Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2022; 10(1): 25-33

Received: 13-11-2021
Accepted: 15-12-2021

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Pollination efficiency of *Apis mellifera* (Hymenoptera: Apidae) on *Lantana camara* (Verbenaceae) flowers at Dang (Ngaoundéré, Cameroon)

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DOI: https://doi.org/10.22271/j.ento.2022.v10.i1a.8919

Abstract
To evaluate the impact of *Apis mellifera* on *Lantana camara* production, foraging and pollination activities of this bee were studied at Dang. In August 2016 and 2017, 540 floral bunches with flowers in bud were labeled on 25 plants to constitute four treatments: 120 bunches left unprotected, 120 bunches protected from insects; 200 bunches covered, then uncovered, visited exclusively by *A. mellifera* and rebagged; 100 bunches protected, then uncovered and rebagged, without insect or any other organism visits. The foraging behavior of *A. mellifera*, on flowers its pollination efficiency, the fruiting rate, the percentage of mature fruit and the percentage of normal (well developed) fruits were evaluated. Results show that among 13 insect species recorded on *L. camara* flowers after two seasons of observations, *A. mellifera* was the most represented with 40.38% of 317 visits. This bee exclusively harvested pollen, almost throughout the day. The fruiting rate, the percentage of mature fruits and the percentage of normal fruits of treatments with unprotected floral bunches were significantly higher than those of treatments with floral bunches protected from insects. Through its pollination efficiency, *A. mellifera* increased the fruiting rate, the percentage of mature fruits and the percentage of normal fruits by 59.95%, 28.27% and 44.12% respectively. This Verbenaceae can be cultivated to help maintain colonies of *A. mellifera* during the rainy season for a good production of honey and pollen as hive products.

Keywords: *Apis mellifera*, *Lantana camara*, flowers, pollination efficiency, yields

1. Introduction

The mutual interaction between plants and animals has an important functional role in terrestrial ecosystems and is at the basis of several ecosystem services such as pollination [1]. It is known that by their attractiveness, herbs often contribute positively to the diversity and abundance of pollinators [2], whose decline is ongoing [3], partly because of the scarcity of nutritional resources [4]. In addition to their essential role in the survival of many plants in the wild, bees and other pollinating insects play a major role in agriculture and food security, notably in our diet, which is 70% dependent on entomophilous pollination [5].

Moreover, the exploitation of Non-Timber Forest Products (NTFP) is of great importance in Cameroon rural development, particularly with the practice of beekeeping, which occupies up to 12.7% of its agricultural population [6]. Despite the floristic potential of this country, its beekeeping sector continues to generate an offer lower to demand [7].

In Cameroon, beekeeping research is booming thanks to in-depth investigations carried out, for example in the Adamawa [8, 9, 10, 11, 12], Center [13, 14] and West [15, 16] regions. Despite this important work, there is no published data on the relationships between several plant species and *A. mellifera*.

Before our research, the published data on the relationships between *L. camara* and flowering insects were collected in Costa Rica [17] and in the Galapagos Islands [18, 19], where its main flower visitors were Lepidoptera, in Queensland (Australia) [20] where bees were the most abundant visitors on its flowers and at Dang in May where *Papilio demodocus* comes in the first position among 18 species of insects recorded, collects exclusively and strongly the nectar; this butterfly has a positive effect on its yields [21].

Previous our work, there has been no previous research reported on the pollination efficiency of *A. mellifera* on this Verbenaceae. Unpublished preliminary investigations indicate that in Dang, in June 2015, *A. mellifera* was one of the most common insect visitors of the flowers of *L. camara*.

This work is a contribution to mastering the relationships between *A. mellifera* and *L. camara*, with a view to their exploitation for the sustainable development of beekeeping production in the Adamawa region of Cameroon. It has five specific objectives: (a) determine the place of *A. mellifera* in the flowering fauna of *L. camara*; (b) study the activity of this bee in the flowers of *L. camara*; (c) estimate the beekeeping value; (d) assess the effect of flowering insects including *A. mellifera* on the fruit production of this plant; (e) determine the pollinating efficiency of *A. mellifera* on the Verbenaceae.

2. Materials and Methods

2.1. Materials

2.1.1. Study site and biological material

The experiment was carried out in august 2016 and 2017, at Dang, in the Adamawa region, which belongs to the ecological zone known as the Guinean high savannahs [22], within the campus of the University of Ngaoundéré in Dang. According to Djoufack *et al.* [22], the climate of this region is of the Sudano-Guinean type, mild and cool, characterized by two seasons: a rainy season (April to October) and a dry season (November to March), with an annual rainfall of about 1500 mm. The mean annual temperature is 22 °C, while the mean annual relative humidity is 70% [23]. The vegetation is represented by crops, ornamental plants, hedge plants and native plant species of the savannah and gallery forests [24]. The plant material was represented by *L. camara* naturally present at the study site. The animal material included many insect species naturally present in the environment. The number of *A. mellifera* colonies located at the study site varied from 51 to 60, between August 2016 and 2017.

2.2. Methods

2.2.1. Determination of the place of *Apis mellifera* in the floral entomofauna of *Lantana camara*

On 9th August 2016 and 5th August 2017, 240 floral bunches (cluster of 15 to 32 individual flowers) with flowers at the bud stage were labeled on 25 plants of *L. camara* (4 to 5 floral bunches per plant), among which 120 were left unattended (treatment 1) and 120 were protected using gauze bags net to prevent insect visitors (treatment 2) [25].

Observations were conducted on flowers of treatments 1 and 3 every day, from the opening of the first flower bud (10th August 2016 and 6th August 2017) to the fading of the last flower (21th August 2016 and 16th August 2017), at 6 - 7 h, 8 - 9 h, 10 - 11 h, 12 - 13 h, 14 - 15 h and 16 - 17 h. For each of these time slots, the different insects encountered on the blooming flowers were counted [26]. Cumulative results were expressed as the number of visits [27]. Data on the frequency of visits of the various identified flowering insects have made it possible to determine the place of *A. mellifera* in the anthophilous entomofauna of *L. camara*. The frequency of visits of the insect *i* on *L. camara* flowers (Fi) was calculated using the following formula:

$Fi = \{[Vi / Vt] * 100\}$, where Vi is the number of visits for insect *i* on unprotected flowers and Vt *is* the number of visits of all insects on the same flowers [26]. Specimens (2 to 3) of all insect taxa, excluded *A. mellifera* were caught using insect net on unlabeled floral bunches and conserved in 70% ethanol, excluding butterflies that were preserved dry [27], for subsequent taxonomic identification.

2.2.2. Study of the activity of *Apis mellifera* on the flowers of *Lantana camara*

In addition to the determination of the flower-visiting insect frequency, direct observation of the foraging activity of *A. mellifera* on flowers was made in the field [26]. The floral products (nectar or pollen) sampled by this bee were noted during the same dates and time slots as for the duration of visits, based on its foraging behavior [26]. Nectar foragers were expected to extend their proboscis to the base of the corolla and the stigma, while pollen gatherers were supposed to scratch the anthers with mandibles and legs [27].

On each sampling day, the number of opened flowers was counted. On the same days as for the frequency of visits, the duration of individual flower visits was recorded (using a stopwatch) at least three times during each of the following daily time frames: 7 - 8 h, 9 - 10 h, 11 - 12 h, 13 - 14 h, 15 - 16 h and 17 - 18 h [26]. The abundance of foragers (highest number of individuals foraging simultaneously on a flower or on 1000 flowers [28] and the foraging speed (number of flowers visited by *A. mellifera* per minute [29] were measured. Abundance per flower was recorded following the direct counting, on the same dates and daily periods as for the registration of the duration of visits. For the abundance per 1000 flowers (A_{1000}), some foragers were counted on a known number of flowers; A_{1000} was then calculated using the formula $A_{1000} = ((Ax/Fx)*1000)$, where Fx and Ax are the number of opened flowers and the number of foragers effectively counted on these flowers at time x [28]. The foraging speed (Fs) was calculated using the formula $Fs = (Fl / du)* 60$, where du is the duration (sec) given by a stopwatch, and Fl, the number of flowers visited during du [26]. A mobile thermo-hygrometer installed in the shade, was used to register the temperature and the relative humidity of the station every 30 min, from 6 h to 18 h, during the entire investigation period [26].

2.2.3. Evaluation of the apicultural value of *Lantana camara*

The apicultural value of *L. camara* was assessed as in other plant species, using data on flowering intensity and the attractiveness of *A. mellifera* workers with respect to pollen and nectar [30].

2.2.4. Evaluation of the effect of insects including *Apis mellifera* on *Lantana camara* production

In parallel to the implementation of treatments 1 to 4, 600 floral bunches with flowers at the bud stage were labeled to constitute four other treatments:

- treatment 5 (2016) or 7 (2017): 200 protected bunches, intended to be uncovered, then then visited exclusively by *A. mellifera* and reprotected. As soon as the flowers on each floral bunch opened in treatments 5 or 7, the gauze bag was gently removed and the flowers were left in free pollination observed for one to 10 minutes, to note their possible visit by *A. mellifera*. After this manipulation, the floral bunches were reprotected and were no longer handled. The floral bunches whose flowers were not visited were included in treatments 6 or 8 [31];
- treatment 6 (2016) or 8 (2017): 100 bunches protected, then uncovered and rebagged, without insects or any

other organism visits. As soon as the flowers in each floral bunch opened, the gauze cloth was gently removed and the blooming flowers were observed for one to 10 minutes, while avoiding visits by insects or any other organism. After this manipulation, the floral bunch was reprotected and were no longer handled [31].

At the maturity of the fruits in treatments 5, 6, 7 and 8, their harvest was made their quality appreciated and the number counted.

The evaluation of the impact of anthophilous insects including *A. mellifera* on fruit production of *L. camara* was based on the impact of anthophilous insects on pollination, the impact of pollination on the fruiting of *L. camara* and the comparison of fruit production (fruiting rate, percentage of mature fruits and percentage of normal or well-developed fruits) of treatments 1, 2, 3, 4, 6 and 8 [26]. For each year of investigation, the fruiting rate due to flowering insects (*Fri*) is calculated using the following formula:

$Fri = \{[(FX - FZ) / (FX + FY - FZ)] * 100\}$, Where *FX, FY* and *FZ* are the fruiting rates in treatments *X* (bunches left in free pollination), *Y* (bunches protected from insects) and *Z* (bunches protected, uncovered and then rebagged, without insects or any other organism visits), respectively [32].

For each treatment, the fruiting rate *(F)* is:

F = (number of fruits formed / number of viable flowers initially borne) * 100 [25];.

The percentage of mature fruits and the percentage of normal fruits due to flowering insects were calculated in the same way as for the fruiting rate.

2.2.5. Assessment of the pollination efficiency of *Apis mellifera* on *Lantana camara*

The contributions of *A. mellifera* in the fruiting rate, the percentage of mature fruits and the percentage of normal fruits were calculated using data from treatments 5, 6, 7 and 8. For each observation period, the fruiting rate due to *A. mellifera* was calculated using the following formula:

$FrA = \{[(FA - FZ) / FA] * 100\}$ [32], Where *FA* is the fruiting rate in treatment A (bunches protected, then uncovered, visited exclusively by *A. mellifera* and again protected).

The contributions of *A. mellifera* in the percentage of mature fruits and the percentage of normal fruits were calculated in the same way as for the fruiting rate.

2.2.6. Data analysis

Data were subjected to descriptive statistics (means, standard deviations and percentages), ANOVA (*F*) for the global comparison of more than two means, Student's *t*-test for the comparison of two means, Pearson correlation coefficient (*r*) for the study of the linear relationships between two variables and Chi-square (χ^2) for the comparison of percentages. Microsoft Excel 2010 software was used for this purpose.

3. Results and Discussion

3.1. Place of *Apis mellifera* in the flower entomofauna of *Lantana camara*

Among the 173 and 144 visits of 11 and 10 insect species recorded on 2574 and 2677 flowers in 2016 and 2017 respectively, *A. mellifera* was the most represented insect species with 71 visits (41.04%) and 57 visits (39.58%) in 2016 and 2017 respectively. This honey bee ranked first in each study year (Table 1).

The present study results confirm those reported in Queensland in September 2002 by Goulson & Derwent [20], where *A. mellifera* was the most abundant visitor to the flowers of *L. camara*. However, in Dang in May 2016 and 2017, Louabé *et al*. [21] identified 18 of insect species on *L. camara* flowers and *Papilio demodocus* ranked first and *Apis mellifera* ranked last in each study year, with 22.18% and 0.35% of 284 visits respectively. The scarcity of *A. mellifera* in May could be explained by the foraging behavior of this bee. It is known that workers of *A. mellifera* only visit pollinating plants when the nitrogen requirements of the colony increase [33]; these needs are themselves a function of the presence of brood, the number of which varies throughout the year in a colony [34].

These observations confirm the fact that flowering entomofauna of a plant species varies over time and with regions [26, 35, 36].

3.2. Activity of *Apis mellifera on Lantana camara* flowers

On *L. camara* flowers, individuals of *A. mellifera* were seen intensively collecting the pollen only (Figure 1).

The strong attractiveness of *L. camara* pollen throughout the day to *A. mellifera* could be partly explained by the availability and quality of this food and the time required for its harvest from the corresponding flowers [37]. This attractiveness is also linked to odoriferous compounds such as sterols [38] and lipids [39]. This is especially so since pollinators can associate the olfactory signal with the flower's rewards [40].

Apis mellifera visits were numerous on *L. camara* plants when the number of opened flowers was highest (Figure 2). Furthermore, we found a positive and highly significant correlation between the number of *A. mellifera* visits and the number of *L. camara* opened flowers in 2016 ($r = 0.96$; $df = 9$; $P<0.001$) as well as in 2017 ($r = 0.92$; $df = 8$; $P<0.001$).

Apis mellifera was active on *L. camara* flowers from 6 h to 5 h in 2016 and 2017, with a peak of visits between 12 h and 13 h (Figure 2). These daily time frames probably correspond to that of the highest availability of pollen on flowers of this Verbenaceae. According to Pesson & Louveaux [41] and Kasper *et al*. [42], workers are more abundant on flowers when food sources are more available and reduce their activity when food decreases in quantity so that the energy spent for foraging is not greater than that drawn from the foraging. The activity of *A. mellifera* could not be conditioned by some climatic factors. In 2016, the correlation was not significant between the number of *A. mellifera* visits and the temperature ($r = 0.87$; $df = 4$; $P>0.05$) and between the same number of visits and the relative humidity ($r = 0.94$; $df = 4$; $P>0.05$) (Figure 3). Equally, in 2017, the correlation was not significant between the number of *A. mellifera* visits and the temperature ($r = - 0.89$; $df = 4$; $P>0.05$) and between the same number of visits and the relative humidity ($r = - 0.93$; $df = 4$; $P>0.05$) (Figure 3).

In 2016, the highest mean number of *A. mellifera* workers simultaneously in activity was one per flower ($n = 113$; $s = 0$) and 23 per 1000 flowers ($n = 113$; $s = 3$; $maxi = 118$). In 2017, the corresponding figures were one per flower ($n = 147$; $s = 0$) and 24 per 1000 flowers ($n = 147$; $s = 3$; $maxi = 20$). The difference between the mean number of foragers per 1000 flowers in 2016 and 2017 was not significant ($t = 1.66$; $df = 258$; $P>0.05$).

The high abundance of *A. mellifera* per 1000 flowers and the positive and significant correlation between the number of *L. camara* flowers and the number of *A. mellifera* visits to highlight the attractiveness of *L. camara* pollen for *A. mellifera*. In fact, the weather during bloom was demonstrated to affect the abundance and foraging of pollinator insects [43].

Besides, the high density of workers per 1000 flowers is due to the natural faculty of honeybees to recruit a high number of workers to exploit an interesting food source [44]. Honeybees can smell or detect pollen or nectar odors [45] using sensory receptors located on the flagellum of their antennae. Worker honeybees dance inside the nest after a successful foraging trip in other to communicate to their nestmates informations about the food odor, the distance and the direction from the hive to the food source [46]. The round dance is performed when the resource is within 50 meters from the hive, while the wagging dance takes place for the resource 100 meters away from the hive [46].

The mean duration of *A. mellifera* visit per *L. camara* flower was 3.13 sec (n = 87, s = 2.07, *maxi* = 9) in 2016 and 3.00 sec (n = 63, s = 1.52, *maxi* = 8) in 2017. The difference between the duration of a visit per flower in 2016 and 2017 is not significant (t = 0.41; df = 148; P>0.05). For the two cumulative years, the mean duration of a visit per flower was 3.06 sec. This mean duration was higher than that recorded in May (1.23 sec) by Louabé *et al*. [21] for *Papilio demodocus* on the same plant. This difference could be explained by the accessibility of pollen. In fact, the workers of *A. mellifera* experienced the difficulty to access the anthers (pollen) because the floral structure (corolla in the form of long narrow tube) of this plant is more suitable for pollination of pollinators on long proboscis (e.g. butterflies) [19].

Apis mellifera visited between 3 and 60 flowers per minute in 2016 and between 6 and 60 flowers per minute in 2017. The mean foraging speed was 14.62 flowers per minute (n = 101, s = 8.43) in 2016 and 18.88 flowers per minute (n = 104, s = 9.46) in 2017. The difference between these means foraging speeds per flower was highly significant (t = -3.38; df = 203; P<0.001). This difference could be explained by the accessibility and availability of pollen or the distance separating the flowers visited during the various foraging trips. For the two cumulated years, the mean foraging speed was 16.75 flowers per minute.

The bee foragers had a high affinity with respect to *L. camara* compared to the neighbouring plant species, indicating their faithfulness to this Verbenaceae, a phenomenon known as «floral constancy» [30]. This flower constancy could be partially due to the texture of the stamens, the size and the quantity of pollen grains which would be stimuli that could make *L. camara* pollen attractive [47].

3.3. Apicultural value of *Lantana camara*

During the flowering period of *L. camara*, we noted a well elaborated activity of *A. mellifera* foragers at the level of its flowers: good daily and seasonal frequency of visits, good pollen harvest and fidelity of the foragers to the flowers during foraging bouts. These data highlight the good attractiveness of the pollen and the unattractiveness of the nectar of this plant for *A. mellifera*. Therefore, *L. camara* is a highly polliniferous bee plant. This Verbenaceae could thus be grown to help stabilize *A. mellifera* colonies during the dry season and increase pollen production as a honey bee hive product.

3.4. Impact of flowering insects including *Apis mellifera* on *Lantana camara* production

During nectar or pollen harvest on *L. camara*, foraging insects always shook flowers and regularly contacted anthers, increasing self-pollination and/or cross-pollination possibilities of this plant species.

Table 2 gives the fruiting rate, the percentage of mature fruits and the percentage of normal fruits in the different treatments of *L. camara*. It appears from this table that:

- the fruiting rates were 53.26%, 9.39%, 66.68%, 7.49%, 17.72%, 10.63%, 22.20% and 11.43% in treatments 1 to 8 respectively. The differences between these eight percentages are highly significant ($\chi 2$ = 4852.46; df = 7; P<0.001). Two - to - two comparisons showed that the difference observed is highly significant between treatments 1 and 2 ($\chi 2$ = 1136.58; df = 1; P<0.001) as well as between treatments 3 and 4 ($\chi 2$ = 2071.86; df = 1; P<0.001). Consequently, in 2016 and 2017, the fruiting rate of bunches left unprotected (treatments 1 and 3) was higher than that of bunches bagged during their flowering period (treatments 2 and 4).
- the percentages of mature fruits were 96.94%, 68.35%, 98.15%, 66.19%, 94.33%, 69.16%, 96.18% and 67.46% in treatments 1 to 8 respectively. The differences between these eight percentages are highly significant ($\chi 2$ = 875.19; df = 7; P<0.001). Two - to - two comparisons showed that the difference observed was highly significant between treatments 1 and 2 ($\chi 2$ = 244.68; df = 1; P<0.001) as well as between treatments 3 and 4 ($\chi 2$ = 388.43; df = 1; P<0.001). Hence, in 2016 and 2017, the percentage of normal fruits from bunches left unprotected was higher than that from bunches bagged during their flowering period.
- the percentages of normal fruits were 81.49%, 44.44%, 78.41%, 54.68%, 91.76%, 41.40%, 82.98% and 55.29% in treatments 1 to 8 respectively. The differences between these eight percentages are highly significant ($\chi 2$ = 382.61; df = 7; P<0.001). Two - to - two comparisons showed that the difference observed was highly significant between treatments 1 and 2 ($\chi 2$ = 113.52; df = 1; P<0.001) as well as between treatments 3 and 4 ($\chi 2$ = 41.93; df = 1; P<0.001). Hence, in 2016/ and 2017, the percentage of normal fruits from bunches left unprotected was higher than that from bunches bagged during their flowering period.

In 2016, the numeric contribution of the anthophilous insects including *A. mellifera* in the fruiting rate, the percentage of mature fruits and the percentage of normal fruits of *L. camara* were 84.35%, 29.73% and 43.82% respectively. In 2017, the corresponding figures were 94.33%, 32.99% and 30.78% respectively. For the two cumulate years, the numeric contributions of flowering insects were 89.34%, 31.36%, and 37.30% for the fruiting rate, the percentage of mature fruits and the percentage of normal fruits respectively. This significant increase in fruit production in the presence of flowering insects including *A. mellifera* is the consequence of their foraging activity on the pollination of the visited flowers.

3.5. Pollination efficiency of *Apis mellifera* on *Lantana camara*

During pollen harvest, workers of *A. mellifera* always came into contact with anthers, increasing the possibilities of *L. camara* pollination. With this pollen, they flew frequently from flower to flower. The percentage of the total number of visits during which forager bees came into contact with the stigma of the visited flowers was 0% for the two seasons.

The fruiting rate due to *A. mellifera* was 17.72% in 2016, 22.20% in 2017 and 19.96% for the two cumulate years. The difference was highly significant between treatments 5 and 6 ($\chi 2$ = 47.99; df = 1; P<0.001) as well as between treatments 7 and 8 ($\chi2$ = 99.75; *df* = 1; *P*<0.001). Hence, in 2016 and 2017, the fruiting rate of bunches protected and visited exclusively by *A. mellifera* was higher than that of bunches protected, uncovered and reprotected without insect or any other organism visit.

The percentage of mature fruits was 94.33% in 2016, 96.18% in 2017 and 95.26% for the two cumulate years. The difference was highly significant between treatments 5 and 6 ($\chi2$ = 81.83; *df* = 1; *P*<0.001) as well as between treatments 7 and 8 ($\chi2$ = 140.25; *df* = 1; *P*<0.001). Our observations pointed out that bunches visited by *A. mellifera* have the highest number of normal fruits compare to those protected then uncovered and rebagged without the visit of insect or any other organism.

The percentage of normal fruits due to *A. mellifera* was 91.76% in 2016, 82.98% in 2017 and 87.37% for the two cumulate years. The difference was highly significant between treatments 5 and 6 ($\chi2$ = 176.06; *df* = 1; *P*<0.001) as well as between treatments 7 and 8 ($\chi2$ = 57.25; *df* = 1; *P*<0.001). Our observations pointed out that bunches visited by *A. mellifera* have the highest number of normal fruits compare to those protected then uncovered and rebagged without the visit of insect or any other organism.

In 2016, the numeric contribution of *A. mellifera* via a single flower visit were 40.00% for the fruiting rate, 26.68% for the percentage of mature fruits and 54.88% for the percentage of normal fruits. In 2017, the corresponding figures were 48.53%, 29.86% and 33.36% respectively. For the two cumulated years, the numeric contribution of *A. mellifera* on the fruiting rate, the percentage of mature fruits and the percentage of normal fruits were 44.26%, 28.27% and 44.12% respectively.

The flowers that were exposed to pollinators provided more fruits than protected flowers, in agreement with previous results reported on the same plant in Queensland [20] where *A. mellifera* has a positive impact on fruit production.

During the pollen harvest from the flowers of *L. camara*, *A. mellifera* was always in contact with the anthers of the flower visited. In fact, this bee was likely to play a positive role in self-pollination, by causing the release of pollen from a flower for an optimal occupation of its stigma. This is all the more probable that autogamy exists in *L. camara* [21]. According to [20], *L. camara* has low self-fertility, taking this consideration, *A. mellifera* also intervened in the known cross-pollination in this Verbenaceae [48]. The positive and significant contribution of *A. mellifera* in the fruit production of *L. camara* is justified by the action of this bee on the pollination of the flowers visited.

Table 1: Diversity of floral insects on *Lantana camara* in August 2016 and 2017, number and percentage of visits of different insects.

Insects			2016		2017		Total	
Order	**Family**	**Genus and species**	n_1	p_1 (%)	n_2	p_2 (%)	n_T	p_T (%)
Hymenoptera	Apidae	*Amegilla* sp. 1 (ne)	0	0	7	4.86	7	2.21
		Amegilla sp. 2 (ne)	5	2.89	0	0	5	1.58
		Amegilla sp. 3 (ne)	13	7.51	3	2.08	16	5.05
		Apis mellifera (po)	71	41.04	57	39.58	128	40.38
		Ceratina sp. (po)	13	7.51	9	6.25	22	6.94
		Xylocopa inconstans (ne)	3	1.73	10	6.94	13	4.10
		Xylocopa olivacea (ne)	2	1.16	0	0	2	0.63
Lepidoptera	Hesperiidae	(1 sp.) (ne)	12	6.94	1	0.68	13	4.10
	Nymphalidae	*Cymothoe* sp. (ne)	0	0	2	1.39	2	0.63
	Papilionidae	*Graphium angolanus* (ne)	28	16.18	5	3.47	33	10.41
		Papilio demodocus (ne)	15	6.67	18	12.50	33	10.41
	Pieridae	*Catopsilia florella* (ne)	8	20.3	32	22.22	40	12.62
		Mylothris chloris (ne)	3	2.26	0	0	3	0.95
Total		13 species	173	100	144	100	317	100

n_1: number of visits on 120 floral bunches in 11 days; n_2: number of visits on 120 floral bunches in 10 days; n_T = total number of visits on 240 floral bunches in 21 days; p_1 and p_2: percentages of visits;
$p_1 = (n_1 / 173) * 100$; $p_2 = (n_2 / 144) * 100$; p_T = total percentages of visits; sp.: undetermined species;
ne: collection of nectar; po: collection of pollen.
Comparison of percentages of *Apis mellifera* visits for the two years: $\chi^2 = 0.07$ (*df* = 1; *P*>0.05)

Table 2: Interrupted visits of *Apis mellifera* on *Lantana camara* flowers in August 2016 and 2017 at Dang.

Years	Number of studied visits	Visits interrupted by insects		Insects responsible of visits' interruption
		Number	**Percentage (%)**	
2016	87	9	10.34	*Apis mellifera*
		5	5.75	*Catopsilia florella*
		3	3.45	*Graphium angolanus*
		2	2.30	*Papilio demodocus*
2017	63	8	12.70	*Apis mellifera*
		2	3.17	*Amegilla* sp. 3
		3	4.76	*Catopsilia florella*

Table 3: Fruiting rate, percentage of mature fruits and percentage of normal fruits according to different treatments of *Lantana camara* in August 2016 and 2017 at Dang.

Treatments	Years	NSF	NFF	% FR	NMF	% NMF	NNF	% NF
1 (Uf)	2016	2574	1371	53.26	1329	96.94	1083	81.49
2 (Pf)		2525	237	9.39	162	68.35	72	44.44
3 (Uf)	2017	2677	1785	66.68	1752	98.15	1379	78.41
4 (Pf)		2803	210	7.49	139	66.19	76	54.68

5 (Fbvp)	2016	2686	476	17.72	449	94.33	412	91.76
6 (Fbwv)		2135	227	10.63	157	69.16	65	41.40
7 (Fbvp)	2017	2833	629	22.20	605	96.18	502	82.98
8 (Fbwv)		2205	252	11.43	170	67.46	94	55.29

Uf: unprotected flowers; Pf: protected flowers; Fbvp: flowers bagged and visited exclusively by *Apis mellifera;* Fbwv: flowers bagged, opened and closed without visit; NFS: number of studies flowers; NFF: number of fruits; FR: fruiting rate; NMF: number of mature fruits; NNF: number of normal fruits; NF: normal fruits.

Fig 1: *Apis mellifera* worker exploring a flower of *Lantana camara* with her baskets full of pollen at Dang in August 2017

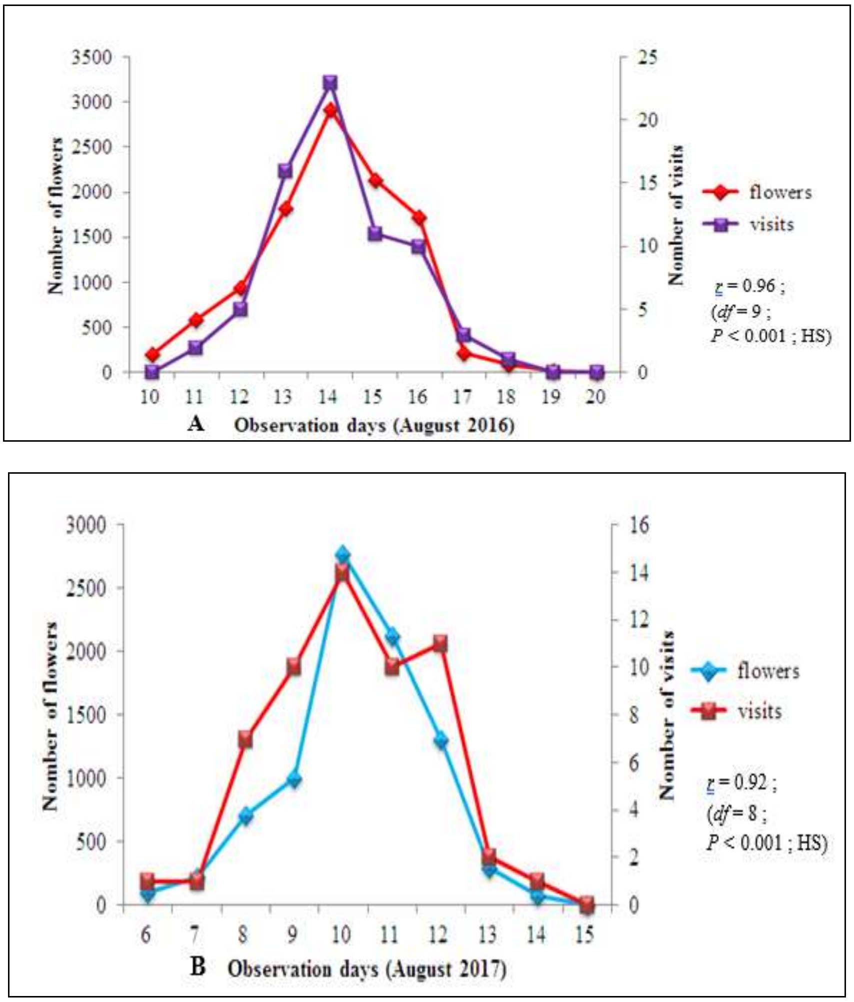
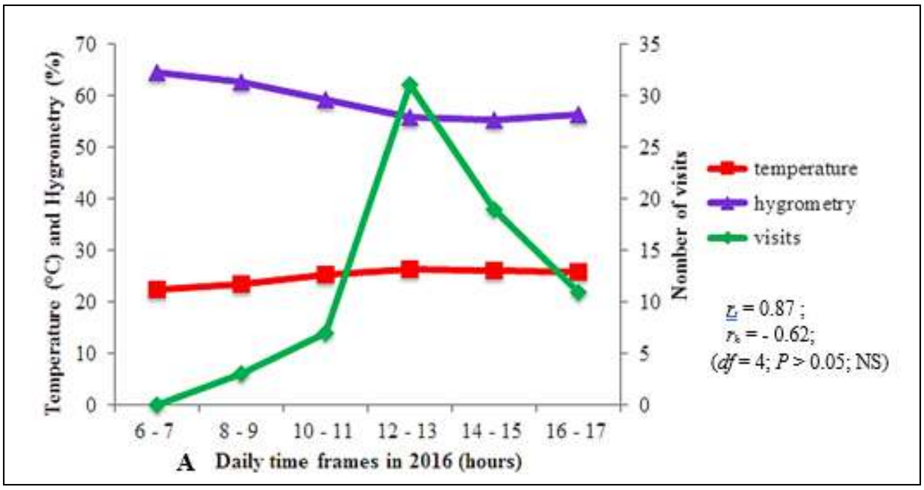


Fig 2: Seasonal variation of the number of *Lantana camara* flowers and the number of *Apis mellifera* visits on these organs in August 2016 (A) and 2017 (B) at Dang *r:* correlation coeffficient between the number of flowers and the number of visits; *df*: degree of freedom; *P*: probability; HS: highly significant



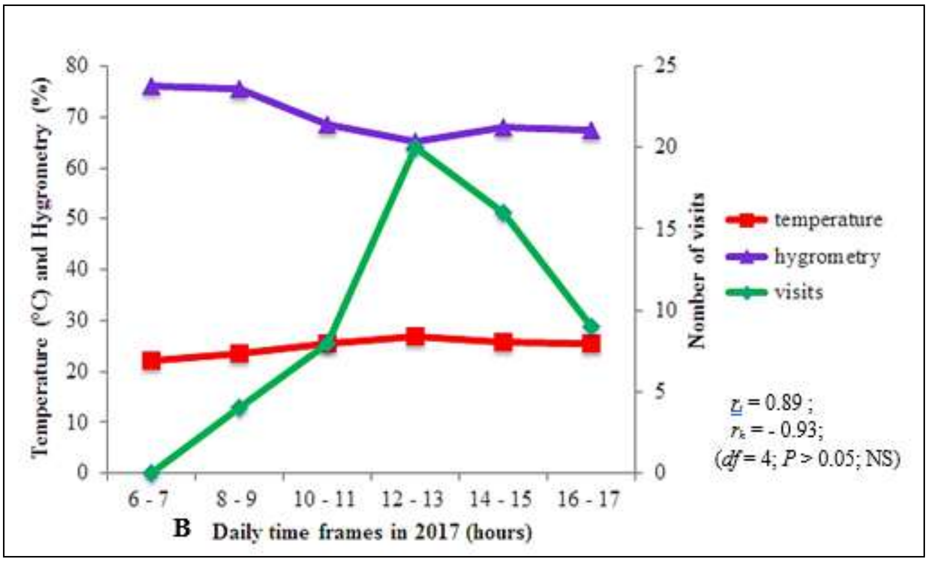


Fig 3: Daily variation of *Apis mellifera* visits on *Lantana camara* flowers, mean temperature and mean humidity of the study site in August 2016 (A) in 2017 (B). *r:* correlation coeffficient between the number of flowers and the number of visits; *df*: degree of freedom; *P*: probability; NS: correlation not significant

4. Conclusion

From our observations, *Lantana camara* is a plant species that highly benefits from pollination by insects among which *Apis mellifera* is one of the most important and harvested pollen. The comparison of fruit yields of bunches visited exclusively by *A. mellifera* with that of the bunches protected from insects then uncovered and reprotected without the visit of insect or any other organism underscores the capacity of this honey bee in increasing fruits production as well as fruits quality. Data on the foraging activity of *A. mellifera* enable the classification of *L. camara* among the highly polliniferous honey bee plant. By its positive action on the pollination of the flowers visited, *A. mellifera* caused a significant increase in the fruiting rate by 44.26%, the number of mature fruits by 28.27% and the number of normal fruits by 44.12%. Thus, *L. camara* plant could be grown or protected to increase pollen production as a honey bee hive product and stabilize *A. mellifera* colonies during the rainy season.

5. References

1. Delbeuck C. Fleurs sauvages et prairies fleuries pour nos pollinisateurs. Guide technique et choix de mélanges, SPW I Bonnes Pratiques. 2013, 36.
2. Dumbardon ME. Des mauvaises herbes pour les abeilles. Fredon. 2016;33:2-3.
3. Rasoloarijao TM. Écologie de l'abeille, *Apis mellifera unicolor* Latreille, dans les écosystèmes forestiers naturels de Ranomafana (Madagascar) et Mare Longue (Réunion): étude du comportement de butinage et de l'utilisation des ressources florales par approche mélissopalynologique. Thèse de Doctorat, en cotutelle Université de La Réunion & Université d'Antananarivo. 2018, 303.
4. Neumann P, Carreck NL. Honey bee colony losses. Journal of Apicultural Research. 2010;49(1):1-6.
5. Klein AM, Vaissière BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C *et al*. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society, London (B). 2007;274: 303-313.
6. Tsafack MAS, Kamajou F, Muluh GA, Takam M. Analyse économique de la structure des coûts de production apicole au Cameroun. Tropicultura. 2008;26(4):220-223.
7. FAO. Pollinator Safety in Agriculture. Balboa, Ancon, Panama. 2014, 138.
8. Tchuenguem FF-N, Mapongmetsem PM, Hentchoya HJ, Messi J. Activité de *Apis mellifica* L. (Hymenoptera: Apidae) sur les fleurs de quelques plantes ligneuses à Dang (Adamaoua, Cameroun). Cameroon Journal of

Biological and Biochemical Sciences. 1997b;7(1):86-91.

9. Tchuenguem FF-N, Fameni TS, Pharaon MA, Messi J, Brückner D. Foraging behaviour of *Apis mellifera adansonii* (Hymenoptera: Apidae) on *Combretum nigricans*, *Eryhrina sigmoidea*, *Lannea kerstingii* and *Vernonia amygdalina* flowers at Dang (Ngaoundéré, Cameroon). International Journal of Tropical Insect Science. 2010a;30(1):40-47.
10. Tchuenguem FF-N, Fameni TS, Pharaon MA, Messi J, Brückner D. Foraging behaviour of *Apis mellifera adansonii* (Hymenoptera: Apidae) on *Daniellia oliveri*, *Delonix regia*, *Hymenocardia acida* and *Terminalia mantaly* flowers in Ngaoundéré (Cameroon). International Journal of Biological and Chemical Sciences. 2010b;4(4):1180-1190.
11. Tchuenguem FF-N, Djonwangwé D, Messi J, Brückner D. Exploitation des fleurs de *Bombax pentandrum*, *Commiphora kerstingii*, *Mytragina ciliata*, *Parkia biglobosa*, *Terminalia macroptera* et *Voacanga africana* par *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) à Dang (Ngaoundéré, Cameroun). In*:* Himmi O. (éd.), Acte de la CIFE, travaux de l'Institut Scientifique, Série Zoologie, Rabat. 2010c;47(1):117- 122.
12. Wékéré C, Kingha TBM, Dongock ND, Djakbé JD, Faïbawa E, Tchuenguem FF-N. Exploitation of *Jatropha curcas, Senegalia polyacantha* and *Terminalia schimperiana* flowers by *Apis mellifera* (Hymenoptera: Apidae) at Dang (Ngaoundéré, Cameroon). Journal of Entomology and Zoology Studies. 2018a;6(2):2072-2078.
13. Tchuenguem FF-N, 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.
14. Kengue J, Tchuenguem FF-N, Adewusi HG. Towards the improvement of safou (*Dacryodes edulis*): population variation and reproductive biology. Forests Trees and Livelihoods. 2002;12:73-84.
15. Dongock ND, Foko J, Pinta JY, Ngouo LV, Tchoumboue J, Zango P. Inventaire et identification des plantes apicoles de la zone Soudano – Guinéenne d'altitude de l'Ouest Cameroun. Tropicultura. 2004;22(3):139-145.
16. Dongock ND, Zapfack L, Mapongmentsem PM, Tchuenguem FF-N. Predominant melliferous plants of the western Sudano Guinean zone of Cameroon. African Journal of Environmental Science and Technology. 2011;5(6):443-447.
17. Schemske DW. Pollinator specificity in *Lantana camara* et *Lantana trifolia* Verbenaceae). Biotropica. 1976;8(4):260-264.
18. Carrión-Tacuri J, Berjano R, Guerrero G, Figueroa ME, Tye A, Castillo JM. Fruit set and the diurnal pollinators of the invasive *Lantana camara* and the endemic *Lantana peduncularis* in the Galapagos Islands. Weed Biology and Management. 2014;10:1-11.
19. Carrión-Tacuri J, Berjano R, Guerrero G, Figueroa ME, Tye A, Castillo JM. Nectar production by invasive *Lantana camara* and endemic *L. peduncularis* in the Galápagos Islands. *Pacific Science*. 2012;66(4):435-445.
20. Goulson D, Derwent LC. Synergistic interactions between an exotic honeybee and an exotic weed: pollination of *Lantana camara* in Australia. Weed Research. 2004;44:195-202.
21. Louabé S, Kingha TBM, Kengni BS, Fameni TS, Tchuenguem FF-N. Activité de butinage et de pollinisation de *Papilio demodocus* (Lepidoptera: Papilionidae) sur les fleurs de *Lantana camara* (Verbenaceae) à Dang (Ngaoundéré, Cameroun). Journal of Chemical, Biological and Physical Sciences. 2020;10(2):227-241.
22. Djoufack V, Fontaine B, Martiny N, Tsalefac M. Climatic and demographic determinants of vegetation cover in northern Cameroon. International Journal of Remote Sensing. 2012;21:6904-6926.
23. Amougou JA, Abossolo SA, Tchindjang M. Variabilité des précipitations à Koundja et à Ngaoundéré en rapport avec les anomalies de la température de l'océan atlantique et el nino. Ivoiry Coast Review of Science and Technology. 2015;25:110-124.
24. Letouzey R. Etude phytogéographique du Cameroun. Paul Le Chevalier (éd.), Paris 5ème. 1968, 511.
25. Tchuenguem FF-N, 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.
26. Tchuenguem FF-N. Activité de butinage et de pollinisation d'*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, Cameroun. 2005, 103.
27. Borror DJ, White RE. Les insectes de l'Amérique du Nord (au nord du Mexique). Broquet (ed.), Laprairie. 1991, 408.
28. Tchuenguem FF-N, Messi J, Brückner D, Bouba B, Mbofung G, Hentchoya HJ. Foraging and pollination behavior of the African honey bee (*Apis mellifera adansonii*) on *Callistemon rigidus* flowers at Ngaoundéré (Cameroon). Journal of the Cameroon Academy of Sciences. 2004;4(2):133-140.
29. 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.
30. Tchuenguem FFN, Djonwangwé D, Brückner D. Foraging behaviour of the African honey bee (*Apis mellifera adansonii*) on *Annona senegalensis*, *Croton macrostachyus*, *Psorospermum febrifugum* and *Syzygium guineense* var. *guineense* flowers at Ngaoundéré (Cameroon). Pakistan Journal of Biological Sciences. 2008a;11:719-725.
31. Tchuenguem FF-N, Djakbé JD, Ngakou A, Wékéré C, Louabé S, Faïbawa E. Impact de l'activité de butinage de *Apis mellifera* Linné (Hymenoptera: Apidae) sur la pollinasation et les rendements de *Ceratotheca sesamoides* Endl. (Pedaliaceae) à Dang (Ngaoundéré, Cameroun). Cameroon Journal of Experimental Biology. 2018;12(1):22-31.
32. Diguir BB, Pando JB, Fameni TS, Tchuenguem FF-N. Pollination Efficiency of *Dactylurina Staudingeri* (Hymenoptera: Apidae) on *Vernonia Amygdalina* (Asteraceae) Florets at Dang (Ngaoundéré, Cameroon). International Journal of Research Studies in Agricultural Sciences (IJRSAS). 2020;6(2):22-31.
33. Fewell JH, Winston ML. Regulation of nectar collection

in relation tohoney storage levels by honey bees, *Apis mellifera*. Behavioral Ecology. 1995;7(3):286-291.
34. Alleaume C. L'abeille domestique (*Apis mellifera*), exemple pour l'étude de l'attractivité des plantes cultivées sur les insectes pollinisateurs. Thèse de Doctorat en Médicine Vétérinaire, Ecole Nationale Vétérinaire d'Alfort. 2012, 112.
35. Michener CD. The bees of the world. 2nd edition. The John Hopkins University Press. Baltimore and London. 2007, 953.
36. Gallais N, Salles J-M, Settele J, Vaissière BE. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics. 2009;68:810-821.
37. Roubik DW. Pollination of cultivated plants in the tropics. Food and Agriculture Organization of the United Nations, Rome, Bulletin n° 1995;188:198.
38. Pierre J, Chauzat MP. L'importance du pollen pour l'abeille domestique. Bullettin Technique Apicole. 2005;32(1):11-28.
39. Manning R. Fatty acids in pollen: a review of their importance for honeybees. Beeworld. 2001;82(2):60-75.
40. Suchet C. Ecologie et Evolution des odeurs florales chez *Antirrhinum majus*. Thèse de Doctorat, Université de Toulouse. 2010, 212.
41. Pesson P, Louveaux J. Pollinisation et productions végétales. INRA, Paris. 1984;663.
42. Kasper ML, Reeson AF, Mackay DA, Austin AD. Environnemental foctors influencing daily foraging activity of *Vespula germanica* (Hymenoptera, Vespidae) in Mediterranean Autralia. Insectes Sociaux. 2008;55:288-296.
43. Julianna KT, Rufus I. Weather during affects pollination and yield of highbush blueberry. Journal of Economic Entomology. 2010;103(3):557-562.
44. Louveaux J. L'abeille domestique dans ses relations avec les plantes cultivées. In: «Pollinisation et productions végétales», Pesson P. & Louveaux J. (eds), INRA, Paris. 1984, 527-555.
45. Free JB. The effect of flower shapes and nectar guides on the behaviour of foraging honeybees. Behaviour. 1970;37:269-285.
46. Frisch K. Von. The dance language and orientation of bees. The Belknap Press of Harvard University Press, Cambridge. 1967, 235.
47. Piroux MM. Ressources pollinifères et mellifères de l'abeille domestique, *Apis mellifera*, en paysage rural du nord - ouest de la France, Paris. 2014, 305.
48. Barrows EM. Nectar robbing and pollination of *Lantana camara* (Verbenaceae). Biotropica. 1976;8:132-135.