Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.52 (2) : 9474-9494 https://doi.org/10.35759/JAnmPlSci.v52-2.5

Assessing the influences of bee's (Hymnoptera: Apidae) floral preference on cashew (Anacardiacae) agronomics performances in Côte d'Ivoire.

D Silué[1]; K Yéo[1], Na Soro[1], W Dekoninck[2], Lmm Kouakou[1], K Ouattara[1], S Tiho[1], S Konaté[1]
[1]Nangui Abrogoua University, UFR des Sciences de la Nature, Lamto Ecological Research Station, Côte d'Ivoire
[2]Royal Belgian Institute of Natural Sciences, OD Taxonomy and Phylogeny, Rue Vautier 29, B-1000 Brussels, Belgium
Corresponding author: *Dolourou SILUE, Nangui Abrogoua University 02 BP 801, Abidjan 01, Côte d'Ivoire, +22547104262. E-Mail: dolourou2015@gmail.com*

Keywords: Agronomics performances, *Apis mellifera, Meliponula bocandei*, Cashew trees, Influence of bees' floral preference.

Submission 06/04/2022, Publication date 31/05/2022, http://m.elewa.org/Journals/about-japs/

1 ABSTRACT

This study aimed to assess the influence of bees' floral preference on cashew agronomics performances in Côte d'Ivoire. Therefore, a sampling design with a total of 40 cashew trees preferred by bees and 40 trees that were not preferred by bees was established in 4 main producing regions. In addition, bees' foragers and agronomics performances of trees were sampled. As results, a total of 46 bee' species with a foraging activity of 4±0.32 visits per minute were observed. *Apis mellifera* (60% of visits, with 2.27±0.17 of visitors per minute) followed by *Meliponula bocandei* (23% of visits with 0.91±0.18 of visits per minute) contributes significantly to the reproduction of cashew trees, compare to the 44 other bees' species (17% of visits; with an activity of 0.69±0.03 of visitors per minute). The preferred trees recorded 40.54±0.57 kg of nuts per tree, with 18.39±0.48 fruits per inflorescence, including 37.12±0.4% of useful kernel per raw nut (yield ratio of 65.45±0.66 pound of useful kernel). Conversely, the non-preferred trees obtained 5.24±0.44kg of nuts per tree, with 1.7±0.21 fruits per inflorescence, including 28.69±0.65% of useful kernel per raw nut (50.6±1.15 pound of useful kernel). Hence, the foraging preference of these two Apidae significantly increased the fruiting rate (83.7±0.01%), the yields (87.08±0.0%), and the kernel rate (22.68±1.76%) in raw cashew nuts. Based in these results, we suggest the foraging preference of *Apis mellifera* as good indicator of high-yielding cashew plants. Moreover, we suggests combination of apicultural and meliponicultrual in cashew farming to boost the yields and farmers livelihoods.

2 INTRODUCTION

In Côte d'Ivoire, cashew nuts (*Ancardium occidentale* L) have become the second most exported crop after cocoa, and the main source of monetary income for more than 5,000,000 people, including 500,000 smallholders in 20 regions out of 31 existing (F.I.R.C.A, 2018; A.F.D, 2010; Ndiaye *et al.,*2008). Also, Côte d'Ivoire is the first worldwide producer and exporter of raw cashew nuts with 25% of the global production and 50% of the world's supply (D.G.P.P.S, 2016). Unfortunately, the studies reveled a low yields of Ivoirian orchards, and a very low quality of the raw cashew nuts (C.C.A, 2016; F.I.R.C.A, 2018). Indeed, the yields of Ivorian cashew orchards varied between 350 and 500 kilograms of nuts per hectare for a kernel

yield ratio that fluctuates between 46 and 48 pound of useful kernel (Ricau, 2019). Conversely, in India (second worldwide producer) the yields of cashew vary between 1000 and 1500 kilograms per hectare and the kernel yield ratio fluctuates between 50 and 52 pound of useful kernel (F.I.R.C.A, 2018; Ricau, 2019). In Vietnam (third worldwide producer), cashew yields vary between 2000 and 2500 kilograms of nuts per hectare and the kernel yield ratio are situated between 52 and 54 pound of useful kernel (F.I.R.C.A, 2018; Ricau, 2019). Screening this statistics, it is clear that, Cote d'Ivoire scores low agronomics performances per tree and a very low competitiveness of the raw cashew nuts on the world market (F.I.R.C.A, 2018). Determining cashew plants with higher yields and excellent quality of nuts have become essential in Côte d'Ivoire. Pollinations services due to bees were recognized to affect the agronomics performances of cashew plants (Free *et al.,* 1976; Freitas *et al.,* 1994; Freitas *et al.*, 2002; Bhattacharya 2004; Freitals *et al.*, 2014, Eradasappa *et al.,* 2016; Lowore, 2018). Recently, bees' floral preference was documented in cashew orchards in Côte d'Ivoire (Silué *et al.,* 2021). The flowers of these cashew trees preferred by bees were visited 5 times more and they attracted 3 times more bee foragers as compared to non-preferred cashew trees (Silué *et al.,* 2021). This preference of bees in cashew orchards rises two important questions. Firstly, does preference of bees influence the agronomics performances (fruiting, yields and nuts quality) of cashew trees? Secondly, what is the main species that contribute to the reproduction cashew trees? In Côte d'Ivoire, studies on bees' communities foraging in cashew agrosystems are almost lacking (R.O.N.G.E.A.D, 2015). In this study, the hypothesis is that bees' floral preference is a good indicator for higher agronomics performances of cashew plants. The goals of this study are to determine: (i) the agronomics performances of cashew trees preferred by bees, and (ii) influences of some particular and dominant bee species on the reproduction. The results of this study may consequently contribute to use of beekeeping for a more effective management and improvement of cashew production in Côte d'Ivoire.

3 MATERIALS AND METHODS

3.1 Studied Sites and Experimental Field: The study was carried out in 4 important cashew-producing regions (Pôrô, Béré, Marahoué, and Hambol see Fig. 1), out of the 20 recognized regions in Côte d'Ivoire (C.C.A, 2016). Savannahs and isolated semi deciduous forests (Sangaré *et al.,* 2009) dominate the natural vegetation in these regions. In each selected region, one orchard was chosen as experimental field. The main criterion of these orchards selection was based on the bees' floral preference that was recently detected in these cashew orchards according to Silué *et al* (2021). In each experimental field, two categories of cashew trees were labelled and sampled in 2020 and 2021. **Category A**: cashew trees were trees preferred by bees (trees with flowers particularly and intensively foraged by bees in flowering periods). Conversely, **category B:** cashew trees were non-preferred by bees, (trees possessing flowers very rarely visited by bees). In addition, a total of 2400 inflorescences on 20 trees (1200 for each category cashew tree, including 120 inflorescences per selected tree) were labelled using a white flack. Samples were collected on the 120 selected inflorescences from the 4 main branches of each cashew tree. These 4 branches (containing 30 selected inflorescences each one) were chosen according to the four cardinal directions (North, South, East and West).

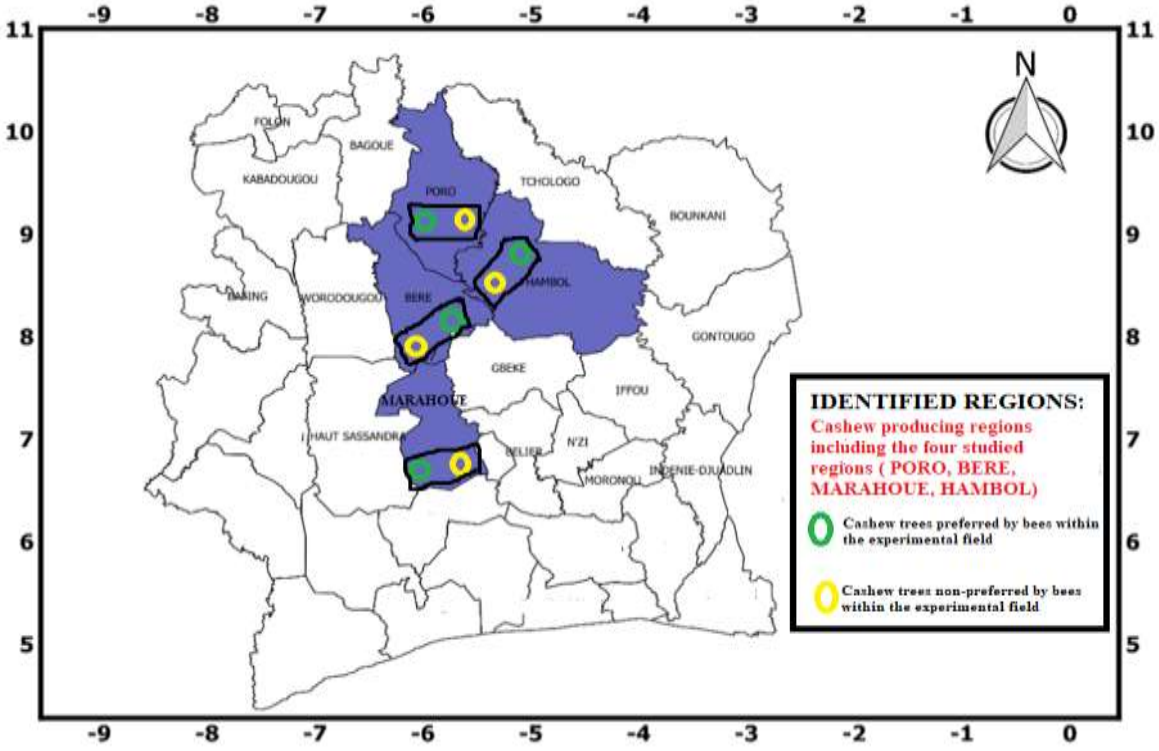

Fig 1. Location of studies sites

3.2 Sampling the bees that contribute to reproduction of cashew plants: data were collected during the peak flowering period from December to February 2020 and 2021, using an entomological net. 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 p.m., 3 p.m., 5 p.m. The sampling duration was 20 minutes split in 5 minutes per branch and per sampling time. Later, bees' specimens were mounted, labelled and identified using the determination keys of Eardley (2004) and Eardley *et al.* (2010) under Olympus SZ61 binocular loupe. The reference collection of bees of Côte d'Ivoire housed in the Lamto Scientific Reserve (Soro 2016; Silué, 2017; and Silué *et al.*, 2021) was also used during this work. Voucher specimens of all the identified species are available at the Lamto Ecological Research Station. After identification, two parameters (foraging activity and the frequency of visits) were calculated according to Tchuenguem Fohouo (2005) and Tchuenguem Fohouo *et al.,* (2001) in order to determine the contribution of bees' species at the reproduction of cashew trees. The Foraging activity (*Ai*) represents the number of visit from each collected specie per inflorescence. It was calculated using this formula: Ai = (*ai*/*TI*). *ai* represents the abundance of each collected specie, and *TI* the total inflorescences per category cashew tree. The Frequency of visits (*Fr*) represents the percentage of visits from each collected specie. It was determined using this formula: *Fr* = (*Ai*/*At*) x 100, where *Ai* is the individual foraging activity per collected specie, and *At* is the total foraging activity from all species.

3.3 Evaluation of agronomics parameters: The data were collected during the dry season from February to May in 2020 and 2021. Hence, the hermaphrodite flowers (expected fruits) were carefully determined and counted per inflorescence (Wunnachit, 1991). After their pollination, the number of observed

fruits was individual counted. In addition, the mature cashew nuts from each labelled tree were carefully collected in separate jute bags. After a process of drying during 3 days in open area, these bags were weighted to determine the yield from each tree (Masawe, 2003). Later, one sample of 40 raw nuts/tree was brought to the laboratory in order to determine of the total useful kernel (A.C.I, 2010). To determine the influences of bees' preference on cashew agronomics performances (Tchuenguem Fohouo *et al.,* 2001; and Tchuenguem Fohouo., 2005), three parameters were calculated: (i) reproduction capacity further called fruiting rate, (ii) total yield and abundances of fruits, and (iii) total useful kernel rate also called kernel yield ratio in the international market .

Fruiting rate (F) due to the influence of bees' preference was obtained using this formula: $F = \{[(Rp - Rnp)/ Rp] \times 100\}$. *Rp* is the reproduction capacity from the preferred trees, and *Rnp* the reproduction capacity from non-preferred trees. In addition, the classification scale developed by Silveira Neto et al., (1976) was used to classify these influences as: (i) Very low (0 %< $F \leq 25\%$), (ii) Low (25% < F <50%), (iii) Medium (F = 50%), (iv) High (50% < $F \leq 75\%$), (v) Very high (75% < $F \leq$ 100 %). Before that, the reproduction capacities (*R*) were determined using this formula: $R = (of/hf) \times 100$. *of* is the average number of observed fruits, and *hf* the number of expected fruits (hermaphrodites flowers) per inflorescence (Karmo *et al.,* 1959).

Percentage of yields (*Y*) due to bees' preference was obtained using this formula: $Y = \{[(Yp - Ynp)/Yp] \times 100\}$. *Yp* is the yields from the preferred trees, and *Ynp* the yields from non-preferred trees. In addition, the classification scale of Silveira Neto et al., (1976) was used to classify these influences as: (i) Very low (0 %< $Y \leq 25\%$), (ii) Low (25% < Y <50%), (iii) Medium (Y = 50%), (iv) High (50% < $Y \leq 75\%$), (v) Very high (75% < $Y \leq$ 100 %). Also, the abundance of mature fruits per inflorescence was obtained by individual counting, considering the fruits that have their apples in red, yellow colour.

The quality of cashew nuts or the percentage of useful kernel (*K*) due to bees' preference was obtained using this formula: $K = \{[(Kp - Knp)/Kp] \times 100\}$. *Kp* is the useful kernels from the preferred trees, and *Knp* the useful kernel from non-preferred trees. Also, the classification scale of Silveira Neto *et al.*, (1976) was used to classify these influences as: (i) Very low (0 %< $K \leq 25\%$), (ii) Low (25% < K <50%), (iii) Medium (K = 50%), (iv) High (50% < $K \leq 75\%$), (v) Very high (75% < $K \leq$ 100 %). The described method of A.C.I (2010) was used for to determine the useful kernels. In practice, raw cashew nuts form each tree was carefully cut using a dissecting forceps in order to weight separately kernels, pellucids and shells. Total useful kernels (*K*) expressed in percentage was calculated using the formula: $K = (100\%\ of\ good\ kernel + 50\%\ of\ dotted\ kernel\ by\ insects + 50\%\ premature\ kernels)$. Also, yield ratio of nuts (*OT*) expressed in pound of useful kernel/trees was calculated using this formula: $OT = (K \times 80)/45.359$ where *K* is the total useful Kernels expressed in percentage. The yield ratio of nuts was also classified according to the established classification of Ricau (2013): (i) Bad ($40 \leq OT$ <45), (ii) Acceptable ($45 \leq OT$ <50), (iv) Good ($50 < OT \leq 55$), (v) Very good ($55 < OT \leq 60$), (vi) Excellent ($60 < OT \leq 65$) (vii) Very excellent ($65 < OT \leq 70$).

3.4 Statistical analysis: The species richness observed (Sobs) was obtained by direct counting of bees' species after identification. The EstimateS software version 9.1 was used to obtain the estimated species richness (Chao 2). In this study, a correlation of Pearson was established between the studied parameters using a Paleontological STatistics (PAST) version 3.09 at a significance level of 0.05. Also, all data were analysed using 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 comparison. If not a

non-parametric multivariate analysis of variance Kruskal-Wallis or test, U of Mann-Whitney was used for comparison.

4 RESULTS

4.1 Contribution of bee' species to the reproduction: A total of 46 bee' species (24 genera and 4 families), with a foraging activity of 4±0.32 visits/minute were observed in this study. Among these 4 families, Apidae (58.2% of the species) was the richest, followed by the Megachilidae (20.08%), Halictidae (18.04%) and Colletidae (2.17%) (Appendix I, II, III, IV). Results showed that, *Apis mellifera* (60% of visits with 2.27±0.17 of visitors/minute) ranked first followed by *Meliponula bocandei* (23% of visits, and 0.91±0.18 of visitors/minute) and 44 other bee' species (17% of visits with 0.69±0.03 of visitors/minute) (Table 1 and 2). Hence, the contribution of *Apis mellifera*, and *Meliponula bocandei* was significantly higher on the reproduction of cashew trees, than the 44 other bees' species (Tukey's pairwise test, p= 0.0014). However, bee' communities including their foraging activity were significantly higher on the inflorescences of preferred cashew trees (43 species, with 3.3±0.2visits/minute), than non-preferred trees (14 species, with 0.7±0.12visits/minute) (Tukey's pairwise test, p= 0.00016). The observed and expected species richness, the bees' abundances and sampling coverage in each orchard are presented in the appendixes. Results indicated that the sampling coverage varied between 50 and 66.66%.

Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.52 (2) : 9474-9494 https://doi.org/10.35759/JAnmPlSci.v52-2.5

Table 1: Bees' foraging activity and their frequency of visits in cashew flowers

		Foraging activity	Number of visitors/minute in the inflorescences				Frequency of visitors (%)		
		Total	*Apis mellifera*	*Meliponula bocandei*	Others 44 bees species		*Apis mellifera*	*Meliponula bocandei*	Others 44 bees species
Pôrô	P	3.5	2.13	0.84	0.54		60.7	23.87	15.4
	NP	0.75	0.4	0.27	0.07		53	36.88	10.1
Béré	P	3.3	1.87	0.7	0.71		57.1	21.2	21.66
	NP	0.5	0.38	0	0.11		77.7	0	22.22
Marahoué	P	3	1.67	0.7	0.58		57	23.46	19.61
	NP	0.77	0.4	0.3	0.08		53.5	35.44	11.1
Hambol	P	3.24	1.83	0.69	0.7		56.7	21.32	21.94
	NP	0.77	0.4	0.27	0.09		52.4	35.41	12.1
Means	P	3.3±0.2a	1.87±0.16a	0.7±0.06a	0.6±0.02a		57.8±0.016	22.46±0.012	19.6±0.05
	NP	0.7±0.12b	0.4±0.011b	0.21±0.12b	0.09±0.01b		59.2±0.10	26.93±0.15	13.8±0.04
Total	Both trees	4±0.32	2.27±0.171	0.91±0.68	0.69±0.03		60	23	17
Value of p		0.00016	0.006	0.008			-	-	-

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

Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.52 (2) : 9474-9494 https://doi.org/10.35759/JAnmPlSci.v52-2.5

Table 2. Daily observation of bees foraging activity and their frequency of visits

	Daily observation time frame													
	7 h		9h		11h		13h		15h		17h		Total	
	Visits/ minutes	Visits (%)	Visits /minutes	Visits (%)	Visits/minutes	Visits (%)	Visits/minutes	Visits (%)	Visits/ minutes	Visits (%)	Visits/ minutes	Visits (%)	Visits/ minutes	Visits (%)
Apis mellifera	1.56	67	1.86	62	3.9	64	3.3	61.11	1.5	55.55	1	48.31	2.2	58.04 a
Meliponula bocandei	0.45	19.35	0.91	30.33	1.6	26.23	1.2	22.22	0.5	18.5	0.42	20.3	0.9	23.74 b
44 Other bees' species	0.315	13.55	0.23	7.6	0.6	9.83	0.9	16.66	0.7	23	0.65	31.4	0.69	18.2a
Total	2.325	100	3	100	6.1	100	5.4	100	2.7	100	2.07	100	3.79	100
Value of p														0.0014

According to the bee' species, the numbers within the same column followed by the letters (a and b) are significantly different by the Tukey's test ($p < 0.05$).

4.2 Influence of bees' floral preferences on agronomics performances: The results of three agronomics parameters (fruiting, yields and nuts quality) were assessed and presented.

4.2.1 Relation between bees' preferences and fruiting rate: The table 3 shows the parameters of fruiting rate: (i) observed fruits, and (ii) reproduction capacity. Among a total of 33.51±1.63 expected fruits, 18.39±0.48 fruits were observed/inflorescence of preferred trees, (a reproduction capacity of 55.2±0.01%). Conversely, 1.7±0.21 fruits were recorded on the non-preferred trees for the total 19.05±1.366 expected fruits/inflorescence (a reproduction capacity of 8.9±0.01%). Results revealed that, results showed that the observed fruits were significantly higher on preferred trees compare to non-preferred trees (Tukey pairwise test, p = 0.003 for the observed fruits, and p = 0.0009 for the reproduction capacity). Hence, the bees' preference significantly increased (from 83.7±0.01%) the fruiting rate compare to their non-preference. According to studied orchards, 18.14 to 19.1 were observed in the inflorescences of preferred trees (a reproduction capacity of 51.34±0.03 to 59.1±0.00%) while 1.38 to 2.01 were observed on the non-preferred trees (reproduction capacity of 7.63±0.01 to 10.98±0.02%). Hence, the influences of bees' preference on fruiting rate varied between 81.4 and 86.77% according to the cashew orchards.

4.2.2 Relation between bees' preferences and total yield and abundances of fruits: The parameters of cashew yields: (i) total yield/trees, (ii) weight of panicles, (iii) abundance of mature fruits/panicle, and (iv) individual weight of raw nuts, are presented in the table 3. The preferred trees have recorded a total of 40.54±0.57 kg of nuts/trees distributed in the panicles of 111.1±11.65g around the canopy, including 18.39±0.48 mature nuts/panicle. Conversely, the non-preferred trees have obtained a total of 5.24±0.44kg of nuts/trees belonging to the panicles of 20.84±2.64g of nuts including 1.7±0.21 mature nuts/ panicle. Results revealed that, results showed that the total yields were significantly higher on preferred trees compare to non-preferred trees (Tukey pairwise test, p = 0.002 for yields, p = 0.0006 for fruits abundances). Hence, the bees' preference significantly increased (from 87.08±0.0%) the total yield and fruits abundances of cashew trees, compare to their non-preference. According to the orchards, these preferred trees recorded between 39.8 and 41.1kg of cashew nuts/trees in dry season, including the weight of panicles fluctuated from 96.5 to 125.69g of nuts, with the densities of nuts situated between 18.14 and 19.1 per panicle. Conversely, the non-preferred trees obtained 4.7 to 5.8kg of nuts/trees, including the weight of panicles varied between 19.2 and 24.5 g of nuts, and the densities of nuts fluctuated from 1.38 to 2.01 per panicle. Hence, the influences of bees' preference varied between 85.7 and 88.3% according to the orchards. Also, the parameters of yields (yields/tree, mass of panicles, density of mature nuts) were significantly higher on preferred cashew trees compare to non-preferred trees (Tukey pairwise test, respectively p = 0.002, p= 0.003, p = 0.0006) (Table 3). However, the individual weight of nuts from the non-preferred cashew trees were significantly higher compare to those from the preferred trees (Tukey pairwise test p = 0.04).

4.2.3 Relation between bees' preferences and total kernels rate (quality of nuts): The cashew trees preferred by bees obtained 37.12±0.4% of useful kernel/raw nut (yield ratio of 65.45±0.66 pound of useful kernel) while the non-preferred trees were recorded 28.69±0.65% of useful kernel/raw nut (50.6±1.15 pound of useful kernel). Results revealed that, results showed that the quality of nuts were significantly higher on preferred trees compare to non-preferred trees (Tukey pairwise test p =0.04). Hence, bees' preference significantly increased (from 22.68±1.76%) the total useful kernel in the raw nuts (Table 3). The excellent quality of kernel was recorded in the raw nuts from preferred trees while the good quality was obtained non-preferred trees (Table 4). According to the cashew orchards, 36.7 to 37.75% of useful kernel/raw nut (yield ratio of 64.74 to 66.55 pound of useful kernel) were

Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.52 (2) : 9474-9494 https://doi.org/10.35759/JAnmPlSci.v52-2.5

recorded in the cashew trees preferred by bees. Conversely, the non-preferred trees obtained 27.6 to 29.38 % of useful kernel/raw nut (yield ratio of 48.68 to 51.79 pound of useful kernel). Hence, the influences of bees' preference varied from 20.7 to 25.3% according to the orchards. Results also showed that, the useful kernel rate and yield ratio were significantly higher on preferred trees compare to the non-preferred trees (Tukey pairwise test p =0.04; p =0.036) (Table 3).

Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.52 (2) : 9474-9494 https://doi.org/10.35759/JAnmPlSci.v52-2.5

Table 3: Influences of bees' preference on cashew agronomics parameters

Cashew orchards		Parameters of Fruiting rate from 2020 to 2021				Parameters of yields from 2020 to 2021					Parameter of nuts quality from 2020 to 2021		
		Expected fruits/ panicle	Observed fruits/ panicle	Reproduction capacity (%)	Influences of bees' Preferences (%)	Mature fruits /panicle	Individual nut (g)	Panicle (g)	Yield of tree (kg)	Influences of bees' Preferences (%)	Useful kernel/tree (%)	Outturn ratio /tree (Ibs)	Influences of bees' Preferences (%)
Pôrô	P	34.8a	18.14±0.64a	52.14±0.02a	82.13	18.14±0.6a	6.5±0.03b	118.6±4.8a	39.8±0.98a	87.2	37.04±0.85	65.31±1.51	20.7
	NP	18.9b	1.77±0.33b	9.36±0.02b		1.77±0.33b	12.4±0.02a	22.1±4.1b	5.1±0.3b		29.38±1.18	51.79±2.1	
Béré	P	31.5a	18.22±0.3a	57.84±0.00a		18.22±0.3a	6.9±0.1b	125.7±0.11a	40.6±1.7a		36.7±1.03	64.74±1.83	
	NP	21.3b	1.625±0.26b	7.63±0.01b	86.77	1.625±0.2b	11.8±0.1a	19.2±3.3b	4.7±1.4a	88.3	28.81±1.31	50.81±2.3	21.5
Marahoué	P	35.4a	18.17±1.3a	51.34±0.03a		18.17±1.3a	5.6±0.4b	103.2±15.4a	41.1±2a		37.75±0.35	66.55±0.65	
	NP	17.7b	1.38±0.18b	7.79±0.01b	84.6	1.38±0.18b	12.7±0.06a	17.6±2.4b	5.8±1.6b	85.8	28.9±2.47	51.1±4.38	23.24
Hambol	P	32.34a	19.1±0.2a	59.1±0.00a		19.1±0.2a	5±0.2b	96.5±5.8a	_		36.98±0.28	65.2±0.5	
	NP	18.3b	2.01±0.44b	10.98±0.02b	81.4	2.01±0.44b	12.2±0.1a	24.5±5.1b	_		27.6±1.5	48.68±2.68	25.3
Means	P	33.51±1.6a	18.39±0.48a	55.2±0.01a		18.39±0.5a	6.03±0.73b	111.1±11.65a	40.54±0.57a		37.12±0.4a	65.45±0.66a	
	NP	19.05±1.36b	1.7±0.21b	8.9±0.01b	83.7±0.01	1.7±0.21b	12.3±0.34a	20.84±2.64b	5.24±0.44b	87.08±0.00	28.69±0.65b	50.6±1.15b	22.68±1.76
Value of p		0.0014	0.003	0.0009		0.003	0.04	0.0006	0.002		0.04	0.036	

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

Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.52 (2) : 9474-9494 https://doi.org/10.35759/JAnmPlSci.v52-2.5

Table 4. Classification kernel outtrun rato (OT) of raw cashew nuts according to Ricau (2013)

Cashew orchards	Classification scale	Very low (40≤ OT <45)	Low (45≤ OT <50)	High (50< OT < 55)	Very high (55 ≤ OT < 60)	- (60 ≤ OT < 65)	- (65 ≤ OT ≤ 70)
	Appreciation scale	Bad	Tolerable	Good	Very good	Excellent	Very excellent
Pôrô	Preferred trees	0	0	0	0	0	65.31±1.51
	Non-preferred trees	0	0	51.79±2.1	0	0	0
Béré	Preferred trees	0	0	0	0	64.74±1.83	0
	Non-preferred trees	0	0	50.81±2.3	0	0	0
Marahoué	Preferred trees	0	0	0	0	0	66.55±0.65
	Non-preferred trees	0	0	51.1±4.38	0	0	0
Hambol	Preferred trees	0	0	0	0	0	65.2±0.5
	Non-preferred trees	0	48.68±2.68	0	0	0	0
Means	Preferred trees	0	0	0	0	0	65.45±0.66
	Non-preferred trees	0	0	50.6±1.15	0	0	0

4.3 Classification of vegetal material and correlation between assessed parameters: Results showed that the agronomics performances of cashew plants preferred by bees were very high, while the non-preferred trees were classified as very low (Table 5). Also, the contribution (foraging and frequency of visit) of *Apis mellifera* was significantly and positively correlated with the assessed parameters of agronomics performances. Conversely, the contribution of *Melipenula bocandei* and 44 bees' species other were not correlated with : (i) reproduction capacity of trees (r = 0,17 ; p = 0,32); (i) Total yields of trees (r = 0,28 ; p = 0,091); and (iii) total useful kernel in nuts (r = 0,23 ; p = 0,078) (Table 6).

Table 5: . Classification of the influence of bees' floral preference (X) according to Silivera *et al* (1976)

		Influences of bees' preference				
	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%)
Fruiting rate (F)	Preferred	0	0	0	0	83.7±0.01
	Non-preferred	0	0	0	0	0
Total yields (Y)	Preferred	0	0	0	0	87.08±0.00
	Non-preferred	0	0	0	0	0
Total kernel (K))	Preferred	22.68±1.76	0	0	0	0
	Non-preferred	0	0	0	0	0
Performances of vegetal material	Preferred	no	no	no	no	yes
	Non-preferred	yes	no	no	no	no

Table 6: Correlation between the assessed parameters

Pearson correlation (r> 0.5 ; p< 0,05**)**	**Fruiting rate**	**Yield of trees**	**Total kernel**	**Contribution of *Apis mellifera***	**Contribution of *Meliponula bocandei***
Fruiting rate	_				
Yield of trees	0,21	_			
Total kernel	0,17	0,2	_		
Contribution of *Apis mellifera*	0,78	0,87	0,66	_	
Contribution of *Meliponula bocandei*	0,17	0,28	0,23	0.61	_

5 DISCUSSION

5.1 Contribution of bee' species to the reproduction and their correlation with the agronomics performances: Results demonstrated that *Apis mellifera* and *Meliponula bocandei* were the main foragers that contribute significantly to the reproduction of cashew trees. Probably, the social structure of these two Apidae (a single colony provides thousands of individuals visitors to flowers), affect their great demand of pollen and nectar for the larvae, adults and beehives (Eardley, 2004; Eardley *et al.,* 2010) and consequently explain their high

contribution to the reproduction. Also, the flowers morphology and resources (nectar and pollen) of cashew plants are probably more attractive and accessible to these two Apidae, and therefore explain their high activities and consequently their high contribution to the reproduction (Mazi *et al.,* 2020). However, the foraging activity and the frequency of visit from one bee' specie (*Apis mellifera*) were significantly and positively correlated with all agronomics parameters (fruiting rate yields, and kernel in nuts). Probably, the high constancy floral (Ribeiro *et al.,* 2019) due to the particular characteristics of host plants available (cashew trees possessing probably necessary resources for *Apis mellifera* during the dry season) could explained these results. The not correlation of the activities from the other bees' species (44 bees' species and *Meliponula bocandei*) with agronomics performances might probably attributed to : (i) the low diversity of cashew flowers resources, and (ii) the regular perturbation of cashew farming due to pesticides using (Eardley, 2004). Also, the non-domestication of these bees' species and mainly *Meliponula bocandei* in Côte d'Ivoire due to the lack knowledge of cashew farmers, might probably explain their low abundances and consequently their non-correlation with the agronomics parameters (Soro *et al.,* 2020).

Moreover, the high frequency of bees visit, their high foraging activity, and high species richness in the inflorescences of preferred trees might probably due to the high apicultural value of these preferred trees, that operate probably 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), (Tchuenguem Fohouo *et al.,* 2001; Mazi *et al.,* 2020).

5.2 Influences of bees' floral preferences on the agronomics performances: Overall results demonstrated that the bees' floral preference is a good indicator of high-yielding cashew plants. Hence, the high fruiting rates, productivities and qualities of nuts that have recorded in preferred trees, reflects that the bees' floral preference muches with the quality of genetic material from cashew plants. Indeed, Freitas, (1995) and Wunnachit *et al.,* (1992) reported that the genetic material of some the cashew plants produce the particular interesting food sources that affect the attractiveness of their flowers and consequently explain the influence of bees' preference on agronomics performances of trees. In other hand, the high recruitments of foliage and twigs on canopies (IBPGR, 1986; Roe, 1996) might also affect the abundance and the quality of the floral resources (nectar and pollen) and explain the bees' preference and their influences on the agronomics performances of cashew plants (Masawe et al., 2006). Also, the quality of soils nutrients under these preferred trees affect probably the quality of nectar and pollen, and therefore explain the high activities of bees and consequently the high fruiting rates, yields, and total useful kernels in nuts (Chipojola, 2009; Wunnachit, 1991). The high agronomics performances of cashew plants might also 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 the pollination due to bees (Chipojola, 2009). We found that the productivity of the preferred cashew trees (varying between 39.8±0.98 and 41.1±2kg/tree) were higher, compare to the trees from : (i) the three genotypes of C.N.R.A in 2015 in Côte d'Ivoire (15kg/tree), (ii) Malawi, where productivity oscillates between 0.5 to 26 kg/tree (Chipojola in 2009), (iii) India, where yields fluctuate between 1.23 and 11.6 kg/tree (Samal *et al.,* 2003), and (iv) Vietnam, where yields of the best clones fluctuate between 20 and 30 kg/tree (in (Le Quy Kha., 2018). Likewise, the useful kernel were higher in the nuts of the preferred cashew trees (fluctuated between 36.7±1.03 to 37.04±0.85%) compare to the trees from: (i) the three genotypes of the C.N.R.A in 2015 and 2017 in Côte d'Ivoire (kernel yield varying between 25.3 and 31.8%), and (ii) Vietnam, where kernel yield of the best clones range

between 28% and 33% (Le Quy Kha, 2018). These difference of results might be attributed to the difference in the methods of selection that have used to identify the high yielding cashew plants. Conversely, the low agronomics performances of cashew trees non-preferred by bees might be explained by several factors. First, the low density of hermaphrodites in their inflorescences might affect negatively the volume of nectar and the bees' activities, and consequently these low agronomics performances (Wunnachit, 1991). Secondly, the non-adapted agricultural practices like using of wild heterogeneous seeds as vegetal material, including uncontrolled pesticides, might negatively affect the floral resources, bees' activity and consequently the agronomics performances of these trees (Djaha *et al.,* 2014). However, the high individual weight of raw nuts from non-preferred cashew trees compare to the preferred trees might be attributed to the big shells that surround the kernel (A.C.I, 2010). Probably, the genetic material from the non-preferred trees might also affect the weight of shells, and therefore explain their high sizes of nuts (Chipojola, 2009). We conclude by stating that, the floral preference of *Apis mellifera* can be used as new criterion to select the best agronomics performances of cashew plants. Also, we suggests and strongly encourages the integration of apicultural and meliponicultrual in the cashew farming in order to improve farmers' livelihoods. Future research might also focus on some specific morphological characteristics, and biological traits of flowers that create more beneficial interactions with bees. Also the impact of the soils nutrients under trees could give relevant information for a sustainable development of cashew crop in Côte d'Ivoire.

6 ACKNOWLEDGEMENTS

We are grateful for the positive suggestions of X anonymous reviewer(s) that improved the quality of this paper. Appreciation goes 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 the fieldwork.

Authors' Contributions

Dolourou SILUE: Investigation, Data collection, Data curation and Writing the original draft.

Nicodénin Angèle SORO, Kolo YEO, Mesmer Maurice KOUAKOU LOMBART, Kaly OUATTARA, Wouter. DEKONINCK; Seydou THIO and Souleymane KONATE: Conceptualization, Methodology, writing, review and editing.

7 REFERENCES

A.C.A (2015). Cashew week An Initiative of CashewInfo.com. Special issue for ACA Conference, 16, 35- 39.

A.C.I (2010). Africain Cajou Initiative. Analyse de la Chaîne de Valeur du Secteur Anacarde de la Côte d'Ivoire. 76p.

Bhattacharya, A. (2004). Flower visitors and fruits set in *Anacardium occidentale*. Annales Botanici Fennici 41, 385-392p

C.C.A, (2016). 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. 60 p.

D.G.P.P.S (2016). (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, p.7.

Eardley C.D. (2004). Taxonomic revision of the African stingless bees (Apoidea: Apidae:

Apinae: Meliponini). African Plant Protection, 10 63-96.

Eardley, C., Kuhlmann, M & Pauly, A. (2010). The Bee Genera and Subgenera of Sub-Saharan Africa. Abc Taxa, 7, 145.

Eradasappa E., & Mohana G.S. (2015). Role of pollination in improving productivity of cashew – A review Department of Genetics and Plant Breeding, Karnataka, India DOI: 10.18805/ar.v37i1.9266

Free, J.B., & Williams, I.H. (1976). Insect pollination of *Anacardium occidentale* L.,on *Mangifera indica* L., *Blighia sapida* Koeng and *Persea american* Mill. Tropical Agriculture 53, 125-139.

Freitas, B. M., Robert, J. P., & Holanda-Neto J. P., (2002). 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. P.229-244

Freitas, B.M. (1995). The pollination efficiency of foraging bees on apples (Malus domestica Borkh) and cashew (*Anacardium occidentale* L.) PhD Thesis, University of Wales, Cardiff, 167p.

Freitas, B.M. (1994). Beekeeping and cashew in North-eastern Brazil: the balance of honey and nut production. Bee World 75, 160-168.

Fidalgo, A. O, & Kleinert, A. M. P., (2010). Floral Preferences and Climate Influence in Nectar and Pollen Foraging by *Melipona rufiventris* Lepeletier (Hymenoptera: Meliponini) in Ubatuba, São Paulo State, Brazil Neotropical Entomology 39, 879-884.

F.I.R.C.A (2018). La Filière du Progrès : filière anacarde acte 20. Magazine d'information du fonds interprofessionnel pour la recherche et le conseil agricoles 56 p.

Lowore J., (2018). Promoting sustainable beekeeping to combat poverty and to build resilient livelihoods. Bees for Development 1 Agincourt Street Monmouth www.beesfordevelopment.org

Mazi, S., Adamou, M., Issaya, K.I., Jean, M. and Esaïe, F. (2020) Impact of *Amegilla calens* and *Apis mellifera* Pollination on *Gossypium hirsutum* var. QR1302 Flowers at Tchabbal-Mounguel (Ngaoundéré, Cameroon). Open Journal of Ecology, 10, 445-459. https://doi.org/10.4236/oje.2020.10702

Ndiaye, A. (2008). Structuration professionnelle de la filière anacarde une contribution durable à la paix – Cote d'ivoire. Rapport RONGEAD/IFCI, 24 p.

N'Da, A. A., Djaha, A. J. B., Kouakou, C. K., Djidji, A. H., Dosso, M., N'Guessan, A. E. B., & Tahouo, O. (2016) Production of plants grafts of cashew in Côte d'Ivoire. National Centre of agronomic research, Côte d'Ivoire, 40p.

R.O.N.G.E.A.D (2015). 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 6 p.

Ricau, P. (2019). The West African cashew sector in 2018: general trends and country profiles, analysis of cashew production, processing and trade in West Africa. www.nitidae.org, www.nkalo.org 30p

Ricau, P. (2013). Connaître et comprendre le marché international de l'anacarde. Rongead- N'kalô. www.rongead.org 49 p.

Sangare, A., Koffi, E., Akamou, F., & Fall, C. A., (2009) Etat des ressources phytogénétiques pour l'alimentation et l'agriculture: Second rapport national. République de Côte d'Ivoire, Ministère de l'agriculture 65p.

Soro, NA, Kouakou LMM, Ouattara K, Koné NA, Silué D, Yéo et al (.2020) :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. 17 :1-10.

Soro, N. A. (2016). 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, 69p.

Silveira, N. S. (1976). Manual de Ecologia dos insetos. 1. ed. São Paulo, SP: Agronômica Ceres, 419 p

Silué, D. (2017). Inventaire préliminaire des abeilles et leurs anacardiers préférés dans les principales zones de production en Côte d'Ivoire. Mémoire de Master Université Nangui Abrogoua 72p.

Silué, D., Yéo, K., Soro, N.A., Dekoninck, W., Lombart, K. M. M., Ouattara, K., Seydou, T., Konaté, S. (2021). Detecting Bee's Floral Preference in Cashew Orchards: an Important Advanced for Bees Preservation and Cashew Crop Development in Côte d'Ivoire. Journal of Entomology and Zoology Studies 9 3-16

Tchuenguem, F.F.N. (2005) Activité de butinage et de pollinisation de *Apis mellifera* Adansonii Latreille (Hymenoptera: Apidae, Apinae) sur les fleurs de trois plantes à Ngaoundéré (Cameroun): *Callistemon rigidus* (Myrtaceae), *Syzygium guineense* var. macrocarpum (Myrtaceae) et *Voacanga africana* (Apocynaceae). Thèse de Doctorat d'Etat, Université de Yaoundé I, Yaoundé.

Tchuenguem Fohouo FN, Messi J, Pauly A (2001). Activity of *Meliponula erythra* on *Dracryodes edulis* flowers and its impact on podding. Fruits 56, 179-188.

Trevian, M. T. S., Pfundstein, B., Haubner, R., Würtele, G., Spiegelhalder, B., Bartsch, H., & Owen, R. W. (2005). Characterization of alkyl phenols in cashew (*Anacardium occidentale* L.) products and assay of their antioxidant capacity. Food and Chemical toxicology 44, 188 – 197.

Wunnachit, W,. (1991) Floral biology of cashew (*Anacardium occidentale*) in relation to pollination and fruits set. 164p

Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)
Vol.52 (2) : 9474-9494 https://doi.org/10.35759/JAnmPlSci.v52-2.5

Supplementary material

Appendix I . Bees' community including their foraging activity in Pôrô cashew orchard

		Pôrô cashew orchard					
		Preferred cashew trees			Non-preferred cashew trees		
		Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)	Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)
Apidae	*Apis mellifera*	2558	2.13166667	60.702421	477	0.3975	53
	Allodape sp.1	3	0.0025	0.071191	0	0	0
	Allodape sp.2	4	0.00333333	0.094922	0	0	0
	Allodape sp.3	4	0.00333333	0.094922	0	0	0
	Ceratina sp.1	1	0.00083333	0.02373	0	0	0
	Ceratina sp.3	9	0.0075	0.213574	0	0	0
	Dactylurina staudingeri	66	0.055	1.566208	12	0.01	1.333333
	Hypotrigona sp.1	94	0.07833333	2.23066	19	0.01583333	2.111111
	Meliponula beccarii	76	0.06333333	1.803512	17	0.01416667	1.888889
	Meliponula togoensis	296	0.24666667	7.024205	30	0.025	3.333333
	Meliponula ferruginea	43	0.03583333	1.020408	11	0.00916667	1.222222
	Meliponula bocandei	1006	0.83833333	23.872805	332	0.27666667	36.888889
	Pasites sp.3	11	0.00916667	0.261035	0	0	0
	Xylocopa sp.1	1	0.00083333	0.02373	0	0	0
Sub-total	***57.69% of species***						
Halictidae	*Acunomia sp.1*	9	0.0075	0.213574	0	0	0
	Crocisaspidia chandleri	1	0.00083333	0.02373	0	0	0
	Pseudapis sp.2	0	0	0	1	0.00083333	0.111111
	Pseudapis sp.4	1	0.00083333	0.02373	0	0	0
	Stictonomia schubotzi	19	0.01583333	0.450878	0	0	0
Sub-total	***23.08% of species***				1		
Megachilidae	*Anthidiini sp.1*	5	0.00416667	0.118652	0	0	0
	Anthidiini sp.2	1	0.00083333	0.02373	0	0	0
	Megachile ianthoptera	4	0.00333333	0.094922	0	0	0
	Lithurgus sp.4	2	0.00166667	0.047461	0	0	0
	Lithurgus sp.8	0	0	0	1	0.00083333	0.111111
Sub-total	**15.38% of species**				1		
Total	Abundance	4173	3.51166667	100	900	0.75	100
	Observed richness	24			9		
	Total observed richness	26					
	Estimated richness	39					
	Sampling coverage	66.66%					

Appendix II. Bees' community including their foraging activity in Béré cashew orchard

		Béré cashew orchard					
		Preferred cashew trees			Non-preferred cashew trees		
		Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)	Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)
Apidae	*Apis mellifera*	2241	1.8675	57.12465	462	0.385	77.777778
	Dactylurina staudingeri	234	0.195	5.964823	24	0.02	4.040404
	Hypotrigona sp.1	120	0.1	3.058884	32	0.02666667	5.387205
	Meliponula togoensis	456	0.38	11.623757	76	0.06333333	12.794613
	Meliponula bocandei	832	0.69333333	21.208259	0	0	0
	Pasites sp.2	1	0.00083333	0.025491	0	0	0
	Xylocopa olivacea	10	0.00833333	0.254907	0	0	0
Sub-total	***43.75% of species***						
Halictidae	*Acunomia sp.1*	3	0.0025	0.076472	0	0	0
	Pseudapis sp.4	3	0.0025	0.076472	0	0	0
	Stictonomia schubotzi	9	0.0075	0.229416	0	0	0
Sub-total	***18.75% of species***						
Megachilidae	*Anthidiini sp.1*	3	0.0025	0.076472	0	0	0
	Anthidiini sp.2	1	0.00083333	0.025491	0	0	0
	Lithurgus spiniferus	3	0.0025	0.076472	0	0	0
	Lithurgus sp.5	4	0.00333333	0.101963	0	0	0
	Litthurgus sp.6	3	0.0025	0.076472	0	0	0
Sub-total	***31.12% of species***						
Total	Abundance	3923	3.3	100	594	0.5	100
	Observed richness	16			4		
	Total observed richness	16					
	Estimated richness	32					
	Sampling coverage	50					

Appendix III. Bees' community including their foraging activity in Marahoué cashew orchard

		Marahoué cashew orchard					
		Preferred cashew trees			Non-preferred cashew trees		
		Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)	Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)
Apidae	*Apis mellifera*	2012	1.67666667	56.932654	498	0.415	53.49087
	Allodape sp.1	13	0.01083333	0.367855	0	0	0
	Allodape sp.2	13	0.01083333	0.367855	0	0	0
	Amegilla sp.2	5	0.00416667	0.141483	0	0	0
	Amegilla sp.3	1	0.00083333	0.028297	0	0	0
	Anthophora sp.1	1	0.00083333	0.028297	0	0	0
	Ceratina sp.1	1	0.00083333	0.028297	0	0	0
	Ceratina sp.2	6	0.005	0.169779	0	0	0
	Ceratina sp.3	6	0.005	0.169779	0	0	0
	Dactylurina staudingeri	135	0.1125	3.820034	24	0.02	2.577873
	Hypotrigona sp.1	0	0	0	2	0.00166667	0.214823
	Meliponula togoensis	451	0.37583333	12.761743	70	0.05833333	7.518797
	Meliponula bocandei	829	0.69083333	23.457838	330	0.275	35.445757
	Meliplebeia sp.1	3	0.0025	0.08489	1	0.00083333	0.107411
	Pasites sp.1	0	0	0	1	0.00083333	0.107411
	Xylocopa albiceps	14	0.01166667	0.396152	3	0.0025	0.322234
	Xylocopa olivacea	6	0.005	0.169779	2	0.00166667	0.214823
Sub-total	***62.96% of species***						
Halictidae	*Lasioglossum sp.1*	3	0.0025	0.08489	0	0	0
	Pseudapis sp.1	10	0.00833333	0.282965	0	0	0
	Pseudapis sp.2	3	0.0025	0.08489	0	0	0
	Pseudoanthidium tuberculiferum	1	0.00083333	0.028297	0	0	0
	Pachynomia amoenula	12	0.01	0.339559	0	0	0
Sub-total	***15.51% of species***						
Megachilidae	*Lithurgus spiniferus*	1	0.00083333	0.028297	0	0	0

	Lithurgus sp.3	1	0.00083333	0.028297	0	0	0
	Lithurgus sp.4	2	0.00166667	0.056593	0	0	0
	Lithurgus sp.5	1	0.00083333	0.028297	0	0	0
	Litthurgus sp.6	1	0.00083333	0.028297	0	0	0
	Lithurgus sp.7	3	0.0025	0.08489	0	0	0
Sub-total	***25.92% of species***						
Total	Abundance	3536 a	3	100	930 b	0.77	100
	Observed richness	26			9		
	Total observed richness	27					
	Estimated richness	43					
	Sampling coverage	62.79					

Appendix IV. Bees' community including their foraging activity in Hambol cashew orchard

		Hambol cashew orchard					
		Preferred cashew trees			Non-preferred cashew trees		
		Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)	Abundances	Visitors/minutes on inflorescences	Frequency of visits (%)
Apidae	*Apis mellifera*	2206	1.83833333	56.738683	489	0.4075	52.467811
	Amegilla sp.2	0	0	0	1	0.00083333	0.107296
	Amegilla sp.3	8	0.00666667	0.205761	0	0	0
	Anthophora sp.1	1	0.00083333	0.02572	0	0	0
	Cleptotrigona sp.1	7	0.00583333	0.180041	0	0	0
	Dactylurina staudingeri	276	0.23	7.098765	45	0.0375	4.828326
	Hypotrigona sp.1	18	0.015	0.462963	0	0	0
	Meliponula togoensis	428	0.35666667	11.00823	55	0.04583333	5.901288
	Meliponula ferruginea	84	0.07	2.160494	12	0.01	1.287554
	Meliponula bocandei	829	0.69083333	21.322016	330	0.275	35.407725
	Meliplebeia sp.1	1	0.00083333	0.02572	0	0	0
Sub-total	***68.75% of species***						
Halictidae	*Pseudapis sp.1*	14	0.01166667	0.360082	0	0	0

	Pseudapis sp.3	13	0.01083333	0.334362	0	0	0
	Steganomus sp.1	1	0.00083333	0.02572	0	0	0
Sub-total	***18.75% of species***						
Megachilidae	*Lithurgus sp.7*	1	0.00083333	0.02572	0	0	0
Sub-total	***6.25% of species***						
Colletidae	*Colletes sp.1*	1	0.00083333	0.02572	0	0	0
Sub-total	***6.25% of species***						
Total	Abundance	3888 a	3.24	100	932 b	0.77	100
	Observed richness	15			6		
	Total observed richness	16					
	Estimated richness	29					
	Sampling coverage	55.42%					