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Emmanuel Basga
(1) Department of Earth and Life Sciences, Higher Teachers' Training College, University of Maroua, P.O. Box 46, Maroua, Cameroon
(2) Laboratory of Applied Zoology, Faculty of Science, University of Ngaoundéré, P.O. Box 454, Ngaoundéré, Cameroon

Fameni Topé Sidonie
Department of Biological Sciences, University of Maroua, P.O. Box 814, Maroua, Cameroon

Fernand-Nestor Tchuenguem Fohouo
Laboratory of Applied Zoology, Faculty of Science, University of Ngaoundéré, P.O. Box 454, Ngaoundéré, Cameroon

Correspondence
Emmanuel Basga
(1) Department of Earth and Life Sciences, Higher Teachers' Training College, University of Maroua, P.O. Box 46, Maroua, Cameroon
(2) Laboratory of Applied Zoology, Faculty of Science, University of Ngaoundéré, P.O. Box 454, Ngaoundéré, Cameroon

Foraging and pollination activity of *Xylocopa olivacea* (Hymenoptera: Apidae) on *Vitellaria paradoxa* (Sapotaceae) flowers at Ouro-Gadji (Garoua, Cameroon)

Emmanuel Basga, Fameni Topé Sidonie and Fernand-Nestor Tchuenguem Fohouo

Abstract
To evaluate the impact of *Xylocopa olivacea* (Hymenoptera: Apidae) on *Vitellaria paradoxa* (Sapotaceae) yields, the foraging and pollination activities of this carpenter bee were studied in January 2011 and from January to February 2012 at Ouro-Gadji. Treatments included unlimited flowers access by all visitors, bagged flowers and limited visit by *X. olivacea* only. The seasonal rhythm of *X. olivacea* activity, its foraging behavior on flowers and its pollination efficiency were recorded. Results show that, carpenter bee intensively harvested nectar and pollen. The mean foraging speed was 9.84 flowers per min. The fruiting rate of unprotected flowers is significantly higher that of protected flowers. Through its pollination efficiency, *X. olivacea* provoked a significant increase of the fruiting rate by 13.40%. Hence, conservation and installation of *X. olivacea* nests close to *V. paradoxa* populations are recommended to improve fruit and seed yields of this plant in the region.

Keywords: *Xylocopa olivacea*, *Vitellaria paradoxa*, foraging, pollination, yields

1. Introduction
In the natural environment and in agro ecosystems, flowers - feeding insects in general and Apoidea in particular have great ecological and economical importance because they have a positive influence on food production [1-4]. Effective pollination by insects can increase fruit yield and quality of seeds [5-10]. The lack of pollinating insects during flowering time can lead to kidney yields fruits and/or seeds for some crops [11-13].
Tropical trees are predominantly outcrossing and many species are self-incompatible [14, 15]. It is estimated that nearly 94% of tropical flowering plant species are animal pollinated [16]. Thus, the interactions of pollinators and tree species used by local people for seed collection are of special interest. Although crucial for the fruit set of many tropical trees, pollinators as well as pollination requirements are still unidentified for many species [17] in many regions. This is also the case for the Shea tree, *Vitellaria paradoxa*, which is distributed in a belt of Africa from Senegal to the Sudan/Ethiopian border [18]. The sweet fruit pulp is eaten fresh, and the kernels contain oil known as Shea butter, which is used both for cooking and as skin cream [18]. Shea fruits are also an important food resource for bats, which contribute to the dispersal of seeds [19]. Fruit production of Shea trees is known to fluctuate across years [20]. Several authors suggest that variation in pollination success plays a significant role in explaining the yearly variation of the fruit production [21-24]. Most authors recognize different species of bees as main pollinators [25, 26, 20], but according to Chevalier [25], wind may also play a role. Shea is predominantly outcrossing, but whether selfing is rare or absent remains to be tested [27]. The Shea flowers emit a strong scent of honeyand attract many visitors, especially insects and birds [22].
In Cameroon, very little information exists on the relationships between *V. paradoxa* and its flowering insects. Before this study, floral entomofauna of *V. paradoxa* have been studied in Ngaoundéré [28, 29]. But it is known that floral entomofauna of a plant can vary from one region to another. This work was conducted to study the activity of *X. olivacea* on the flowers of *V. paradoxa* to assess the effectiveness of pollination on yields of this Sapotaceae in Garoua for the first time.

2. Materials and Methods

2.1 Study Site

The studies were conducted in January 2011 and from January to February in 2012 respectively at Ouro-Gadji (Latitude 9°31 48 N, Longitude 13°19 15 E and altitude 251 a.s.l.), a village located in the North West of the city of Garoua in the North Region of Cameroon. This region belongs to the Sahel-Sudanian ecological zone [30]. It has Sudanian climate type characterized by two annual seasons: a rainy season (April to October) and a dry season (November to March). August is the wettest month of the year [31, 30]. Annual rainfall varies from 750 to 1250 mm and the mean annual temperature is 27 °C [32, 30]. The plants chosen for observation were located on an area of 60 000 m^2. Vegetation was represented by the native plant species of the savannah.

2.2 Biological materials

The plant material was represented by *V. paradoxa* naturally present in the study site. The animal material was represented by *X. olivacea* and other insects naturally present in the environment.

2.3 Determination of the reproduction mode of *Vitellaria paradoxa*

On January 5 and 6, 2011, 200 inflorescences of *V. paradoxa* with flowers in bud stage were labeled among which 100 were left unattended (Figure 1) (treatment 1) and 100 were bagged using gauze bags (Figure 2) (treatment 2) to prevent visitors or external pollinating agents [33]. On January 11 and 12, 2012, the same treatments were set up, 200 inflorescences of *V. paradoxa* with flowers in bud stage were labeled among which, 100 where left unattended (treatment 3) and 100 were bagged using gauze bags to prevent visitors or external pollinating agents (treatment 4). For each year, twenty days after the wilting of the last flower, the number of formed fruits was counted in each treatment. The fruiting index (*Ifr*) was then calculated for each treatment using the following formula: $Ifr = (F_1 / F_2)$ were F_1 is the number of formed fruits and F_2 the number of viable flowers initially set [34]. The allogamy rate (*TC*) from which derives the autogamy rate (*TA*) was calculated using the formula: $TC = \{[(Ifr_X - Ifr_Y) / Ifr_X] * 100\}$, where Ifr_X and Ifr_Y are the mean fruiting indexes of free treatment and bagged treatment respectively [35]. The autogamy rate was calculated using the formula: $TA = [100 - TC]$.

Fig 1: Inflorescence of *Vitellaria paradoxa* showing unattented flowers.

Fig 2: Inflorescence of *Vitellaria paradoxa* protected from insect visit using a gauze bag.

2.4 Study of foraging activity of *Xylocopa olivacea* on *Vitellaria paradoxa* flowers

Observations were conducted on flowers of treatments 1 and 3, from the opening of the first flower bud (8th January 2011 and 15th January 2012) to the fading of the last flower (5th February 2011, 12th February 2012) according to six daily time frames: 6-7h, 8-9h, 10-11h, 12-13h, 14-15h and 16–17h. The identity of all insects that visited *V. paradoxa* flowers was recorded at each daily time frame. All insects encountered on flowers were recorded and the cumulated results expressed in number of visits have been used to determine the relative frequency of *X. olivacea* (F_x) in the anthophilous fauna of *V. paradoxa*.

For each year of study, $F_x = [(V_x / V_i) * 100]$, where V_x is the number of visits of *X. olivacea* on flowers of free treatment and *Vi*, the total number of insect visits on flowers of the same treatment [36].

During each day of investigation, before starting visit counts, the number of open flowers was counted. The same days as for the frequency of visits, the floral products (nectar and / or pollen) collected by the carpenter bee were recorded for the same date and daily time frame as that of insects' counts. The study of this parameter indicates whether *X. olivacea* is strictly pollinivorous or nectavore or pollinivorous and nectarivorous on *V. paradoxa* flowers [37]. This can give an idea of its involvement in the pollination of this plant. The duration of the individual flower visits was recorded (using a stopwatch) according to six daily time frames: 6-7h, 8-9h, 10-11h, 12-13h, 14-15h, 16-17h [38]. The foraging speed (number of flowers visited by a carpenter bee per minute according to [39]) was calculated using the following formula [38]: $V_b = (F_i / d_i) * 60$ where *di* is the time (s) given by a stopwatch and F_i is the number of flowers visited during d_i. The abundance of foragers (highest number of individuals foraging simultaneously) per flower or per 1000 flowers (A_{1000}) were recorded on the same dates and time slots as the registration of the duration of visits. Abundance per flower was recorded as a result of direct counting. For determining the abundance per 1000 flowers, some foragers were counted on a known number of opened flowers and A_{1000} was calculated using the following formula: $A_{1000} = [(A_x / F_x) * 1000]$, where F_x and A_x are respectively the number of flowers and the number of foragers effectively counted on these flowers at time *x* [34]. The disruption of the activity of foragers by competitors or predators and the attractiveness exerted by other plant species on this insect was assessed by direct observations. For the second parameter, the number of times the carpenter bee went from *V. paradoxa* flowers to other plant species and vice versa was noted throughout the period of investigation. During each observation date, temperature and relative humidity in the station were registered after every 30 minutes using a mobile thermo-hygrometer installed in the shade [38].

2.5 Evaluation of the impact of flowering insects on *Vitellaria paradoxa* yields

For each year of study, it was based on the impact of flowering insects on pollination, the impact of pollination on *V. paradoxa* fruiting and the comparison of the fruiting rate of treatment $_x$ (unprotected flowers) and treatment $_y$ (bagged flowers) [33]. The fruiting rate due to the influence of foraging insects was calculated using the following formula [36]: $P_i = \{[(F_x - F_y) / F_x] * 100\}$, where F_x and F_y are the fruiting rate in treatment $_x$ (treatment 1 or 3) and $_y$ (treatment 2 or 4) respectively. The fruiting rate (F_r) of each treatment is: $F_r = [(F_2 / F_1) * 100]$, where F_2 is the number of fruits formed and F_1 the number of flowers initially set [38].

2.6 Evaluation of the pollination efficiency of *Xylocopa olivacea* on *Vitellaria paradoxa*

To evaluate the pollination efficiency of *X. olivacea*, along with the development of treatments 1 and 2, 20 inflorescences were isolated (treatment 5) as those of treatment 2. Along with the development of treatments 3 and 4, 20 inflorescences were isolated (treatment 6) as those of treatment 4. Between 8 and 11 a.m. of each observation date, the gauze bag was delicately removed from each inflorescence of treatment 5 and 6, and the flowers observed for up to 15 min. Flowers visited by *X. olivacea* were labeled and unattended flowers were eliminated. After this manipulation, inflorescences were protected once more [38]. Twenty days after, for each study year, the contribution of *X. olivacea* on fruiting (Fr_x) was calculated using the formula: $Fr_x = \{[(Fr_z - Fr_y) / Fr_z] \text{ x } 100\}$ [37] where Fr_z and Fr_y are the fruiting rates in treatment $_z$ (flowers protected and visited exclusively by *X. olivacea*) and $_y$ (protected flowers).

2.7 Data analysis

Data were analyzed using descriptive statistics, Student's *t* -test for comparison of means of two samples, correlation coefficient (*r*) for the study of linear relationship between two variables, Chi-Square (X^2) for the comparison of percentages and Microsoft Excel 2010 sheet.

3. Results

3.1 Reproductive system of *Vitellaria paradoxa*

In 2011, the fruiting index was 0.27 and 0.10 respectively for treatment 1 and 2, while in 2012, it was 0.18 for treatment 4 and 0.08 for treatment 5. For the two cumulated years, the fruiting index was 0.22 and 0.09 respectively for treatment $_x$ (unprotected flowers) and treatment $_y$ (bagged flowers). Thus in 2011, the allogamy rate was 62.96% and the autogamy rate was 37.04%. In 2012, the corresponding figures were 55.55% and 44.55%. For the two cumulated years, the allogamy rate was 59.25% and the autogamy was 40.75%. It appears that *V. paradoxa* has a mixed mating system, autogamous-allogamous, with the predominance of allogamy over autogamy.

3.2 Activity of *Xylocopa olivacea* on *Vitellaria paradoxa* flowers

3.2.1 Frequency of the visitors of *Vitellaria paradoxa*

Amongst the 740 and 598 visits of 9 and 12 insects species recorded on the flowers of *V. paradoxa* in 2011 and 2012 repectively, *X. olivacea* is one of the most represented insect with 194 visits (26.29%) and 111 visits (18.56%) in 2011 and 2012 respectively. This carpenter bee species ranked second in each study year (Table 1). The difference between these two percentages is highly significant ($\chi^2 = 20.49$; $df = 1$; $P<0.001$).

Table 1. Diversity of floral insects on *Vitellaria paradoxa* flowers in 2011 and 2012 at Ouro-Gadji, number and percentage of visits of different insects.

Order	Family	Genus and species	2011		2012		Total$_{2011/2012}$	
			n_1	p_1 (%)	n_2	p_2 (%)	n_T	p_T
Coleoptera		(1 sp.) (po)	8	1.08	15	2.50	23	1.71
Diptera	Muscidae	*Musca domestica* (ne, po)	18	2.43	9	1.50	27	2.01
		Calliphora sp. (ne, po)	-	-	7	1.17	7	0.52
Hymenoptera	Apidae	*Apis mellifera* (ne, po)	203	27.43	206	34.44	409	30.56
		Xylocopa olivacea (ne, po)	194	26.29	111	18.56	305	22.79
		Xylocopa sp. (ne, po)	131	17.70	135	22.57	266	19.88
	Formicidae	*Palthotyreus tarsatus* (ne)	31	4.18	28	4.68	59	4.40
	Halictidae	*Lasioglossum* sp. 1 (ne, po)	14	1.89	12	2.00	26	1.94
		Lasioglossum sp. 2 (ne, po)	114	15.40	57	9.53	171	12.78
	Sphecidae	*Philanthus triangulum* (pr)	-	-	4	0.66	4	0.29
	Vespidae	*Belonogaster juncea* (ne)	27	3.64	10	1.67	37	2.76
		(1 sp.) (ne)	-	-	4	0.66	4	0.29
Total	Visites		740	100	598	100	1338	100
	Espèces		(8 species)		(12 species)		(12 species)	

n_1: number of visits on 100 inflorescences in 16 days; n_2: number of visits on 100 inflorescences in 13 days; p_1 and p_2: percentages of visits; $p_1 = (n_1 / 740) * 100$; $p_2 = (n_2 / 598) * 100$; sp.: undetermined species; ne: visitor collected nectar; po: visitor collected pollen; pr: visitor hunted preys. Comparison of percentages of *Xylocopa olivacea* visits for two years: $\chi^2 = 20.49$ ($df = 1$; $P<0.001$).

3.2.2 Floral products harvested

During each flowering period, *X. olivacea* harvested preferably and regularly nectar (Figure 3). The collection of pollen was less frequent (Table 2).

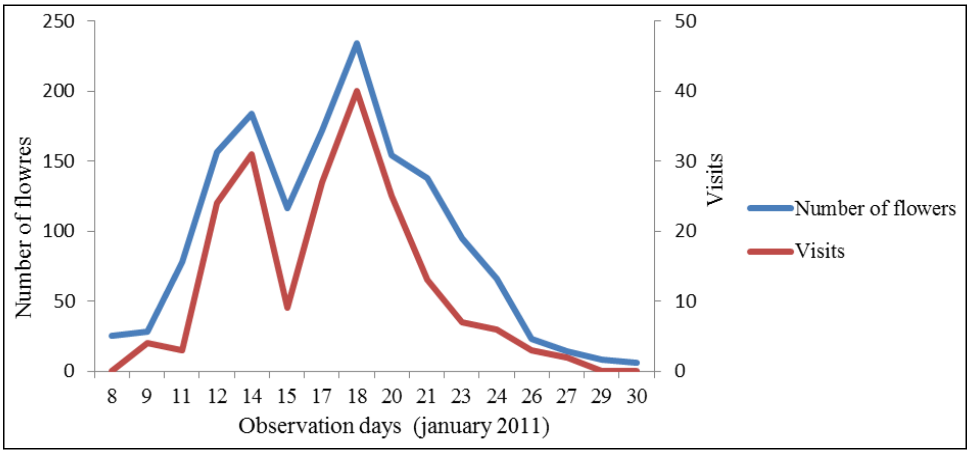
Fig 3: *Xylocopa olivacea* collecting nectar in a flower of *Vitellaria paradoxa*.

Table 2: Products harvested by *Xylocopa olivacea* on *Vitellaria paradoxa* flowers in 2011 and 2012 at Ouro-Gadji.

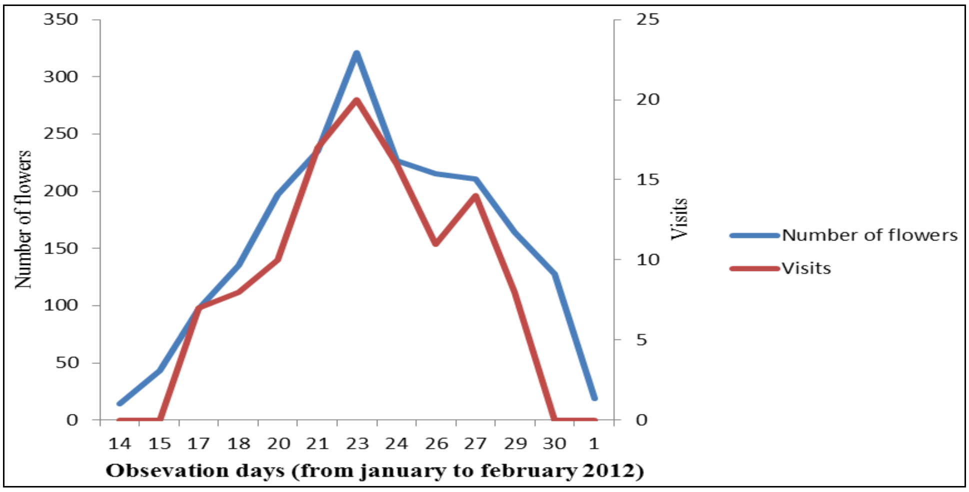
Years	Number of visits studied	Visits for nectar harvest		Visits for pollen harvest	
		Number	%	Number	%
2011	194	157	80.93	37	19.07
2012	111	86	77.37	25	22.63
Total	305	243	79.67	62	20.33

3.2.3 Relationship between visits and flowering stages

Overall, visits of *X. olivacea* were more numerous on treatment 1 and 3 when the number of opened flowers was highest (Figures 4A and B). A positive and highly significant correlation was found between the number of *V. paradoxa* opened flowers and the number of *X. olivacea* visits in 2011 (r = 0.94; df = 14; $p<0.05$) and in 2012 (r = 0.93; df = 11; $p<0.05$).



(A)

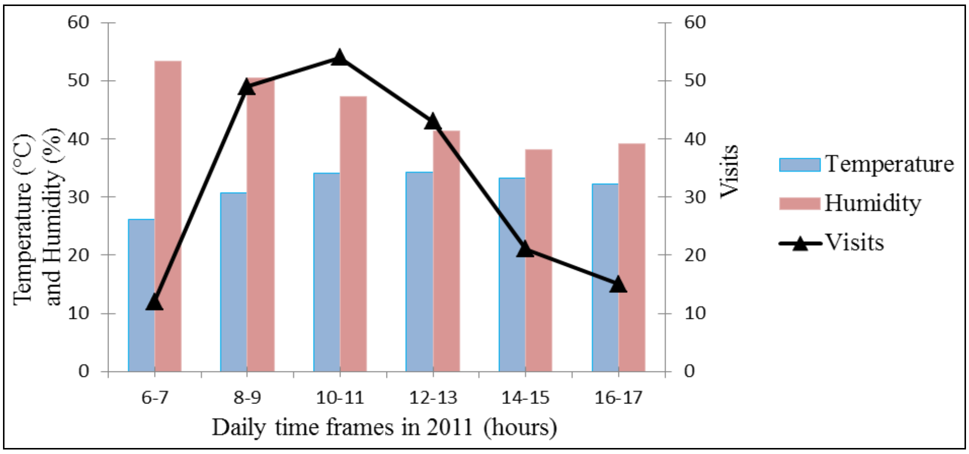


(B)

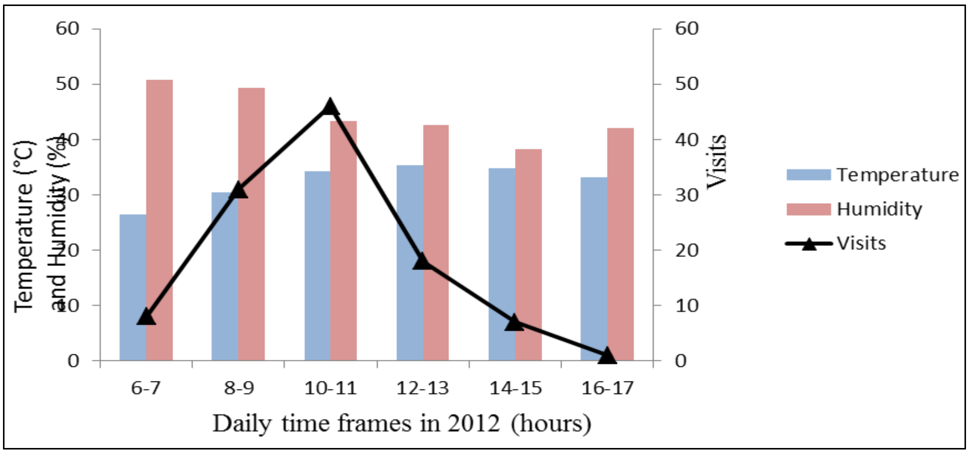
Fig 4: Seasonal variation of the number of *Vitellaria paradoxa* flowers and the number of *Xylocopa olivacea* visits in 2011 (A) and 2012 (B).

3.2.4 Diurnal flower visits

Xylocopa olivacea has been active on *V. paradoxa* flowers throughout the day, with a peak of activity being observed between 10 and 11 a.m. in 2011 and 2012 (Figures 5A and B). The activity of *X. olivacea* was not significantly influenced by temperature and relative humidity. The correlation was not significant between the number of *X. olivacea* visits and the temperature in 2011 (r = 0.52; df = 5; $p>0.05$) and in 2012 (r = 0.18, df = 5, $p>0.05$). The correlation was not significant between the number of *X. olivacea* visits and relative humidity in 2011 (r = 0.15; df = 5; $p>0.05$) as well as in 2012 (r = 0.19; df = 5; $p>0.05$).



(A)



(B)

Fig 5: Daily variation of the number of *Xylocopa olivacea* visits on *Vitellaria paradoxa* flowers during 16 days in 2011 (A) and during 13 days in 2012 (B) at Ouro-Gadji, mean temperature and mean humidity of the study site.

3.2.5 Duration of a visit per flower

The mean duration of a *X. olivacea* visit on *V. paradoxa* flower varied significantly, depending on the substance taken. In 2011 the mean duration of a visit for pollen collection was 13.18 sec (n = 50, s = 11.15, *maxi* = 48); for the collection of nectar, it was 22.87 sec (n = 50, s = 12.53, *maxi* = 75). In 2012, the corresponding results were 16.31 sec (n = 50, s = 13.42, *maxi* = 54) and 28.38 sec (n = 50, s = 21.05, *maxi* = 82) for pollen and nectar harvest respectively. For the two cumulative years, the mean duration of a visit for pollen collection and that for nectar collection was 14.74 sec and 25.62 sec respectively. The difference between the duration of a visit for nectar harvest in 2011 and 2012 is significant (t = 7.87; df = 98; p<0.001), as well as the difference between durations of visit for pollen harvest in 2011 and 2012 (t = 6.27; df = 98; p<0.001). The difference between the duration of visit for pollen harvest and that for nectar harvest was highly significant in 2011 (t = 19.94; df = 98; p<0.001) as well as in 2012 (t = 16.92, df = 98; p<0.001).

3.2.6 Abundance of *Xylocopa olivacea*

In 2011 and 2012, the highest mean number of *X. olivacea* simultaneously in activity was 1 per flower (n = 50, s = 0). The corresponding figures per 1000 flowers were 147.24 (n = 50, s = 77.04, *maxi* = 339) and 97.81 (n = 50, s = 42.31, *maxi* = 207) respectively. The difference between the mean number of foragers per 1000 flowers in 2011 and 2012 was highly significant (t = 19.68; df = 98; p<0.001). For the two cumulative years, the mean highest number of *X. olivacea* individuals simultaneously in activity per 1000 flowers was 122.52.

3.2.7 Foraging speed of *Xylocopa olivacea* on *Vitellaria paradoxa* flowers

Xylocopa olivacea visited between 3 and 29 flowers/min in 2011 and between 2 and 21 flowers/min in 2012. The mean foraging speed was 8.17 flowers/min (n = 60, s = 3.54) in 2011 and 11.51 flowers/min (n = 60, s = 4.11) in 2012. The difference between these means was highly significant (t = -25.90; df = 118; p<0.001). For the two cumulated years, the mean foraging speed was 9.84 flowers/min.

3.2.8 Influence of Wildlife

During the period of observation, flowers of many other plant species growing near *V. paradoxa* were visited for nectar (ne) and/or pollen (po) by *X. olivacea* individuals. The most representative of these plants were *Mangifera indica* (Anacardiaceae, ne) and *Daniellia oliveri* (Fabaceae, ne and po). During one foraging trip, an individual carpenter bee foraging on *V. paradoxa* was not observed moving to the neighbouring plant species or vice versa.

Individuals of *X. olivacea* were disturbed in their foraging by other arthropods that were competitors for the search of pollen or nectar. These disturbances resulted in the interruption of certain *X. olivacea* visits. In 2011, for 194 visits of *X. olivacea*, 2 (1.03%) were interrupted by *Lasioglossum* sp.1. In 2012, for 111 visits of *X. olivacea*, 1 (0.90%) was interrupted by *Apis mellifera*. For their load of pollen some individuals of *X.* olivacea who suffered such disturbances were forced to visit more flowers and/or plants during the corresponding foraging trip.

3.3 Impact of Anthophilous insects including *Xylocopa olivacea* in the pollination and *Vitellaria paradoxa* yields

During pollen and/or nectar harvest, flowers-feeding insects of *V. paradoxa* were in regular contact with the anthers and stigma. These arthropods therefore increased the possibilities of this Sapotaceae pollination. Table 3 presents the results on the fruiting rate in different treatments. It is clear from this table that the comparison of fruiting rates shows that the differences are highly significant between treatments 1 and 2 (χ^2 = 244.47; df = 1; P<0.001) and treatments 3 and 4 (χ^2 = 98.77; df = 1; P<0.001). Consequently, in 2011, the fruiting rate of unprotected flowers (treatment 1) was higher than that of protected flowers (treatment 2). In 2012, the fruiting rate of unprotected flowers (treatment 3) was higher than that of protected flowers (treatment 4). The fruiting rate due to the action of flowering insects including *X. olivacea* was 62.97% in 2011, 55.55% in 2012 and 59.26% for the two studied years.

Table 3: Fruiting rate according to different treatments of *Vitellaria paradoxa* in 2011 and 2012 at Ouro-Gadji.

Treatments	Years	NF	NFF	FR
1 (unprotected flowers)	2011	2765	747	27.01
2 (protected flowers)		2458	246	10
3 (Fl_x)		58	9	15.51
4 (unprotected flowers)	2012	1976	356	18.01
5 (protected flowers)		2386	191	8.00
6 (Fl_x)		46	6	13.04

NFS: number of flowers studied; NFF: number of fruits formed; FR: fruiting rate

Fl_x: Flowers protected and exclusively visited by *Xylocopa olivacea*

3.4 Pollination efficiency of *Xylocopa olivacea* on *Vitellaria paradoxa*

From Table 3, it appears that the comparison of fruiting rates shows that the differences are significant between treatments 2 and 5 (χ^2 = 1.90; df = 1; P<0.001) and treatments 4 and 6 (χ^2 = 1.54; df = 1; P<0.001). Consequently, in 2011, the fruiting rate of unprotected flowers (treatment 1) was higher than that of protected flowers (treatment 2). In 2012, the fruiting rate of unprotected flowers (treatment 3) was higher than that of protected flowers (treatment 4). The fruiting rate due to the action of *X. olivacea* was 16.50% in 2011, 10.31% in 2012 and 13.40% for the two studied years.

4. Discussion

Xylocopa olivacea individuals were the main floral visitors of *V. paradowa* after *A. mellifera* workers during the observation periods. This carpenter bee is known as an insect flower visitor of *V. paradoxa* in Ghana [40] and in the Adamaoua region of Cameroon [28, 29]. *Xylocopa olivacea* has been shown to be the most abundant floral visitor of: *Ananas comosus* [41], *Luffa aegyptiaca* [42], *Vigna unguiculata* [43] and *Phaseolus coccineus* [44, 45]. Previous researches carried out in other parts of the country also revealed that *X. olivacea* ranks second among the floral insects visiting *Cajanus cajan* [46] and *V. unguiculata* [47]. This rank could be due to the relative abundance of *X. olivacea* in different study areas, though the abundance and diversity of floral insects to a plant varies depending on the region [48]. The significant difference between the percentages of *X. olivacea* visits of the two study years could be attributed to the presence of their natural nests close to the experimental site variation. The peak of *X. olivacea* activity on *V. paradoxa* flowers was located between 10.00 am to 11.00 am, which correlated with the highest availability period of nectar and pollen on this Sapotaceae. The abundance of *X. olivacea* individuals per 1000 flowers and the positive and highly significant correlation between the number of *V. paradoxa* flowers in bloom as well as the number of *X. olivacea* visit indicates the attractiveness of pollen and nectar with respect to this bee.

The significant difference between the duration of the pollen harvest visits and that of nectar collection visits in 2011 and 2012 could be explained by the availability and/or the accessibility of each of these floral products or the variation of diversity of flowering insects from one year to another.

During each of the two flowering periods of *V. paradoxa*, *X. olivacea* intensively and regularly harvested nectar. This could be attributed to the needs of individual carpenter bees during the flowering period. The disruptions of visits by other insects reduced the duration of certain *X. olivacea* visits. Similar observations were made for the same carpenter bee foraging on flowers of *Phaseolus coccineus* [45] in Youndé and on flowers of *Phaseolus vulgaris* in Ngaoundéré [49].

During the collection of nectar or pollen on each flower, *X. olivacea* individuals regularly come into contact with the stigma and anthers. They also carried pollen with their hairs, legs, thorax, abdomen and mouth accessories from a flower of one plant to the stigma of the same flower, to the stigma of another flower of the same plant or to that of another plant; individuals of this carpenter bee can thus influence self-pollination and cross-pollination [50, 51]. Similar observations have been made for *X. olivacea* foraging on flowers of *Phaseolus vulgaris* in Western Kenya [52], on *Ananas comosus* flowers in Ghana [41] and on *Sesanum radiatum* in Benin [53].

The weight of *X. olivacea* played a positive role in the self-pollination [42]: when collecting nectar and/or pollen, *X. olivacea* shakes flowers; this movement could facilitate the liberation of pollen by anthers, for optimal occupation of the stigma [42]. Results of the present study confirm those of the studies carried out by [45, 44] on *Phaseolus coccineus* in yaoundé and Ngaoundéré respectively, [49] on *Phaseolus vulgaris* in Ngaoundéré, [42] on *Luffa aegyptiaca* in Ghana. The present study demonstrates that during one foraging trip, an individual bee foraging on *V. paradoxa* scarcely visits other plant species.

The higher productivity of fruits in unlimited visits when compared with bagged flowers showed that insect visits were effective in increasing cross and/or self-pollination. Higher productivity of flowers exposed to visits by *X. olivacea* compared with those under unlimited visits by all kinds of visitors shows that this carpenter bee is an important pollinator of *V. paradoxa* and thus can be targeted for the managed pollination of this plant.

The positive and significant contribution of *X. olivacea* to the *V. paradoxa* yields through its pollination efficiency is in agreement with similar findings in Yaoundé on *Phaseolus coccineus* [44] and in Ngaoundéré on *Phaseolus vulgaris* [49].

5. Conclusion

Vitellaria paradoxa is a plant species that benefit highly from pollination by insects among which, *Xylocopa olivacea* is the most important pollinator. This carpenter bee harvests pollen and nectar in *V. paradoxa* flowers. The comparison of fruits set of unprotected flowers with that of flowers visited exclusively by *X. olivacea* underscores the value of this carpenter bee in increasing mature fruits rate of *V. paradoxa*. The installation of *X. olivacea* nests at the vicinity of *V. paradoxa* field is recommended for the increase of fruit yield of this plant species in the region.

6. References

1. Mutsaers M. Honeybees in their natural environment in south western Nigeria. The Nigerian Field. 1991; 56:19-28.
2. Desquesne PH. Apiculture tropicale en Afrique de l'Ouest. Abeille de France. 1996; 813:131-132.
3. Morison N, Vaissière BE, Martin F, Pécaut P, Cambon G. Pollinisation de l'artichaut (*Cynara scolymus* L.) par l'abeille domestique (*Apis mellifera* L.) en production de semences hybrides sous abris grillagés. Apidologie. 2000a; 31:115-128.
4. Tchuenguem FFN, Messi J, Pauly A. L'activité de butinage des Apoïdes sauvages (Hymenoptera Apoidea) sur les fleurs de maïs à Yaoundé (Cameroun) et réflexions sur la pollinisation des graminées tropicales. Biotechnologie, Agronomie Société et Environnement. 2002; 6(2):87-98.
5. Philippe JM. La pollinisation par les abeilles: pose des colonies dans la culture en floraison en vue d'accroître les rendements des productions végétales. EDISUD, la calade, Aix-en-Provence, 1991, 179.
6. Vaissière BE, Izard D. La pollinisation, un facteur à ne pas négliger. Melon Haute Définition. Fruits et Légumes, Spécial Issue, 1995, 57-60.
7. Segeren P, Mulder V, Beetsma J, Sommeijer R. Apiculture sous les tropiques. Agrodok 32, 5ème edition, Agromisa, Wageningen, 1996, 88.
8. Keller FL, Waller DM. Inbreeding effects in wild populations. Trends in Ecology and Evolution. 2002; 17:230-241.
9. Fluri P, Frick R. Apiculture in Sweden: state and perspectives. Revue Suisse d'Agriculture. 2005; 37(2):81-86.
10. Klein AM, Vaissière BE, Cane JH, Steffan DI, Cunnigham SA, Kremen C *et al*. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B, Biological Sciences. 2007; 274(1608):303-316.
11. McGregor SE. Insect pollination of cultivated crop plants. Agricultural Research Service. United States Department of Agriculture, Agricultural Handbook, Washington DC. 1976; 496:411.
12. Delbrassine S, Rasmont P. Contribution à l'étude de la pollinisation du colza, *Brassica napus* L. var. *oleifera* (Moench) Delile, en Belgique. Bulletin des Recherches Agronomiques de Gembloux. 1988; 23(2):123-152.
13. Tchuenguem FFN, Ngakou A, Kengni BS. Pollination and yield responses of cowpea (*Vigna unguiculata* L. Walp.) to the foraging activity of *Apis mellifera adansonii* (Hymenoptera: Apidae) at Ngaoundéré (Cameroon). African Journal of Biotechnology. 2009b; 8:1988-1996.
14. Bawa KS, Perry DR, Beach JH. Reproductive biology of tropical lowland rain forest trees. Sexual systems and incompatibility mechanisms. American Journal of Botany. 1985; 72(3):331-345.
15. Ward M, Dick CW, Gribel R, Lowe AJ. To self, or not to self. A review of outcrossing and pollen mediated gene flow in neo tropical trees. Heredity. 2005; 95:246-254.
16. Ollerton J, Winfree R, Tarrant S. How many flowering plants are pollinated by animals? Oikos. 2011; 36(120):321-326.
17. Rodger JG, Baklkwill K, Gemmill B. African pollination studies: where are the gaps? International Journal of Tropical Insect Science. 2004; 24:5-28.
18. Hall JB, Aebischer DP, Tomlinson HF, Osei-Amaning E, Hindle JR. *Vitellaria paradoxa*: a monograph, School of Agricultural and Forest Sciences, University of Wales, Bangor, 1996, 105.
19. Djossa BA, Fahr J, Kalko EKV, Sinsin BA. Fruit selection and effects of seed handling by flying foxes on germination rates of Shea trees, a key resource in northern Benin, West Africa. Ecotropica. 2008; 14:37-48.
20. Ruyssen B. Le karité au Soudan. Agronomie Tropicale. 1957; 12:143-172.
21. Guinko S, Guenda W, Millogo-Rasolodimby J, Tamini Z, Zoungrana I. Importance apicole du karité *Butyrospermum paradoxum* subsp. *parkii* (G. Don) Hepper. *In*: Séminaire national sur la valorisation du karité pour le développement national. Bilan et perspectives. CNRST/U, Ouagadougou, 1988, 68-73.
22. Millogo-Rasolodimby J. Importance apicole du karité, *Butyrospermum paradoxum* (Gaert. Hepper) et du néré, *Parkia biglobosa* (Jacq. Benth.). Revue Française d'Apiculture. 1989; 482:72-74.
23. Okullo JBL, Hall JB, Eliot M. Reproductive biology and breeding systems of *Vitellaria paradoxa*. Improved management of agroforestry parkland systems in Sub Saharan Africa. Teklehaimanot Z. (Ed), School of Agricultural and Forest Sciences, Bangor, 2003, 66-84.
24. Soro D, N'guessan K, Soro K. Variability of production out of fruits of Shea trees. Agricultural and Biological Journal of Northern America. 2011; 2:239-243.
25. Chevalier A. Nouvelles recherches sur l'arbre à beurre du Soudan, *Butyrospermum parkii*. Revue Internationale de Botanique Appliquée et d'Agriculture Tropicale. 1948; 28:241-256.
26. Guinko S, Guenda W, Millogo-Rasolodimby J, Tamini Z, Zoungrana I. Etude des plantes mellifères dans l'ouest du Burkina Faso (Provinces du Houet, de la Comoe et du Kenedougou). Rapport d'études. Projet TCP/BKF/4510 (T). Développement de l'apiculture, Ouagadougou, 1987, 97.
27. Kelly BA, Hardy OJ, Bouvet JM. Temporal and spatial genetic structure in *Vitellaria paradoxa* (Shea tree) in an agroforestry system in southern Mali. Molecular Ecology. 2004; 13:1231-1240.
28. Tchuenguem FFN, Mapongmetsem PM, Hentchoya Hemo J, Messi J. Activité de *Apis mellifera* L. (Hymenoptera: Apidae) sur les fleurs de quelques plantes ligneuses à Dang (Adamaoua, Cameroun). Cameroon Journal of Biology and Biochemistry Sciencies. 1997b; 7(1):86-91.
29. Djonwangwé D, Tchuenguem FFN, Messi J, Brückner D. Impact de l'activité de butinage de *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) sur la pollinisation et la chute des jeunes fruits du karité *Vitellaria paradoxa* (Sapotaceae) à Ngaoundéré (Cameroun). International Journal of Biological and Chemical Sciences. 2011c; 5(4):1538-1551.
30. MINEPAT. Rapport sur le développement économique du Cameroun (RADEC). Région du Nord, 2014, 180.
31. Donfack P. Végétation des jachères du Nord-Cameroun: Typologie, Diversité, Dynamique, Production. Thèse de doctorat du 3ème cycle, Biologie Végétale, Université de

Yaoundé I (Cameroun), 1998, 118.
32. Hieng IO. Etude des paramètres géotechniques des sols du Cameroun. Ed. Clé. Yaoundé, 2009, 147.
33. Roubik DW. Pollination of cultivated plants in the tropics. FAO Agricultural Services Bulletin. 1995; 118:1-198.
34. Tchuenguem FFN, Messi J, Brückner D, Bouba B, Mbofung G, Hentchoya Hemo J. Foraging and pollination behaviour of the African honey bee (*Apis mellifera adansonii*) on *Callistemon rigidus* flowers at Ngaoundéré (Cameroon). Journal of the Cameroon Academy of Sciences. 2004; 4:133-140.
35. Demarly Y. Génétique et amélioration des plantes. Masson, Paris, 1988, 577.
36. Tchuenguem FFN, Messi J, Pauly A. Activité de *Meliponula erythra* sur les fleurs de *Dacryodes edulis* et son impact sur la fructification. Fruits. 2001; 56(3):179-188.
37. Tchuenguem FFN, Dounia. Foraging and pollination behavior of *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) on *Glycine max* L. (Fabaceae) flowers at Maroua. Journal of Research in Biology. 2014; 4(1):1209-1219.
38. Tchuenguem FFN. 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, 2005, 103.
39. Jacob-Remacle A. Comportement de butinage de l'abeille domestique et des Abeilles sauvages dans des vergers de pommiers en Belgique. Apidologie. 1989; 20(4):271-285.
40. Stout JC, Nombre I, de Bruijn B, Delaney A, Doke DA, Gyimah T *et al*. Insect pollination improves yield of Shea (*Vitellaria paradoxa* Subsp. *paradoxa*) in the agroforestry land of West Africa. Journal of Pollination Ecology. 2018; 22(2):11-20.
41. Kudom AA, Kwapong PK. Floral visitors of *Ananas comosus* in Ghana: A preliminary assessment. Journal of Pollination Ecology. 2010; 2(5):27-32.
42. Mensah BA, Kudom AA. Foraging dynamic and pollination efficiency of *Apis mellifera* and *Xylocopa olivacea* on *Luffa aegyptiaca* Mill. (cucurbitaceae) in Southern Ghana. Journal of Pollination Ecology. 2011; 4(5):34-38.
43. Pando JB, Tchuenguem FFN, Tamesse JL. Activité de butinage et de pollinisation de *Xylocopa olivacea* Fabricius 1787(Hymenoptera : Apidae) sur les fleurs de *Vigna unguiculata* (L) Walp. 1843 (Fabaceae) à Yaoundé-cameroun. 2013; 66:47-59.
44. Tchenguem FFN, Fameni TS, Brückner D. Foraging and pollination behaviour of *Xylocopa olivacea* (Hymenoptera: Apidae) on *Phaseolus coccineus* (Fabaceae) flowers at Ngaoundéré (Cameroon). 2014a; 34(2):127-137.
45. Pando JB, Tchuenguem FFN, Tamesse JL. Foraging and pollination activities *Xylocopa calens* Lepeletier (Hymenoptera: Apidae) on *Phaseolus coccineus* (Fabaceae) flowers at Yaoundé (Cameroon). Entomological Research. 2011a; 41:185-193.
46. Tchuenguem FFN, Pando JB, Tamesse JL. Pollination efficiency of *Xylocopa olivacea* (Hymenoptera: Apidae) on *Cajanus cajan* (Fabaceae) flowers at Yaoundé, Cameroon. International Journal of Tropical Insect Science. 2014b; 34(2):138-148.
47. Kegni BS, Ngakou A, Tchuenguem FFN. Pollination and Yields attributes of (cowpea) *Vigna unguiculata* L. Walp. (fabaceae) as influenced by the foraging activity of *Xylocopa olivacea* (Hymenoptera: Apidae) and inoculation with *Rhizobium* in Ngaoundéré, Cameroon. International Journal of Agronomy and Agricultural Research. 2015; 6(2):62-76.
48. Roubik DW. Pollination system stability in Tropical America. Conservative Biology. 2000; 14:1235-1236.
49. Kingha TMB, Tchuenguem FFN, Ngakou A, Brückner D. Foraging and pollination activities of *Xylocopa olivacea* (Hymenoptera, Apidae) on *Phaseolus vulgaris* (Fabaceae) flowers at Dang (Ngaoundéré-Cameroon). Journal of Agricultural Extension and Rural Development. 2012; 4:330-339.
50. Moffett JO, Stith LS, Burkhart CC, Shipman CW. Honey bee visits to cotton flowers. Environmental Entomology. 1975; 4:203-206.
51. Rao CM, Nadre KR, Suryanarayana MC. Studie on the utility of honey bees on production of foundation seed of cotton cv NCMHH-20 Indian Bee Journal. 1996; 58:13-15.
52. Kasina M, Kraemer M, Martius C, Wittmann D. Diversity and activity density of bees visiting crop flowers in Kakamega, Western Kenya. Journal of Apicultural Research and Bee World. 2009b; 48(2):134-139.
53. Ahohuendo BC, Sinebou VCO, Ahoton LE, Eteka AC, Dansi A, Ahanchede A *et al.* Study of the phenology and floral biology of *Sesamum radiatum* Schumach. & Thon., a traditional leafy vegetable in domestication in Benin. Acta Botanica Gallica. 2012; 159(3):335-344.