than the non-preferred ones. Specifically, we collected a total of 18875 foraging bees of which 15518 on preferred trees (83 ± 2.2% of total abundance) and 3357 on non-preferred trees (17 ± 2.2% of total abundance). Likewise, the flowers of these cashew trees preferred by bees are intensely foraged (1.1 ± 0.013 flowers/minute) compared to non-preferred trees (0.23 ± 0.04 flowers/minute). These results demonstrated probably a high quality of floral resources (nectar and pollen) detected by bees in the flowers of these preferred cashew trees. This high quality of floral resource, could probably be explained by the distinct genetic material from these cashew plants that produce the particular food sources affecting the attractiveness of their flowers such as: (i) volume of nectar and sugar concentration, (ii) quantity of amino-acid and vitamin C in nectar and pollen, and (iii) total polyphenolic and titratable acid in nectar and pollen [44-46]. In other hand, the particularity of phenology of flowers could probably explained also this foraging preference of bees toward these trees [46]. Indeed, we noted for the first time in Côte d'Ivoire some preliminary floral characteristics of cashew trees preferred by bees namely: (1) two flowering and fruiting season per year (in dry season from October to February, and rain season from June to September), and (2) great number of flowers per inflorescence (560 flowers per inflorescence). So, our results evidenced that the preferred cashew trees operate as melliferous plants, and produce the necessary resources (nectars and pollens) including calories for bees during the dry season (where the most habitats are not flowering in the North of Côte d'Ivoire).

Conversely, the assessed parameters of floral preference were significantly lower on the flowers from non-preferred trees compare to the flowers of preferred cashew trees. These results could probably be attributed at the disadvantageous climate factors (sunny, temperature and relative humidity) that are probably affect negatively reproduction phenology in these non-preferred trees, and consequently the availability of floral resources like nectar and pollen [43-47]. Indeed, we noted one late flowering and fruiting season per year (only in dry season from January to April) with low number of flowers per inflorescence (250 flowers/inflorescence) during the reproduction period of these trees. So, our results evidenced that the non-preferred cashew trees operate as non-melliferous plants during the dry season (where the most habitats are not flowering in the North of Côte d'Ivoire).

**Table 3:** Bee abundances, their foraging activity and frequency of visits

| | | Sampling hours | | | | | | | Values of p |
|---|---|---|---|---|---|---|---|---|---|
| | | **Categories of cashew trees** | **7 am** | **9 am** | **11 am** | **1 pm** | **3 pm** | **5 pm** | **Total** | |
| Pôrô region | Abundance | P | 605 a | 736 a | 807 a | 698 a | 583 a | 744 a | 4173 a | p = 0.002 |
| | | NP | 125 b | 129 b | 203 b | 138 b | 114 b | 191 b | 900 b | |
| | Foraging activity (Flowers/minute) | P | 1.01 a | 1.23 a | 1.35 a | 1.16 a | 1 a | 1.24 a | 1.15 ± 0.13 a | p = 0.0031 |
| | | NP | 0.21 b | 0.22 b | 0.34 b | 0.23 b | 0.19 b | 0.32 b | 0.25 ± 0.05 b | |
| | Frequency of visits (%) | P | 82.9 a | 85.1 a | 79.9 a | 83.5 a | 83.6 a | 79.6 a | 82.4 a | p = 0.002 |
| | | NP | 17.1 b | 14.9 b | 20.1 b | 16.5 b | 16.4 b | 20.4 b | 17.6 b | |
| Béré region | Abundance | P | 580 a | 704 a | 790 a | 656 a | 561 a | 632 a | 3923 a | p = 0.0019 |
| | | NP | 89 b | 103 b | 125 b | 91 b | 81 b | 105 b | 594 b | |
| | Foraging activity (Flowers/minute) | P | 0.96 a | 1.1 a | 1.32 a | 1.09 a | 0.93 a | 1.05 a | 1.1 ± 0.13 a | p = 0.0027 |
| | | NP | 0.15 b | 0.1 b | 0.21 b | 0.15 b | 0.13 b | 0.17 b | 0.16 ± 0.02 b | |
| | Frequency of visits (%) | P | 86.7 a | 87.2 a | 86.3 a | 87.8 a | 87.4 a | 85.8 a | 86.9 ± 2.2a | p = 0.0019 |
| | | NP | 13.3 b | 12.8 b | 13.7 b | 12.2 b | 12.6 b | 14.2 b | 13.1 ± 2.2b | |
| Marahoué region | Abundance | P | 506 a | 626 a | 695 a | 612 a | 493 a | 604 a | 3536 a | p = 0.002 |
| | | NP | 131 b | 145 b | 201 b | 151 b | 116 b | 186 b | 930 b | |
| | Foraging activity (Flowers/minute) | P | 0.84 a | 1.04 a | 1.16 a | 1.02 a | 0.82 a | 1.01 a | 1 ± 0.12 a | p = 0.004 |
| | | NP | 0.22 b | 0.24 b | 0.33 b | 0.25 b | 0.19 b | 0.31 b | 0.26 ± 0.05 b | |
| | Frequency of visits (%) | P | 79.4 a | 81.2 a | 77.6 a | 80.2 a | 80.9 a | 76.5 a | 79.3 ± 2.3a | p = 0.002 |
| | | NP | 20.6 b | 18.8 b | 22.4 b | 19.8 b | 19.1 b | 23.5 b | 20.7 ± 2.1b | |
| Hambol region | Abundance | P | 538 a | 669 a | 772 a | 648 a | 562 a | 699 a | 3888 a | p = 0.0021 |
| | | NP | 118 b | 166 b | 190 b | 147 b | 126 b | 185 b | 932 b | |
| | Foraging activity (Flowers/minute) | P | 0.9 a | 1.11 a | 1.3 a | 1.08 a | 0.94 a | 1.16 a | 1.08 ± 0.13 a | p = 0.0029 |
| | | NP | 0.19 b | 0.28 b | 0.32 b | 0.24 b | 0.21 b | 0.31 b | 0.26 ± 0.04 b | |
| | Frequency of visits | P | 82 a | 80.1 a | 80.2 a | 81.5 a | 81.7 a | 79.1 a | 80.8 ± | p = 0.0021 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (%) | | | | | | | | 2.1a | |
| | | NP | 18 b | 19.9 b | 19.8 b | 18.5 b | 18.3 b | 20.9 b | 19.2 ± 2b | |
| Total | Abundance | P | - | - | - | - | - | - | 15,518 a | p = 0.0021 |
| | | NP | - | - | - | - | - | - | 3,357 a | |
| | | Total | - | - | - | - | - | - | 18,875 | |
| | Foraging activity (Foragers/minute) | P | - | - | - | - | - | - | 1.1 ± 0.013 a | p = 0.0036 |
| | | NP | - | - | - | - | - | - | 0.23 ± 0.04 b | |
| | Frequency of visits (%) | P | - | - | - | - | - | - | 83 ± 2.2 a | p = 0.0021 |
| | | NP | - | - | - | - | - | - | 17 ± 2.2 b | |

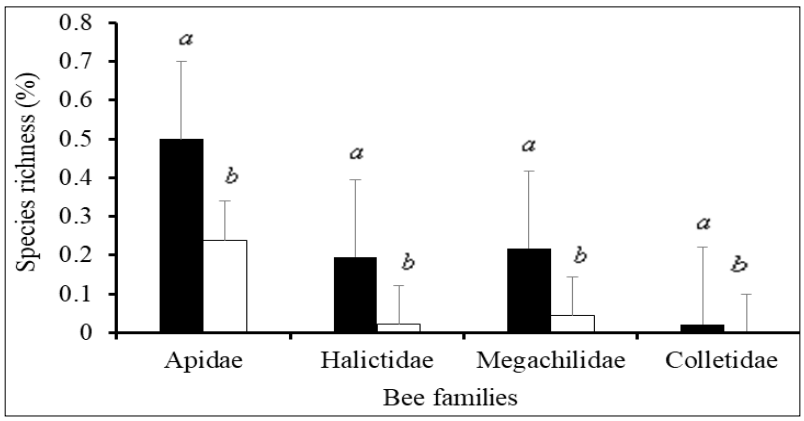
According to sampling times, the numbers followed by the letters (a and b) within the same column are significantly different by the Mann Whitney's test ($p < 0.05$). Abbreviations: P = preferred cashew trees, NP = Non-preferred cashew trees

**Species richness and bees' diversity, attractive capacity and preference index of cashew flowers**

A total of 46 bee species belonging to 24 genera and 4 families were recorded during the identification of bees' floral preference. Among these 4 families of bees collected on the flowers of the two categories of cashew trees, the family of Apidae (73.91% of the species) was the richest, followed by the Megachilidae (26.08%), Halictidae (21.74%) and Colletidae (2.17%) (Fig 2 and Table 4). The observed and expected species richness in each orchard are showed in the table 5. Sampling coverage was 55.42% for the 4 studied regions. Regarding the categories trees, the flowers of preferred cashew trees attract 3 times more bees species compared to the non-preferred cashew trees. Specifically, 43 bees' species were recorded on the flowers of cashew trees identified by producers as preferred by bees while 14 species were found on trees identified as non-preferred. Also, the Simpson's index was higher for the flowers of preferred cashew trees (0.8) compared to the non-preferred trees (0.6). However, the evenness was higher on the flowers of non-preferred cashew trees (0.4) compared to preferred cashew trees (0.2). Hence, the comparison of the parameters of bees' diversity including: (1) species richness, (2) diversity and (3) evenness, revealed a significant difference between these two categories of cashew trees (Mann Whitney U test, respectively for these 3 parameters of diversity $p = 0.003$; $p = 0.030$; $p = 0.031$) (Table 5). This high diversity of bee' communities might explain the high foraging intensity of bees on the flowers from these preferred cashew trees, and consequently affect positively their pollination, fruit-set, and productivity. So, ours results also evidenced that the (1) high foraging activity, and (2) high diversity of bee' communities on the flowers from these preferred cashew trees might probably suggest their potential high productivity. This result could be attributed at the quality of soils nutrients under these trees that affect probably the quality of nectar and pollen, and therefore explain the high diversity of bees and their foraging intensity [40-46].

The table 5 also reported that, the attractive capacity and preference index were significant higher on flowers from the preferred cashew trees than non-preferred trees (Mann Whitney U test, respectively for these 2 parameters of preference $p = 0.027$; $p = 0.033$). Amongst the regions, this attractive capacity of flowers varied between 93.75 and 100% of the observed species on the preferred trees while it fluctuated from 22.22 to 37.5% of the observed species on the flowers of non-preferred trees. Likewise, the preference index of cashew flowers varied between 51. 28 and 60.04% of estimated bee species for preferred trees while it fluctuated from 12 to 21% of estimated bee species for the non-preferred trees. This result could be explained by the occurrence of pests on the flowers of these preferred trees that are probably very low, and consequently don't affect the qualities of floral resources, and their pollination, fruits-sets, and potential productive capacity [40].

Conversely, ours results revealed that: (1) the diversity of bees' community, (2) attractive capacity and preference index, were significantly lower on the flowers from non-preferred trees compare to the preferred cashew trees. These results could probably explain the low foraging intensity of bees on the flowers of these trees, and consequently affect negatively their pollination, fruit-set, and productivity. So, the results evidenced that this low diversity of bees on the flowers from these trees might probably suggest their potential low productivity. These results could probably due to the volume of nectar and the quantity of pollen that are probably low, and therefore affect negatively the attractiveness of flowers and consequently the bees 'diversity [42-47].




According to the bees families, the proportions followed by letter (a and b) within the same family are significantly different by the Mann Whitney's test ($p < 0.05$)

**Fig 2:** Bee families recorded within cashew orchards per category tree

**Table 4:** Bee species collected within the cashew orchards of Côte d'Ivoire

| | Categories of cashew trees | Pôrô region | | Béré region | | Marahoué region | | Hambol region | |
|---|---|---|---|---|---|---|---|---|---|
| | | P | NP | P | NP | P | NP | P | NP |
| Apidae | *Apis mellifera* | 2558 | 477 | 2241 | 462 | 2012 | 498 | 2206 | 489 |
| | *Allodape* sp.1 | 3 | 0 | 0 | 0 | 13 | 0 | 0 | 0 |
| | *Allodape* sp.2 | 4 | 0 | 0 | 0 | 13 | 0 | 0 | 0 |
| | *Allodape* sp.3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Amegilla* sp.2 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 1 |
| | *Amegilla* sp.3 | 0 | 0 | 0 | 0 | 1 | 0 | 8 | 0 |
| | *Anthophora* sp.1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| | *Ceratina* sp.1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | *Ceratina* sp.2 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 |
| | *Ceratina* sp.3 | 9 | 0 | 0 | 0 | 6 | 0 | 0 | 0 |
| | *Cleptotrigona* sp.1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 |
| | *Dactylurina staudingeri* | 66 | 12 | 234 | 24 | 135 | 24 | 276 | 45 |
| | *Hypotrigona* sp.1 | 94 | 19 | 120 | 32 | 0 | 2 | 18 | 0 |
| | *Meliponula beccarii* | 76 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Meliponula bocandei* | 296 | 30 | 456 | 76 | 451 | 70 | 428 | 55 |
| | *Meliponula ferruginea* | 43 | 11 | 0 | 0 | 0 | 0 | 84 | 12 |
| | *Meliponula togoensis* | 1006 | 332 | 832 | 0 | 829 | 330 | 829 | 330 |
| | *Meliplebeia* sp.1 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 0 |
| | *Pasites* sp.1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | *Pasites* sp.2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | *Pasites* sp.3 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Xylocopa albiceps* | 0 | 0 | 0 | 0 | 14 | 3 | 0 | 0 |
| | *Xylocopa olivacea* | 0 | 0 | 10 | 0 | 6 | 2 | 0 | 0 |
| | *Xylocopa* sp.1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Halictidae | *Acunomia* sp.1 | 9 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| | *Crocisaspidia chandleri* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Lasioglossum* sp.1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| | *Pseudapis* sp.1 | 0 | 0 | 0 | 0 | 10 | 0 | 14 | 0 |
| | *Pseudapis* sp.2 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 |
| | *Pseudapis* sp.3 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 |
| | *Pseudapis* sp.4 | 1 | | 3 | 0 | 0 | 0 | 0 | 0 |
| | *Pseudoanthidium tuberculiferum* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | *Pachynomia amoenula* | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 |
| | *Steganomus* sp.1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | *Stictonomia schubotzi* | 19 | 0 | 9 | 0 | 0 | 0 | 0 | 0 |
| Megachilidae | *Anthidiini* sp.1 | 5 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| | *Anthidiini* sp.2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | *Megachile ianthoptera* | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Lithurgus spiniferus* | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 |
| | *Lithurgus* sp.3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| | *Lithurgus* sp.4 | 2 | | 0 | 0 | 2 | 0 | 0 | 0 |
| | *Lithurgus* sp.5 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 0 |
| | *Litthurgus* sp.6 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 |
| | *Lithurgus* sp.7 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 |
| | *Lithurgus* sp.8 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Colletidae | *Colletes* sp.1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

Abbreviations: P = preferred cashew trees, NP = Non-preferred cashew trees.

**Table 5:** Parameters of bees' diversity and floral preference

| Studies regions | | Parameters of bees 'diversity | | | | | Parameters of floral preference | |
|---|---|---|---|---|---|---|---|---|
| | Categories of cashew trees | Observed richness | Estimated richness (Chao 2) | Samples coverage (%) | Simpson index | Evenness | Attractive capacity of flowers (%) | Preference index of flowers (%) |
| Pôrô | Preferred | 20 a | 39 | 53.84 | 0.7 a | 0.106 b | 95.23 a | 51. 28a |
| | Non-preferred | 8 b | | | 0.51 b | 0.256 a | 38.09 b | 20.05 b |
| | Total | 21 | | | 0.75 | 0.101 | - | - |
| Béré | Preferred | 18 a | 32 | 56.25 | 0.59 a | 0.144 b | 100 a | 56.25 a |
| | Non-preferred | 4 b | | | 0.3 b | 0.355 a | 22.22 b | 12.5 b |
| | Total | 18 | | | 0.6 | 0.134 | - | - |
| Marahoué | Preferred | 26 a | 43 | 62.79 | 0.75 a | 0.098 b | 96.29 a | 60.04 a |
| | Non-preferred | 9 b | | | 0.6 b | 0.27 a | 33.33 b | 20.93 b |
| | Total | 27 | | | 0.78 | 0.094 | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Hambol | Preferred | 15 a | 29 | 55.17 | 0.57 a | 0.215 b | 93.75 a | 51.72a |
| | Non-preferred | 6 b | | | 0.5 b | 0.409 a | 37.5 b | 20.68 b |
| | Total | 16 | | | 0.65 | 0.195 | - | - |
| Total | Preferred | 43 a | 83 | 55.42 | 0.8 a | 0.2 b | 93.47 a | 51.8a |
| | Non-preferred | 14 b | | | 0.6 b | 0.4 a | 30.43 b | 16.86b |
| | Total | 46 | | | 0.82 | 0.3 | - | - |
| Mean | Preferred | - | - | - | - | - | 96.5 ± 2.2 a | 54.75 ± 4.2 a |
| | Non-preferred | - | - | - | - | - | 32.5 ± 6.3 b | 18.5 ± 3.7 b |
| Values of p | | p = 0.003 | - | - | p = 0.030 | p = 0.031 | p = 0.027 | p = 0.033 |

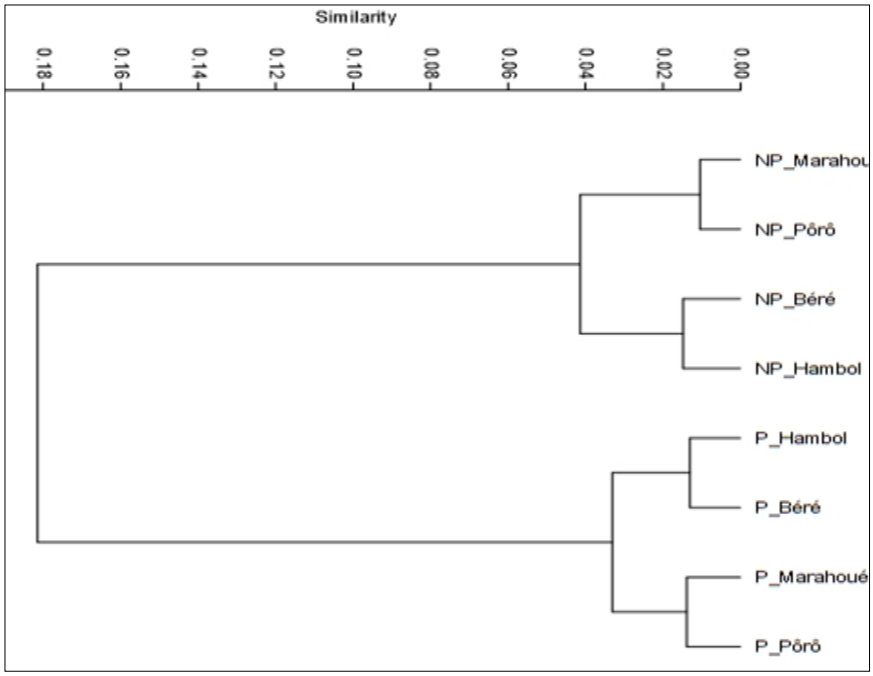
According to the parameters of bees diversity and floral preference, the numbers followed by the letters (a and b) within the same column are significantly different by the Mann Whitney's test ($p < 0.05$). Abbreviations: P = preferred cashew trees, NP = Non-preferred cashew trees

Community composition and classification of cashew trees

We found that the bee' communities collected on the flowers from these two categories cashew trees (preferred and non-preferred by bees) were dominated by the family of Apidae and manly *Apis mellifera*. This result might explain the low values of the Evenness. The irregular distribution of the bee' abundances and the domination of *Apis mellifera* among species, could probably explained by the: (1) social characters of bees from the Apidae (a single colony provides thousands of individuals visitors to flowers), and (2) great demand of pollen and nectar to the larvae, adults and beehives [28, 29, 33, 48].

Ascending Hierarchical Classification (AHC) revealed two groups of bees according to the cashew trees (Fig.3). The first group of bees occurred on the preferred trees (category A), second group on the non-preferred trees (category B) (Mann Whitney U test, $p = 0.004$). The table 6 also indicated the trees from category A (cashew trees identified by producers as cashew trees preferred by bees) possess very highly visited flowers. These flowers seem to be attractive and preferred by bees, and consequently explain formally the bees' preference. This preference of bees, could probably be due to the habitat types that surround the orchards, the position of preferred cashew trees in the orchards that are probably sundrenched with good climate influence due to the temperature and relative humidity [14, 27, 43].

Conversely, the assessed parameters classified the trees from category B as very rarely visited. This result might explain the non-attraction of bees towards the flowers of these trees, and therefore their non-preference. This non-preference of bees, could probably be explained by the quality of seeds (heterogeneous wild nuts) that are probably low performant, and consequently affect negatively the quality of their floral resources like the volume of nectar, and calories from pollen and nectar [40, 41, 44].




Abbreviations: NP = Non-preferred cashew trees; P = preferred cashew trees

**Fig 3:** Bee species composition per category of cashew tree per study region

**Table 6:** Classification of the parameters (X) of bees' floral preference according to Silivera *et al.* [36]

| Parameters of floral preference of bees | Categories of cashew trees | Very low (0% < X ≤ 25%) | Low (25 < X < 50) | Medium (X = 50) | High (50 < X ≤75) | Very high (75% < X ≤ 100%) |
|---|---|---|---|---|---|---|
| Frequency of bees visits (F) | P | 0 | 0 | 0 | 0 | 83 ± 2, 2 |
| | NP | 17 ± 2.2 | 0 | 0 | 0 | 0 |
| Attractive capacity of flowers (A) | P | 0 | 0 | 0 | 0 | 96.5 ± 2. 2 |
| | NP | 0 | 32.5 ± 6.3 | 0 | 0 | 0 |
| Preference index of flowers (P) | P | 0 | 0 | 0 | 54.75 ± 4.2 | 0 |
| | NP | 18.5 ± 3.7 | 0 | 0 | 0 | 0 |

Abbreviations: P = preferred cashew trees, NP = Non-preferred cashew trees

## Conclusion

Bee' floral preference was detected by a few cashew producers in 16 producing regions. The results of experimental detection in 4 producing regions demonstrated that the flowers of cashew trees preferred by bees are 5 times more visited and attract 3 times more foragers' species than flowers of non-preferred trees. Based on these results, we recommend for cashew producers: (1) the vegetative multiplication of these preferred cashew trees that operate as melliferous plants and potentially high productive trees, and (2) to graft the non-preferred trees using the grafts from the preferred trees. This recommendation may contribute progressively to regenerate the cashew orchards and food sources for bees, and consequently affect positively the bee' communities, yields, and producers' livelihoods by the trade of cashew fruits in Côte d'Ivoire. Hence, complementary researches are necessary in order to determine on these preferred trees: (i) the morphological characteristics, (ii) the biological traits of flowers that create the benefic interaction with bees, (iii) the agronomic performances (iv) soils nutrients under trees, and (v) genetics characteristics.

## Acknowledgements

We are grateful to the anonymous reviewer which improve the quality of this paper by the positive suggestions. Thank you to cashew farmers' cooperatives and the cashew sectors authorities of Côte d'Ivoire (Conseil du Coton et de l'Anacarde de Côte d'Ivoire) for their collaboration during these works.

## References

1. Trevian MTS, Pfundstein B, Haubner R, Würtele G, Spiegelhalder B, Bartsch H *et al*. Characterization of alkyl phenols in cashew (*Anacardium occidentale* L.) products and assay of their antioxidant capacity. Food and Chemical toxicology 2005;44:188-197.
2. Bezerra MA, Claudivan de LF, Enéas GF, Carlos de AB, José P. T. Physiology of cashew plants grown under adverse conditions, Braz. J Plant Physiol 2007;36:191-201
3. Martin KP. Plant regeneration through direct somatic embryogenesis on seed coat explants of cashew (*Anacardium occidentale* L.). Sci. Hortic Amsterdam 2003;98:299-304.
4. ACI Africain Cajou Initiative. Analysis of the Cashew Sector Value Chain in Côte d'Ivoire 2010, 76.
5. Sivagurunathan P, Sivasankari S, Muthukkaruppan SM. Characterisation of cashew apple (*Anacardium occidentale* L.) fruits collected from Ariyalur District. Journal of Bioscience Research 2010;1:101-107.
6. F.I.R.C.A. La Filière du Progrès: filière anacarde acte N°6 du premier trimestre 2010. Magazine d'information du fonds interprofessionnel pour la recherche et le conseil agricoles 2010, 56.
7. F.I.R.C.A. La Filière du Progrès: filière anacarde acte 20. Magazine d'information du fonds interprofessionnel pour la recherche et le conseil agricoles 2018, 56.
8. A.F.D. Etat des lieux de la filière anacarde en Côte d'Ivoire. Rapport de stage 2010, 71.
9. Ndiaye A. Structuration professionnelle de la filière anacarde une contribution durable à la paix - cote d'ivoire. Rapport RONGEAD/IFCI 2008, 24.
10. C.C.A. Conseil du Coton et de l'Anacarde. Plan d'action de la stratégie nationale de préservation et d'amélioration de la qualité des noix brutes de cajou en Côte d'Ivoire 2015, 27.
11. D.G.P.P.S. Direction Générale De Le Planification, Du Contrôle Des Projets Et Des Statistiques. Terms of reference entitled pest and pesticide management plan for the project to support the competitiveness of the cashew value chain in Côte d'Ivoire 2016, 7.
12. Ricau P. The West African cashew sector in 2018: general trends and country profiles, analysis of cashew production, processing and trade in West Africa 2019;30:28. www.nitidae.org, www.nkalo.org
13. C.C.A. Conseil du Coton et de l'Anacarde. Termes de référence: Plan d'action de la stratégie nationale de préservation et d'amélioration de la qualité des noix brutes de cajou en Côte d'Ivoire 2016, 60.
14. Eradasappa E, Mohana GS. Role of pollination in improving productivity of cashew - A review Department of Genetics and Plant Breeding, UAS, GKVK, Bengaluru-650 001, Karnataka India 2015. DOI: 10.18805/ar.v37i1.9266
15. R.O.N.G.E.A.D. Document de Synthèse Bibliographique: La reproduction de l'anacardier, Anacardium occidentale: Un important facteur de rendement Projet de Recherche Appliquée Agro-Climatique Anacardier en Côte d'Ivoire 2015, 6.
16. Freitas BM, Robert JP, Holanda-Neto JP. Identifying pollinators among an array of flower visitors, and the case of inadequate cashew pollination in NE Brazil. IN: Kevan P & Imperatriz Fonseca VL (eds) - Pollinating Bees - The Conservation Link Between Agriculture and Nature - Ministry of Environment/Brasília 2002, 229-244.
17. Soro NA. Inventaire des agents pollinisateurs de l'anacardier (*Anacardium occidentale* L: Anacardiaceae) et estimation du potentiel de leur efficacité dans le Nord-Est de la Côte d' Ivoire (Bouna). Mémoire Master Université Nangui Abrogoua 2016, 69.
18. Bhattacharya A. Flower visitors and fruits set in *Anacardium occidentale*. Annales Botanici Fennici 2004;41:385-392.
19. Freitas BM, Filho AJSPF, Andrade PB, Lemos CQL, Rocha EEM, Pereira *et al*. Forest remnants enhance wild pollinator visits to cashew flowers and mitigate pollination deficit in ne Brazil. Journal of Pollination Ecology 2014;12(4):22-30.
20. Aidoo K. The study of the effects of integrating beekeeping into Cashew farms in Ghana and Benin. Rapport pour African Cashew Initiative 2013, 14. (www.africancashewalliance.com/en/news-and-info/newsletter/bees-cash-ew 20 April 2021.
21. Reddi EUB. Under-pollination: a major constraint of cashew nut production. Proceedings of the Indian National Science Academy 1987;53:249-252.
22. Lowore J. Promoting sustainable beekeeping to combat poverty and to build resilient livelihoods. Bees for Development 1 Agincourt Street Monmouth 2018, 16. www.beesfordevelopment.org 28 April 2021.
23. Freitas BM. Beekeeping and cashew in North-eastern Brazil: the balance of honey and nut production. Bee World 1994;75:160-168.
24. Smith FG. Beekeeping observations in Tanganyika 1949-1957. Bee World 1958;39:29-36.
25. Aidoo K. Boosting cashew production in Ghana. Bee for development journal 2009;91:2.

26. Free JB, Williams IH. Insect pollination of *Anacardium occidentale* L., *Mangifera indica* L., *Blighia sapida Koeng* and *Persea american* Mill. Tropical Agriculture 1976;53:125-139.
27. Abou-Shaara HF. The foraging behaviour of honey bees *Apis mellifera*. Faculty of Agriculture, Damanhour University, Damanhour, Egypt: Review Article Veterinarni Medicina 2014;59(1):1-10.
28. Chagnon M. Causes et effets du déclin mondial des pollinisateurs et les moyens d'y remédier. Bureau régional du Québec de la Fédération canadienne de la faune 2008, 75.
29. Payette A. *Abeilles indigènes*: connaître et recruter plus de pollinisateurs. Insectarium de Montréal Présenté dans le cadre des Journées Horticoles Régionales de St-Rémi 2003, 2004, 7.
30. Sangare A, Koffi E, Akamou F, Fall CA. Etat des ressources phytogénétiques pour l'alimentation et l'agriculture: Second rapport national. République de Côte d'Ivoire, Ministère de l'agriculture 2009, 65.
31. Goujon P, Lebfevre A, Leturq Ph, Marcellesi AP, Praloran JC. Études sur l'anacardier. Bois et Forêts des Tropiques 1973;115:27-53.
32. Eardley CD. Taxonomic revision of the African stingless bees (Apoidea: Apidae: Apinae: Meliponini). African Plant Protection 2004;10:63-96.
33. Eardley C, Kuhlmann M, Pauly A. The Bee Genera and Subgenera of Sub-Saharan Africa. Abc Taxa 2010;7:145.
34. Soro NA. Evaluation de la biodiversité, la phénologie et la préférence florale des abeilles au cours de l'année dans une savane arbustive (Lamto, Côte d'Ivoire) Mémoire Master Université Nangui Abrogoua 2015, 66.
35. Silué D. Inventaire préliminaire des abeilles et leurs anacardiers préférés dans les principales zones de production en Côte d'Ivoire. Mémoire de Master Université Nangui Abrogoua 2017, 72.
36. Silveira NS. Manual de Ecologia dos insetos. 1. ed. São Paulo, SP: Agronômica Ceres 1976, 419.
37. Cerrutti N. Pontet C. Differential attractiveness of sunflower cultivars to the honeybee *Apis mellifera* 2016;10:1-5.
38. Colwell RK. Statistical Estimate of Species Richness and Shared Species from samples. Version 6.0b1. Edu/estimates conservation 2001;12:1371-1389. Website: http://viceroy.eeb.ubconn.
39. Hammer Ø, Harper DAT, Rian PD. PAST: Paleontological statistic software package for education and analysis. Palaeontol Electron 2001;4:1-9.
40. Chipojola FM. Phenotypic characterization and evaluation of factors affecting grafting success of cashew nut (*Anacardium occidantale* L.) in Malaw. PhD Thesis University of Malawi Bunda College of Agriculture 2009, 118.
41. Djaha AJB, N'Da HA, Koffi KE, N'Da Adopo A, Ake S. Diversité morphologique des accessions d'anacardier (*Anacardium occidentale* L.) introduits en Côte d'Ivoire. Rev. Ivoir. Sci. Technol 2014;23:244-258.
42. Soro NA, Kouakou LMM, Ouattara K, Koné NA, Silué D, Yéo *et al*. Connaissances traditionnelles des populations locales à la périphérie du Parc National de la Comoé sur les abeilles sociales dans le Nord-Est de la Côte d'Ivoire. Afrique SCIENCE 2020;17(2):1-10.
43. Fidalgo AO, Kleinert AMP. Floral Preferences and Climate Influence in Nectar and Pollen Foraging by Melipona rufiventris Lepeletier (Hymenoptera: Meliponini) in Ubatuba, São Paulo State, Brazil Neotropical Entomology 2010;39(6):879-884.
44. Freitas BM. The pollination efficiency of foragingn bees on apples (Malus domestica Borkh) and cashew (*Anacardium occidentale* L.) PhD Thesis, University of Wales, Cardiff, UK 1995, 167.
45. Prasifka JR, Mallinger RE, Portlas ZM, Hulke BS, Fugate KK, Paradis *et al*. Using Nectar-Related Traits to Enhance Crop-Pollinator Interactions. Front. Plant Sci 2018;9:8-12.
46. Wunnachit W. Floral biology of cashew (*Anacardium occidentale*) in relation to pollination and fruits set 1991, 164.
47. Rabinowitch HD, Fahn A, Meir TAL, Lensky Y. Flower and nectar attributes of pepper (*Capsicum annuum* L.) plants in relation to their attractiveness to honeybees (*Apis mellifera* L.). Annu. Appl. Biol 1993;123:221-232.
48. Freitas BM, Paxton RJ. A comparison of two pollinators: the introduced honey bee (*Apis mellifera*) and an indigenous bee (*Centris tarsata*) on cashew (*Anacardium occidentale* L.) in its native range of Ne Brazil. Journal of Applied Ecology 1998;35:109-121.