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Foraging and pollination activities of *Xylocopa olivacea* (Hymenoptera: Apidae) on *Luffa cylindrica* (Cucurbitaceae) flowers at Dang (Ngaoundere, Cameroon)

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Abstract

To evaluate the impact of a single floral visit of *Xylocopa olivacea* on the production of *Luffa cylindrica*, its foraging and pollinating activities were studied at Dang in July 2013 and 2014. The Experiments were carried out on 440 flowers labeled at bud stage and divided in three treatments: two differentiated according to the presence or absence of flowers protection regarding insect visits and the third protected and uncovered when flowers were opened, to allow *X. olivacea* visits. Results indicate that among nine insect species recorded on flowers of *L. cylindricao*, *X. olivacea* was ranked second and harvested nectar and pollen. Throughout the pollination efficiency of a single flower visit, *X. olivacea* provoked a significant increase of the podding rate, the mean number of seeds per pod and the percentage of normal seeds by 89.50 %, 47.18 %, and 76.93 % respectively. The conservation and installation of *X. olivacea* nests close to *L. cylindrica* fields is recommended to improve its pod production and seed quality.

Keywords: *Xylocopa olivacea***,** *Luffa cylindrica***,** flowers, pollination, Dang

Introduction

Luffa cylindrica (smooth *Luffa*), belongs to the plant family Cucurbitaceae. It is a herbaceous plant and thrives commonly with twining tendrils [1]. It is a large succulent tendril climber with slender, slightly hairy furrowed stem [2]. The interior is cucumber-like when immature, but quickly develops into a network of fiber surrounding large number of flat blackish seeds [2]. The plant is reported to have originated from tropical countries of Asia and Africa [3]. The main commercial production countries are China, Korea, India, Japan and Central America [4]. The matured fruits are used for domestic purposes as sponge [2]. It is an excellent fruit in nature containing all the essential constituents required for good health of humans [5]. Its kernel contains between 45 - 51 % oil which is composed of mainly oleic and linoleic acids [6]. The seeds have been reported to be useful in the treatment of asthma, sinusitis and fever [7]. It is reported to possess antiviral, anti-tumor, antioxidant, anti-inflammatory and immunomodulatory activities [8]. Despite these attributes, its yield is very low in Cameroon while the seed demand is increasing over the years in this country [9]. Therefore, it is important to investigate on the possibilities of increasing the production of *L. cylindrica* seeds in Cameroon. To expect substantial yields, famers should consider all factors that can improve the production of this crop. Among these factors is pollinating insects. Indeed, more than 70 % of the world's crop species depend on anthophilous pollination for their survival or evolution [9, 10, 11 and 12]. Xylocopes are one for the best pollinisators of *L. cylindrica* [14]. In Cameroon, there has been no previous research reported on the pollination efficiency of *X. olivacea* on *L. cylindrica* flowers. The main objective of this study was to contribute to the understanding of the relationships between *L. cylindrica* and *X. olivacea* for their optimal managment. It had four specific objectives: determine the place of *X. olivacea* in *L. cylindrica* floral entomofauna; study of the activity of this carpenter bee on this Cucurbitaceae flowers; assess the impact of flowering insects including *X. olivacea* on pod and seed production of this plant; evaluate the pollination efficiency of this Apidae on *L. cylindrica.*

2. Material and methods

2.1 Material

2.1.1 Study site

The experiment was carried out from 16th May to 09th August 2013 and 08th May to 04th August 2014 at Dang, within the experimental field of the Unit for Apply Apidology (latitude 07°42.26'N, longitude 13°53.94'E and altitude 1106 m above sea level) of the Faculty of Science, University of Ngaoundere, Cameroon. The site belongs to the high-altitude Guinean savannah agroecological zone [15]. The climate is characterized by a rainy season (April to October) and dry or season (November to March), with an annual rainfall of approximately 1500 mm. The mean annual temperature is 22°C, while the mean annual relative humidity is 70 % [15]. The vegetation is represented by crops, ornamental, hedge and native plants of savannah and gallery forests.

2.1.2 Biological materials

The plant material was *L. cylindrica* seeds (Fig 1) came from research field in 2012 at Dang. The animal material was mainly represented by insects naturally present in the environment of the study site. *X. olivacea* digs its nest in the trunks of the trees and floor in the natural conditions.

Fig 1: *Luffa Cylindrica* seeds from the research field in 2012 at Dang

2.2 Methods
2.2.1 Sowing and weeding

From April 15th to May 6th 2013 and from April 10th to May 4th 2014, the experimental plot was delimited, ploughed and divided into eight subplots, each measuring 8*4.5 m^2. On May 9th 2013 and May 5th 2014, sowing was done on four lines per subplot, each of which had four holes per line. Five seeds were sown per hole. Holes were separated 150 cm from each other, while lines were 200 cm apart [9]. From germination (May 21th 2013 and May 16th 2014) to the blooming (July 25th 2013 and July 31th 2014), the field was regularly weeded with hoe and was performed manually as necessary to keep plots weed-free until the maturation of pods. A week after germination, the plants were thinned and only two were left per hole.

2.2.2 Determination of the reproduction mode of *Luffa cylindrica*

On July 25th 2013, 240 females' flowers at bud stage were labeled and divided in two treatments: 120 unprotected flowers (treatment 1) and 120 bagged flowers using gauze bags net to avoid all visits (treatment 2) [16]. Similarly, on July 31th 2014, 240 females' flowers at the budding stage were labeled of which 120 were left unprotected (treatment 4), while 120were bagged (treatment 5). For each cropping year, a week after shedding of the last labeled flower, the number of pods was assessed in each treatment. The podding index (*Ifr*) was then calculed as described by [16]:

Ifr = (*Na* / *Nf*), where Na is the number of pods formed and *Nf* the number of viable flowers initially borne.

For each study season, the difference between the podding indixes in the treatments for flowers left in free pollination and that in the treatment for flowers protected from insects made it possible to assess the rates of allogamy (*TC*) and autogamy (*TA*) according to the following formulas [17]:

- *TC* = {[(*IfrX* - *IfrY*) / *IfrX*] * 100}, where *Ifr X* and *Ifr Y* are the fruiting indices in treatments *X* (flowers in free pollination) and *Y* (protected flowers);
- *TA* = [*100* - *TC*].

2.2.3 Determination of the place of *Xylocopa olivacea* on *Luffa cylindrica* entomofauna

Obsevations were conducted on flowers of treatments 1 and 4, every day, from 26th August to 7th September 2013 and from 1st to 14th September 2014. During each observation day, before starting visit counts, the number of open flowers in each treatment was counted. Data were taken according to six daily time frames: 6 - 7 am, 8 - 9 am, 10 - 11 am, 12 - 13 pm, 14 - 15 pm and 16 - 17 pm. In a slow walk along all labeled flowers of treatments 1 and 4, the identity of insects that visited *L. cylindrica* flowers was recorded [16].

All insects encountered on flowers were registered [18] and the cumulated results expressed as the number of visits to determine the relative frequency of each insect species in anthophilous entomofauna of *L. cylindrica* [19]. Data obtained were used to determine the frequency of visits (F_i) of each insect species on *L. cylindrica* flowers. For each study period:

Fi = [(*Vi* / *Vt*) * 100], with *Vi* the number of visits of insect *i* on treatment with unprotected flowers and *Vt* the total number of insect visits of all recorded insect species on these flowers [16]. Specimens (3 to 5) for all insect taxa, excluded *Apis mellifera* were caught using insect net on unlabeled flowers and conserved in 70 % ethanol, excluding butterflies that were preserved dry [20] for subsequent taxonomic identification.

2.2.4 Study of the foraging activity of *Xylocopa olivacea* on *Luffa cylindrica* flowers
2.2.4.1 Floral product harvested

The floral products (nectar or pollen) harvested by *X. olivacea* during each floral visit were recorded based on its foraging behavior. Nectar foragers were expected to extend their proboscis in the corolla, while pollen gatherers were supposed to scratch anthers using mandibles and legs [21]. During the same time that *X. olivacea* visits on flowers were registered, the type of floral product collected by this carpenter bee was noted [15].

2.2.4.2. Duration of visits and foraging speed

During the same days as for the frequency of visits, the duration of individual flower visits was recorded (using stopwatch) according to six daily time frames: 7 - 8 am, 9 - 10 am, 11 - 12 am, 13 - 14 pm and 15 - 16 pm. Moreover, the number of visits during which the bee came into contact with the stigma [22] was registered. Regarding the foraging speed (*Fs*) which is the number of flowers visited by an individual bee per minute [22], data were registrated during the same dates and according to same time frames and daily period as for duration of visits. The stopwatch, previously set to zero was switched on as soon as an individual landed on a flower and the number of visited, flowers was concomitancy counted. The stopwatch was stopped as soon as the visitor was lost to sight or when it left *L. cylindrica* flower for another plant species. The foraging speed (F_s) was calculated using the following formula:

$F_s = (Nf / d_v) * 60$, where *dv* is the time (sec) given by a stopwatch and *Nf* the number of flowers visited during d_v.

During the observation, when a forager returns to previously visited flower, counting is performed as two different flowers [18].

2.2.4.3 Abundances per flower and per 1000 flowers

The abundances of foragers (highest numbers of individuals foraging simultaneously) per flower and per 1000 flowers (A_{1000}) were recorded on the same dates and daily time frames as for the registration of duration of visits. Abundance per flower was recorded as a result of direct counting. For determining the abundance per 1000 flowers, foragers were counted on a known number of opened flowers and A1000 was calculed using the following formula:

$A_{1000} = [(Ax / Fx) * 1000]$, where *Fx* and *Ax* are respectively the number of flowers and the number of foragers effectively counted on these flowers at time *x* [16].

2.2.5 Foraging ecology

The disruption of the activity of foragers by competitors or predators and the attractiveness exerted by other plant species on *X. olivacea* was assessed by direct observations [18]. For the second parameter, the number of times that the carpenter bee left *L. cylindrica* flowers to other plant species and vice versa was noted through the investigation period [18].

During each daily period of investigation, ambiant temperature and relative humidity in the station were registered every 30 minutes using a mobile thermo-hygrometer (HT-9227) [18]. installed in the shade.

2.2.6 Evaluation of the impact of the flowering insects including *Xylocopa olivacea* on *Luffa cylindrica* yields

Parallel to the constitution of treatments 1, 2, 4 and 5, 400 females flowers at bud stage were protected; 200 flowers (treatment 3) in 2013 and 200 flowers (treatment 6) in 2014 protected using gauze bag nets to prevent insect visits and destined to receive one visit of *X. olivacea*. As soon as the flowers were opened, each flower of treatments 3 and 6 were inspected. Hence, gauze bag was delicately removed and this flower was observed for up to 10 minutes; the flowers visited by *X. olivacea* were marked and then reprotected. At maturity, pods were harvested and counted from each treatment. The mean number of seeds per pod and percentage of normal (well developed) seeds [23] were then evaluated.

The estimation of the effect of insects including *X. olivacea* on *L. cylindrica* production was based on the impact of flowering insects on pollination, the impact of pollination on *L. cylindrica* podding and the comparison of yields (podding rate, number of seeds per pod and percentage of normal seeds) of treatments 1, 2, 4 and 5. For each observations year, the podding rate due to the flowering insects including *X. olivacea* (*Pri*) was calculated using the following formula: $Pri = \{[(PX - PY) / PX] * 100\}$, With *PX* the podding rate in treatments *X* (flowers left in free pollination) and *PY*, the podding rate in treatments *Y* (flowers protected from all insect visits). The podding rate of a treatment (*Pr*) is: $Pr = [(b / a) * 100]$, where *a*is the number of viable flowers initially set and *b* the number of formed pods [16].

The impact of flower visiting insects including *X. olivacea* on the number of seeds per pod and the percentage of normal seeds were evaluated using the same method as mentioned above for the podding rate.

2.2.7 Assessement of the pollination efficiency of *Xylocopa olivacea* on Luffa *cylindrica*

The contribution of *X. olivacea* on the podding rate, the number of seeds per pod and the percentage of normal seeds was calculated using the data of treatments 2 and 3 for 2013 and those of treatments 5 and 6 for 2014. For each observation year, the contribution of *X. olivacea* on the podding rate (*PrX*) was calculated using the following formula:

$PrX = \{[(PY - PZ) / PY] * 100\}$, where *PY* is the podding rate in treatment Y (flowers visited exclusively by the carpenter bee, *X. olivacea*) and *PZ* the podding rate in treatment Z (protected flowers to avoid all visits) [23]. The impact of *X. olivacea* on the number of seeds per pod and the percentage of normal seeds were evaluated using the same method as mentioned above for the podding rate.

2.2.8 Data analysis

Data were analyzed using descriptive statistics (means, standard deviation and percentages), ANOVA (*F*) for the general comparison of means of more than two samples, student's *t*-test for the comparison of means of two samples, Pearson correlation coefficient (*r*) for the study of the association between two variables and chi-square (χ^2) for the comparison of percentages and using Microsoft Excel 2010 software.

3. Results

3.1 Reproduction mode of *Luffa cylindrica*

The podding indexes of *L. cylindrica* were 0.94, 0, 0.95 and 0 for treatments 1, 2, 4 and 5 respectively. Thus in 2013, the allogamy rate was 100 % whereas the autogamy rate was 0 %. In 2014, the corresponding figures were 100 % and 0 %. For the two cumulated years, the allogamy rate was 100 % and the autogamy rate was 0 %. *L. cylindrica* had a reproduction mode allogamous strictively.

3.2. Place of *Xylocopa olivacea* in *Luffa cylindrica* floral entomofauna

Among 286 and 418 visits of six and eight insect species recorded on *L. cylindrica* flowers in 2013 and 2014 respectively, *X. olivacea* ranked second with 45 visits (15.73 %) in 2013 and second with 40 visits (9.57 %) in 2014 after *A. mellifera* (Table 1). The difference between the percentages of *X. olivacea* visit for the two years is significant ($\chi^2 = 6.08$; $df = 1$; $P < 0.05$). This difference could be the consequence of climatic factors and seasonal variations in flower resources availability. It can also be attributed to the variation of the number of *X. olivacea* nests in the study site from one year to another (12 nests in 2013 and 10 in 2014). Other observations have revealed that *X. olivacea* is one of the most frequent insect visitors on flowers of *Luffa aegyptiaca* [25], *P. coccineus* [26], *Vigna unguiculata* [27] and *Vitellaria paradoxa* [28].

Table 1: Diversity of flowering insects on *Luffa cylindrica* in 2013 and 2014 at Dang, number and percentage of visits of different insects.

Insects			2013		2014		Total$_{2013/2014}$	
Order	Family	Genus and species	n_1	P_1 (%)	n_2	P_2 (%)	n_T	P_T (%)
Hymenoptera	Apidae	*Apis mellifera* (ne)	175	61.19	177	42.34	352	49.37
		Xylocopa olivacea (ne)	45	15.73	40	9.57	95	13.32
		Xylocopa inconstans (ne)	6	2.10	27	6.46	33	4.63
		Dactylurina staudingeri (ne)	-	-	53	12.68	53	7.43
		Meliponula ferruginea (ne)	-	-	43	10.29	43	6.03
		Total Apidae	226	79.02	340	81.34	576	80.78

	Formicidae	*Myrmicaria opaciventris* (ne)	56	19.58	71	16.98	127	17.81
Total Hymenoptera			282	98.88	411	98.32	703	98.59
Coleoptera	Meloidae	*Coryna* sp. (mange les fleurs)	1	0.35	-	-	1	0.14
Lepidoptera	Pieridae	*Eurema eximia* (ne)	3	1.06	4	0.96	7	0.98
		Eurema sp. (ne)	-	-	3	0.72	3	0.42
		Total Pieridae	3	1.06	7	1.68	10	1.4
Total			286	100	418	100	714	100
		Species	6		8		8	

n1 and *n2*: number of visits on 120 females flowers in 2013 and 2014; *P1* and *P2*: percentages of visits in 2013 and 2014; sp: undetermined species; ne: collection of nectar; po: collection of pollen; *P1* = (*n1* / 241) * 100; *P2* = (*n2* / 197) * 100.

3.3.2 Activity of *Xylocopa olivacea* on *Luffa cylindrica* flowers

3.3.1 Floral product harvested

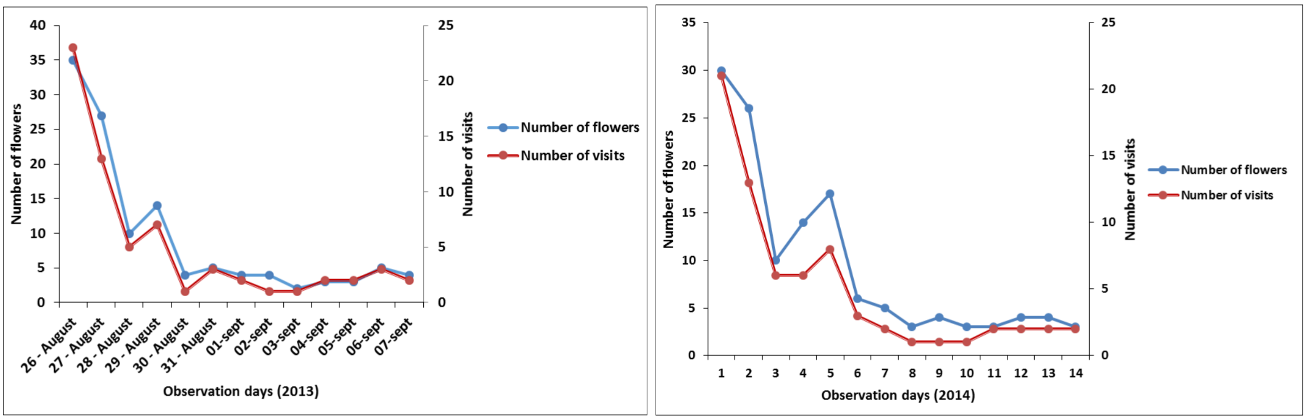
During each flowering period, individuals of *X. olivacea* were found (Fig 2) to harvest intensively nectar and pollen on *L. cylindrica* flowers.

A B

Fig 2: *Xylocopa olivacea* collecting nectar (A) and pollen (B) in a *Luffa cylindrica* flowers at Dang in 2013.

3.3.2 Rhythm of visits according to the flowering stages

Xylocopa olivacea visits were more numerous on treatments 1 and 4 when their number of opened flowers was highest (Fig 3).



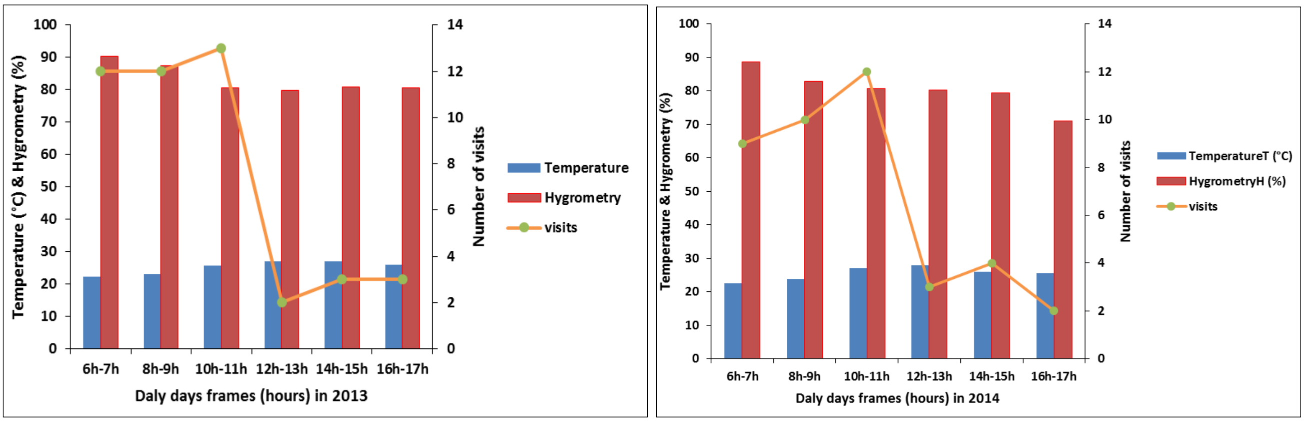
A B

Fig 3: Seasonal variations of the number of *Luffa cylindrica* opened flowers and the number of *Xylocopa olivacea* visits on these organs in 2013 (A) and 2014 (B) at Dang.

Moreover, we found a positive and highly significant correlation between the number of *X. olivacea* visits and the number of *L. cylindrica* opened flowers in 2013 ($r = 0.98$; $df = 11$; $P < 0{,}001$) (Fig 3 A) as well as in 2014 ($r = 0.97$; $df = 12$; $P < 0{,}001$) (Fig 3 B). This result highlights the good attractiveness of the nectar of *L. cylindrica* towards *X. Olivacea*.

3.3.3 Daily rhythm of visits

The carpenter bee was active on *L. cylindrica* flowers from 6 am to 5 pm in 2013 as well as in 2014. The peak of activity was situated between 10 and 11 am in 2013 as well as in 2014 (Fig 4).



A B

Fig 4: Variation of the temperature, the humidity and the number of *Xylocopa olivacea* visits on *Luffa cylindrica* flowers according to the daily frames time in 2013 (A) and 2014 (B) at Dang.

Ambiant temperature and relative humidity did not influenced the activities of *X. olivacea* on *L. cylindrica* (Fig 4). In 2013, the correlation was not significant between the number of *X. olivacea* visits and the temperature (r = -0.79; df = 4; P > 0.05), and between the same number of visits and the relative humidity (r = 0. 56; df = 4; P > 0.05). Equally, in 2014, the correlation was not significant between the number of *X. olivacea* visits and the temperature (r = - 0.33; df = 4; P > 0.05), and beetwen the same number of visits and the relative humidity (r = 0.63; df = 4; P > 0.05).The peak of activity could be linked to the period of highest availability of nectar on the *L. cylindrica* flowers. The same result have been obtained at Dang (Cameroon) by Farda and Tchuenguem [9] on the same plant species indicating, the peak of activity of *A. mellifa* was situated between 10 and 11 am. According to [29], the peak of activity of this carpenter bee on *P. vulgaris* flowers was situated between 10 am and 11 am in Ngaoundere (Cameroon).

3.3.4 Abundance of *Xylocopa olivacea*

In 2013, the highest mean number of *X. olivacea* individuals simultaneously in activity was 1 per flower (n = 97; s = 0.29) and 145 per 1000 flowers (n = 50; s = 27.7; $maxi$ = 98). In 2014, the corresponding figures were 1 per flower (n = 93; s = 0.32) and 102 per 1000 flowers (n = 64; s = 22; $maxi$ = 99). The difference between these two means is highly significant (t = - 4.59; df = 245; P < 0,001). For the two cumulated years, the highest mean number of *X. olivacea* individuals simultaneously in activity per 1000 flowers was 55. This last result is nether than that pointed out at Dang by Deli *et al.* [29] who observed that the abundance of this carpenter bee was 214.55 per 1000 flowers on *P. vulgaris* Bigarre variety. The difference between these two means is highly significant. This difference could be explained by the variation of the number of *X. olivacea* nests over the years. Indeed, during the two years of observation, we registrated 8 nests compared to 20 noted by these authors.

3.3.5 Duration of visits per flower

In 2013 and 2014 the mean duration of *X. olivacea* visit per female flower for the foraging nectar was 4.97 sec (n = 333; s = 3. 62; $maxi$ = 24) and 5.7 sec (n = 258; s = 5.20; $maxi$ = 43) respectively. The difference between these two means is not significant (t = -1.92; df = 589; P > 0, 05).

On the male flower in 2013 and 2014 the mean duration of *X. olivacea* visit for the foraging nectar was 31.16 sec (n = 173; s = 22.31; $maxi$ = 107) and 30.34 sec (n = 162; s = 20.15; $maxi$ = 87) respectively. The difference between these two means is not significant (t = 0.35; df = 333; P > 0, 05) and the mean duration of *X. olivacea* visit for the foraging pollen was 4.88 sec (n = 416; s = 3.99; $maxi$ = 28) in 2013 and 4.40 sec (n = 157; s = 3; $maxi$ = 27) in 2014. The difference between these two means is not significant (t = 0.4; df = 571; P > 0, 05).

3.3.6 Foraging speed

In *L. cylindrica* field, the mean foraging speed of *X. olivacea* was 12.24 flowers per minute (n = 248; s = 4.91; $maxi$ =29) in 2013 and 11.74 flowers per minute (n = 176; s = 10.78; $maxi$ = 94) in 2014. The difference between these two means is highly significant (t = 0.54; df = 422; P < 0.001). For the two cumulated years, the mean foraging speed was 11.99 flowers per minute.

The later difference could be explained by the accessibility and availablility of nectar or the distance separating the flowers visited during the various foraging trips. This foraging speed is smaller than that recorded by Adamou *et al*. [30] on *Bixa orellana* in Dang (Ngaoudere, Cameroon). These authors noted that the mean foraging speed of *X. olivacea* was 49.77 flowers/min. The difference between these two means is highly significant (t = 121.61; df = 344; P < 0.001). This difference could be explained by the availablility and accessibility of nectar on each plant species.

3.3.7 Influence of the fauna

Individuals of *X. olivacea* were disturbed in their foraging activity by other individuals of the same species or those from other species, which were competitors for *L. cylindria* nectar and pollen.

In 2013, for 922 visits, 45 (4.88 %) were interrupted by *X. olivacea*, 11 (1.19 %) by *A. mellifera* and 21 (6.30 %) by *X. inconstans* and 6 (0.65 %) by *M. opaciventris*. In 2014, for 577 visits, 29 (5.02 %) were interrupted by *X. olivacea*, 13 (2.25 %) by *X. inconstans*, 37 (4.41 %) by *A. mellifera*, 14 (2.42 %) by *M. opaciventris*, 13 (3.98 %) by *D. staudingeri*, 7 (1.21 %) by *M. ferruginae*. In order to obtain their optimal nectar and pollen load, individuals of *X. olivacea* who suffered from such disturbances were forced to visit more flowers during the corresponding foraging trip.

The perturbation of individuals of *X. olivacea* in their foraging activity by other insect species have been observed by Basga *et al.* [28] on *Vitellaria paradoxa* flowers in Garoua (Cameroon), Deli *et al.* [29] on flowers of *P. vulgaris* Bigarre variety at Dang (Ngaoundere, Cameroon) and Mainkete *et al.* [31] on flowers of *P. vulgaris* Large White Seeds variety in Doyaba (Chad).

3.3.8 Influence of neighboring flora

During the flowering period of *L. cylindrica*, flowers of other plant species surrounding *L. cylindrica* field were visited by *X. olivacea* for either nectar (ne) or pollen (po). Among these plants were: *Tithonia diversifolia* (Asteraceae: ne and po), *Vigna subterranea* (Fabaceae: ne and po) and *P. vulgaris* (Fabaceae: ne). During the two years of study, we observed no passage of *X. olivacea* from *L. cylindrica* flowers to flowers of another plant species and vice versa. Hence during foraging trips on *L. cylindrica*, individuals of *X. olivacea* were faithful to this Cucurbitaceae. The faithfulness of individuals of *X. olivacea* was also reported at Dang (Ngaoundere, Cameroon) by Deli *et al.* [29] on *P. vulgaris* Bigarre variety, Adamou *et al.* [30] on *Bixa Orellana* and at Doyaba (Sarh, Chad) by Mainkete *et al.* [31] on *P. vulgaris*.

3.4 Impact of anthophilous insects including *Xylocopa olivacea* on *Luffa cylindrica* production

The podding rate, the mean number of seeds per pod and the percentage of normal seeds in the different treatments of *L. cylindrica* are shown in table 5. This table shows that:

a) The podding rates were 94.17 %, 0 %, 88.5 %, 95 %, 0 % and 90.5 in treatments 1 to 6 respectively. The differences between these six percentages are globally highly significant (χ^2 = 2.36; *df* = 5; *P* < 0,001). The two - by - two comparisons showed that the difference observed is not significant between treatments 1 and 3 (χ^2 = 2.83 =; *df* = 1; *P* > 0.05) and between treatments 4 and 6 (χ^2 = 2.11; *df* = 1; *P* > 0, 05). Consequently in 2013 and 2014, the females flowers protected from insects don't product the pods

b) The mean numbers of seeds per pod were 95.43, 51.89, 71.11and 42.48, in treatments 1, 3, 4 and 6 respectively. The differences between these four means are globally highly significant (*F* = 276.65; df_1 = 5; df_2 = 949; *P* < 0,001). Two - to - two comparisons showed that the difference observed is highly significant between treatments 1 and 3 (*t* = 6040.84; *df* = 22026; *P* < 0,001) as well as between treatments 4 and 6 (*t* = 4103.22; *df* = 17269; *P* < 0,001).

c) The percentages of normal seeds were 85.29 %, 83.22 %, 89.52 % and 76.65 % in treatments 1, 3, 4 and 6 respectively. The differences between these four percentages are globally highly significant (χ^2 = 735.76; *df* = 5; *P* < 0,001). Pairwise comparisons showed that the difference observed is not significant between treatments 1 and 3 (χ^2 = 1.47; *df* = 1; *P* > 0, 05) and highly significant between treatments 4 and 6 (χ^2 = 513.02; *df* = 1; *P* < 0,001).

In 2013 and in 2014, the contribution of anthophilous insects in the podding rate, were 100 %.

Table 2: Podding rate, mean number of seeds per pod and the percentage of normal seeds according to the different treatments of *Luffa cylindrica* in 2013 and 2014 at Dang.

Years	Traitments	NF	NP	PrR (%)	Number of seeds/pod		TNS	TS	% NS
					M	*DF*			
2013	1 (Uf)	120	113	94.17	95.43	43.35	11651	9767	85.29
	2 (Pf)	120	0	0	-	-	-	-	-
	3 (Fpvx)	200	177	88.5	51.89	34.81	10377	8636	83.22
2014	4 (Uf)	120	114	95	73.11	39.53	8773	7854	89.52
	5 (Pf)	120	0	0	-	-	-	-	-
	6 (Fpvx)	200	181	90.5	42.48	22.99	8498	6512	76.65

NF: number of flowers; NP: number of pods; PrR: podding rate; TNS: total number of seeds; NS: number of normal seeds; %NS: percentage of normal seeds; *m*: mean; *DF*: standard deviation; Uf: unprotected flowers; Pf: protected flowers; Fpvx: flowers visited exclusively by carpenter bee, *X. olivacea*.

3.5 Pollination efficiency of *Xylocopa olivacea* on *Luffa cylindrica*

During the pollen harvest, individuals of *X. olivacea* always came into contact with anthers of Males flowers and stigma of female's flowers during the nectar harvest. Thus they increased self-pollination or cross-pollination possibilities of visited flowers.

The podding rates due to *X. olivacea* is 100 % in 2013 and in 2014.

During the nectar and pollen harvest on *L. cylindrica* flowers, *X. olivacea* individuals always shake flowers and come into contact with anthers and stigma. Similar observation was reported by Farda and Tchuenguem [9] on *L. cylindrica* flowers who *A. mellifera* individuals always shake flowers and come into contact with anthers and stigma. *Xylocopa olivacea* individuals could enhance self-pollination by applying pollen of a flower on the stigma of another flower of the same plant (geitonogamy) [16]. This carpenter bee could provide allogamous pollination through carrying a pollen on their hairs, legs and mouth accessories from a flower of one plant, which is consequently deposited on another flower belonging to a different plant of the same species (xenogamy) [9,16].

4. Conclusion

The results obtained from this study reveal that *L. cylindrica* is a plant that benefits from the pollination by insects, among which *X. olivacea* is one of the most important and harvest nectar and pollen. The comparison of pod and seed sets of flowers visited once exclusively by *X. olivacea* with those of flowers bagged then uncovered and reprotected without the visit of this carpenter bee or any other organism underscores the value of this carpenter bee in increasing the podding rate, the mean number of seeds per pod and the percentage of normal seeds of *L. cylindrica*. Thus conservation and installation of *X. olivacea* nests close to *L. cylindrica* is recommended to improve its pod production as well as its seed quality and to favor the population of this carpenter bee in the Adamawa region.

5. References

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