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Evaluation of the Foraging Activity and Pollination Efficiency of *Apis mellifera* L. (Hymenoptera: Apidae) on *Urena lobata* L. (Malvaceae) Flowers at Dang (Ngaoundere, Cameroon)

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Abstract: ***Field surveys of Urena lobata plant plots were conducted during two seasonsin 2020 and 2021 aiming to determine the apicultural value of U. lobata and assess the pollination efficiency of Apis mellifera on fruiting rate and seed production. Observations were carried out on 540 flowers divided in four treatments: 120 flowers accessible to all insects; 120 flowers bagged to avoid all visits; 200 flowers protected, uncovered, visited once by A. mellifera and rebagged; 100 flowers bagged then uncovered and rebagged without the visit of insects or any other organism. The foraging behavior of A. mellifera on flowers and its pollination efficiency were recorded. Results show that, among the flowering insects of U. lobata, A. mellifera was the main visitor and it intensely harvested nectar and slightly collected pollen. The highest mean number of honeybees per 1000 flowers was 132 and 209 in the morning between 8 am and 9 am during the flowering stage for the two studied period respectively in 2020 and 2021. The mean foraging speed was 8 flowers per minute in 2020 and in 2021. Via the pollination efficiency of one flower visit on U. lobata, A. mellifera has increased the fruiting rate by 10.46% and the percentage of normal seeds by 13.47%.***

Keywords: *Urena lobata*, Pollination efficiency, *Apis mellifera*, Production, Dang

1. Introduction

Ecosystem services are functions provided by nature that improve and sustain human wellbeing [1]. So naturally, many arthropods provide valuable ecosystem services, such as those that support human food production [2]. Among these arthropods are pollinating insects which increase the productivity of field and horticultural crops, assuring self-pollination [3] and cross-pollination [4] with advantages such as producing larger perfectly shaped pods, a greater proportion of early flower set and promotion of hybrid vigour [5]. Meantime, many pollinator-dependent crops are pollinated by *Apis mellifera* [6], [7], due to their ease of management and high abundance during crop bloom, achieved by bringing hives to fields [2]. With the contribution of other pollinators, this arthropod generates considerable incomes for the agricultural sector [8]. The domestication of *A. mellifera* has therefore enabled to better bring together demand and supply for pollination services [8]. The honeybee, *A. mellifera* is the principal species used for crop pollination worldwide [6]. Moreover, *A. mellifera* is flower constant, which means that on any foraging trip, it focuses on only one kind of flower [9]. Pollen is transferred between flowers of the same species and this is one of the features that make honeybees so popular for commercial pollination of crops [9].

Urena lobata L.1753 of Malvaceae family is a shrub 0.6 to 3.0 m in height and up to 7 cm in basal diameter [10]. It is found wild in the tropical and temperate zones of North and South America and in Asia, Indonesia, Philippines, and Africa [11]. *Urena lobata* is an annual in subtropic and perennial in the tropics [12]. The flowers of this shrub are small, clustered in the axils; the corolla measure 15 mm long and is pink in color [13]. In Ouagadougou, [14] has noticed that this plant blooms from July until the end of the rainy season and produces the nectar which attract *A. mellifera*. The fruits are 8 to 10 mm globose capsules that break into five fine barbed mericarps [10]. Medically, the different extracts of the leaves and roots of *U. lobata* are used to treat diverse ailments such as cough, malaria, venereal diseases and rheumatism [15]. The leaves and flowers are eaten as famine food in Africa [16].

In Cameroon, the demand for honey and pollen is increasing while their production is low, particularly due to the insufficient knowledge of the relationships between honeybee and several plants including *U. lobata*.

Prior to our work, the researches conducted on the relationship between *U. lobata* and insects including *A. mellifera* are those of [17] in Nigeria and [14] in Ouagadougou where *A. mellifera* visited the flowers of this plant to collect only nectar. The detailed study of the foraging activity by this honeybee and its impact on fruit production were not addressed in these works.

The general aim of our investigation was to contribute to the understanding of the relationships between *U. lobata* and *A. mellifera*, for their optimal management in Cameroon. Specific objectives were to register the activities of *A. mellifera* on flowers of *U. lobata*, to evaluate the apicultural

value of this plant and to estimate the pollination efficiency of one flower visit of this bee on the Malvaceae.

2. Material and Methods

2.1. Biological material and site

The animal material consisted of insect species naturally found in the environment of the study site and the plant material consisted of the flowering plants of *U. lobata* grown as spontaneous plants.

Field experiments were conducted during two seasons from June to July in 2020 and 2021 in order to identify insect visitors of *U. lobata*. These periods correspond to the peak of flowering season of *U. lobata*, in Dang, a village in the Vina Division, Adamawa Region of Cameroon. This Region is located within the high-altitude Guinean savannah agro-ecological zone; the climate is characterized by a rainy season (April to October) and a dry season (November to March), with an average annual rainfall of about 1500 mm; the mean annual temperature is 22°C, while the mean annual relative humidity is 70% [18]. The vegetation in the study site was represented by crops, ornamentals, hedge and native plants of the savannah and gallery forests.

2.2. Determining the reproduction mode of *Urena lobata*

In June 9th, 2020, 240 flowers of *U. lobata* at the bud stage were labeled among which 120 were left unprotected (treatment 1) and 120 were bagged using gauze bags (treatment 2) to prevent insect visits [19]. In June 4th, 2021, the same treatments were set up (treatment 1' and 2').

For each studied year, ten days after the shading of the last labelled flower, the number of formed fruits was assessed in each treatment.

The fruiting index (*Fri*) was then calculated as described by [20]: $Fri = Fb / Fa$, where *Fb*is the number of formed fruits and *Fa* the number of viable flowers initially set.

The allogamy rate (*Alr*) from which derives the autogamy rate (*Atr*) was expressed as the difference in fruiting indexes between treatment X (unprotected flowers) and treatment Y (protected flowers) [21].

$$Alr = [(FiX - FiY) / FiX] * 100,$$

where *Fi*X and *Fi*Y are respectively the mean fruiting indexes in treatment X and treatment Y.

$$Atr = 100 - Alr$$

2.3 Determination of the position of *Apis mellifera* in *Urena lobata* entomofauna

Observations were conducted on 120flowers accessible to all insects (treatment 1 and 1'), every day, from 9thto 13thJune2020 and from 4thto 9thJune 2021. For each year of observation, the number of open flowers in treatments1 and 1'was first recorded. Data were taken according to six daily time frames each day: 6-7 am, 8-9 am, 10-11 am, 12-1 pm, 2-3 pm and 4-5 pm. In a slow walk along all the flowers of treatments 1 and 1', all insects encountered on flowers were registered [22] and the cumulated results expressed as the number of visits to determine the relative frequency of each insect species in anthophilous entomofauna of *U. lobata* [23]. Data obtained were used to determine the frequency of visits (*Fi*) of each insect species on *U. Lobata*. 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 [20]. Specimens for all insect species, excluding *A. mellifera* were caught using insect net on unlabeled flowers and conserved in 70% ethanol, apart from butterflies that were preserved dry [24] for subsequent taxonomic identification.

2.4 Activity of *Apis mellifera* on the flowers of *Urena lobata*

In addition to the determination of frequency of flowering insect, direct observation of the foraging activity of *A. mellifera* on flowers was made in the field. The floral products (nectar and / or pollen) harvested by honeybee were noted during the same period and time slots as for the duration of visits, based on its foraging behavior on the flowers. 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 their mandibles and legs [24].

The duration of visits per flower was recorded during the following daily time frames: 7-8 am, 9-10 am, 11 am-12 pm, 2-3 pm and 4-5 pm. The abundance of foragers (highest number of individuals simultaneously in activity per flower and per 1000 flowers) [25] and the foraging speed (number of flowers visited per minute) [26] were registered at the same period and daily time frames as for the duration of visits. The abundance of foragers per flower was noted following direct counting. For the abundance per 1000 flowers (A_{1000}), the number of individuals of *A. mellifera* was counted on a known number of flowers at the moment *x*. The abundance per 1000 flowers was then calculated using the formula $A_{1000} = [(Ax / Fx) * 1000]$, where *Fx* and *Ax* are respectively the number of opened flowers and the number of foragers effectively counted on these flowers at time *x [*22]. The foraging speed (*Fs*) was calculated using the formula:

$Fs = (Fl / du) * 60$, where *du* is the duration (second) given by the stopwatch, and *Fl*, the number of flowers visited during *du [*22]. During each daily period of investigation, 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 am to 6pm, during the entire flowering period [21].

2.5 Evaluation of the apicultural value of *Urena lobata*

The apicultural value of *U. Lobata* was assessed using data on its flowering intensity and the degree of attractiveness of *A. mellifera* foragers with respect to its nectar and pollen [27], [28]. The evaluation of the concentration in total sugars of the nectar was recorded using a portable refractometer (0-

90% Brix) and a thermometer that gave the ambient temperature.

2.6. Evaluation of the effect of insects including *Apis mellifera* on *Urena lobata* production

For each investigation year, this evaluation was based on the impact of flowering insects on pollination, the impact of pollination on *U. lobata* fruiting, and the comparison of production (fruiting rate, percentage of fruits with seed and percentage of normal or well developed seeds) of unprotected flowers and those of protected flowers [19]. For each observation period, the fruiting rate due to the influence of foraging insects (*Fri*) was assessed using the following formula:

Fri = {[(*FX* + *Eg*)-*FY* / (*FX* + *Eg*)] * 100}, where *FX* and *FY* are the fruiting rates in treatment *X (*unprotected flowers) and treatment *Y (*flowers protected from all insect visits), and *Eg* the effect of the gauze bag net which can be calculated using the formula *Eg= FY-FZ*, where *FZ* is the fruiting rate in treatment *Z (*flowers protected then unbagged and rebagged without insect or any other organism visit) [29]. Finally, *Fri* = { [(*FX-FZ*) / (*FX* + *FY-FZ*)] * 100} [29].

The fruiting rate of a treatment (*Fr*) is *Fr*= [(*b/a*) * 100], where *b* is the number of fruits formed and *a*is the number of viable flowers initially set [25].

At the maturity, fruits from each treatment were harvested and counted. The fruiting rate and the percentage of normal seeds were then determined for each treatment.

The impact of flower visiting insects including *A. mellifera* on normal seeds was evaluated using the same method as mentioned above for the fruiting rate.

2.7 Assessment of the pollination efficiency of *Apis mellifera* on *Urena lobata*

In parallel to the constitution of treatments 1, 1', 2 and 2', 300 flowers at the bud stage were labeled in 2020 and 2021, and two treatments were formed:

- Treatments 3 in 2020 or3' in 2021: 200 flowers protected using gauze bags to prevent insect visitors and destined to receive one visit of *A. mellifera*. Each opened flower of treatment 3 and 3' were inspected. Hence, the gauze bag was delicately removed and this flower was observed for up to 10 minutes. Each flower visited once by *A. mellifera* was marked then reprotected. Unvisited flowers by this bee were included in treatments 4 or 4' [30];
- Treatments 4 in 2020 or4' in 2021: 100 flowers destined to be unbagged and rebagged without the visit of insects or any other organism. Each opened flower of treatments 4 and 4' were inspected. Hence, the gauze bag was delicately removed and this flower was observed for up to 10 minutes, while avoiding its visit by insects or any other organism [30].

The contribution of *A. mellifera* in the fruiting rate and the percentage of normal seeds were calculated using data of treatments 3 and 4 for 2020 and those of treatments 3' and 4' for 2021.

For each observation year, the contribution of *A. mellifera* in the fruiting rate (*FrA*) was calculated using the following formula: *FrA*= {[(*FA-FZ*) / *FA*] * 100}, where *FA* is the fruiting rate in treatment *A* (flowers visited exclusively by *A. mellifera*) [30]. The impact of *A. mellifera* on normal seeds was evaluated using the same method as mentioned above for the fruiting rate.

2.8 Data treatment

The statistical analysis was done using Excel 2016 and Statgraphics plus 5.0fawasoftware. Data were analysed using descriptive statistics (calculation of means, standard deviations and percentages) and four tests: ANOVA (*F*) for the comparison of means of more than two samples; Student's *t*-test for comparing the means of two samples; Chi-square (χ^2) for the comparison of percentages; Pearson's correlation coefficient (*r*) for the study of linear relationships between two variables.

3. Results and Discussion

3.1 Reproduction mode of *Urena lobata*

In 2020, the fruiting index was 1 and 0.86 respectively for treatments 1 and 2, while in 2021 it was 0.97 for treatment 1' and 0.80 for treatment 2'. Hence, *Alr* was 14% and *Atr*was86% in 2020 against 17% and 83% in 2021. Thus *U. lobata* has a mixed mating mode, allogamous and autogamous, with the predominance of autogamy over allogamy. A mixed reproduction regime with the predominance of autogamy over allogamy could be explained by the structure of the flower [31]. *Urena lobata* are self-compatible and usually self-pollinated [32], [33].

3.2 Place of *Apis mellifera* in *Urena lobata* floral entomofauna

In total, 10 insect's species belonging to eight families under seven orders visiting the *U. lobata* flowers were recorded during the two studied period (table 1). Out of these, five species belonged to Hymenoptera (87.75%), three to Lepidoptera (7.75%), one to Coleoptera (2.04%) and one to Diptera (2.85%). A total of 110 visits in 2020and 135 visits in 2021 were recorded from all insect species. Among these visits, *A. mellifera* alone recorded 88 (80%) in 2020 and 93 (68.88%) in 2021 (Table 1). The difference between these two percentages is not significant ($\chi 2$ = 3.25; *df*= 1; *P* > 0.05). *Apis mellifera* was also shown to be the main floral visitors of another Malvaceae, *Gossypium hirsutum* L., in Maroua [34]. The fact that, *A. mellifera* was the main floral insect visitor could be explained by the strategies adopted by this bee which consist of recruiting a great number of workers for the exploitation of an interesting nutritional source [35], [36], [37]. Consequently, there may be a limitation of the number of visits of other insect species due to the occupation of the majority of open flowers by *A. mellifera* workers.

Table 1: Diversity of flowering insects on *Urena lobata* in 2020 and in 2021 at Dang, number and percentage of visits of different insects

Insects			2020		2021		2020 / 2021	
Order	**Family**	**Genus and species**	n_1	p_1 (%)	$n_{1'}$	$p_{1'}$ (%)	n_T	p_T (%)
Diptera	Calliphoridae	*Calliphora sp.* (ne)	-	-	7	5.18	7	2, 85
Hymenoptera	Apidae	*Apis mellifera* (ne, po)	88	80	93	68.88	181	73, 87
		Amegilla sp.1 (ne)	3	2.72	6	4.44	9	3, 26
		Amegilla acraensis (ne)	-	-	1	0.74	1	0, 01
	Halictidae	*Braunsapis* sp. (po)	6	5.45	13	9.62	19	7, 75
	Formicidae	(1 sp.) (ne)	2	1.81	3	2.22	5	2, 04
Lepidoptera	Hesperiidae	(1 sp.) (ne)	2	1.81	1	0.74	3	1, 22
	Papilionidae	*Papilio demodocus* (ne)	7	6.36	5	3.70	12	4, 89
	Pieridae	*Catopsilia florella* (ne)	1	0.90	2	1.44	3	1, 22
Coleoptera		(1 sp.) (ne)	1	0.90	4	2.96	5	2, 04
Total			**110**	**100**	**135**	**100**	**245**	**100**
			8 species		**10 species**		**10 species**	

n_1: number of visits on 120 flowers in 4 days; $n_{1'}$: number of visits on 120 flowers in 5 days; $p_1$and $p_{1'}$: percentages of visits; $p_1 = (n_1 / 88) * 100$; $p_{1'} = (n_{1'} / 135) * 100$; sp.: undetermined species; ne: nectar collection; po: pollen collection

3.3. Activity of *Apis mellifera* on *Urena lobata* flowers

On *U. lobata* flowers, individuals of *A. mellifera* harvested nectar (Figure 1) regularly and intensively. The collection of pollen was less frequent. The difference observed between the mean number of nectar collection visits and that of pollen harvest visits was highly significant in 2020 (t = 6.05; df = 581; P< 0.001) as well as in 2021 (t = 17.57; df = 462; P< 0.001). This difference could be explained by the accessibility of each of these floral products and by the needs of the colonies of the foraging bees [38], [39]. Otherwise, according to [14] in Ouagadougou, *A. mellifera* intensely harvested exclusively nectar on the same plant species. The variations observed in this study could be explained mainly by the real needs of the colonies from which originated honeybee workers [40].

Figure 1: *Apis mellifera* worker collecting nectar in a flower of *Urena lobata*

The strong attractive nectar of this Malvaceae with respect to *A. mellifera* could be partly explained by the availability and the quality of this food as well as the best time to harvest it at the level of the flowers [37].

The activity of *A. mellifera* is link to the flowering of the studied plant. We found a positive and highly significant correlation between the number of *A. mellifera* visits and the number of *U. lobata* opened flowers in2020 (r = 0.99; df= 21; P < 0.01) (Figure 2A) as well as in 2021 (r = 0.98; df= 5; P < 0.01) (Figure 2B).

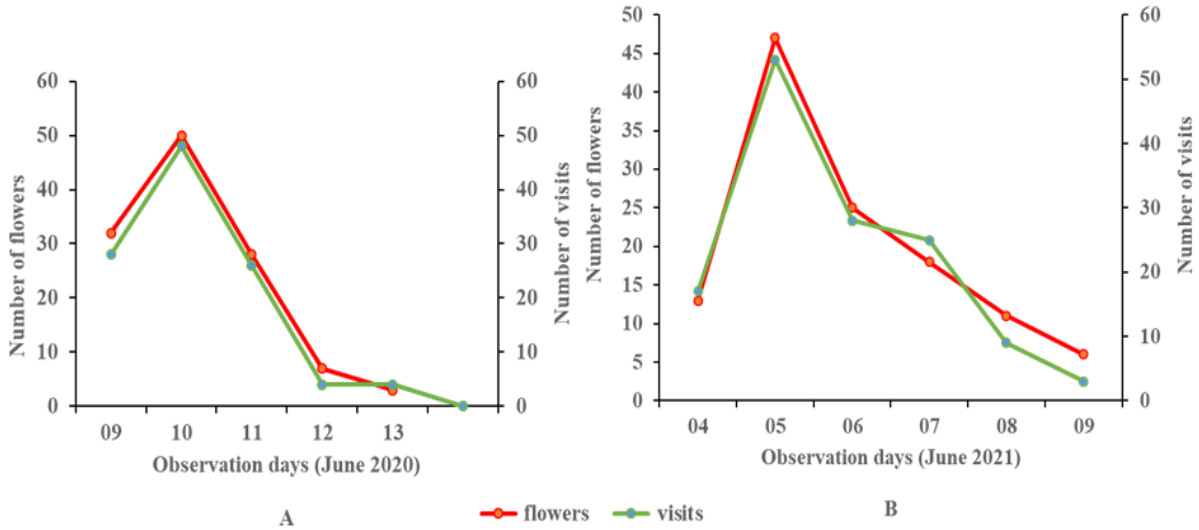

Figure 2: Daily variation of the number of *Urena lobata* open flowers and the number of *Apis mellifera* visits on these organs in 2020 (A) and in 2021 (B) at Dang

The daily observation results show that *A. mellifera* workers were active on the flowers of *U. lobata* from 6 am to 1 pm, with a peak of visits between 8 am and 9 am in 2020as well as in 2021 (Figure 3). This daily period probably corresponds to the moment of highest availability of nectar and pollen in the flowers of this Malvaceae. Results of the present study confirm those carried out by [14] in Ouagadougou on the same plant species indicating that the peak of activity of *A. mellifera* was situated between 8 and 9 am. The period of daily activity of many flowering insects on a given plant species depends on the availability of pollen [41] or nectar [42] in its flowers.

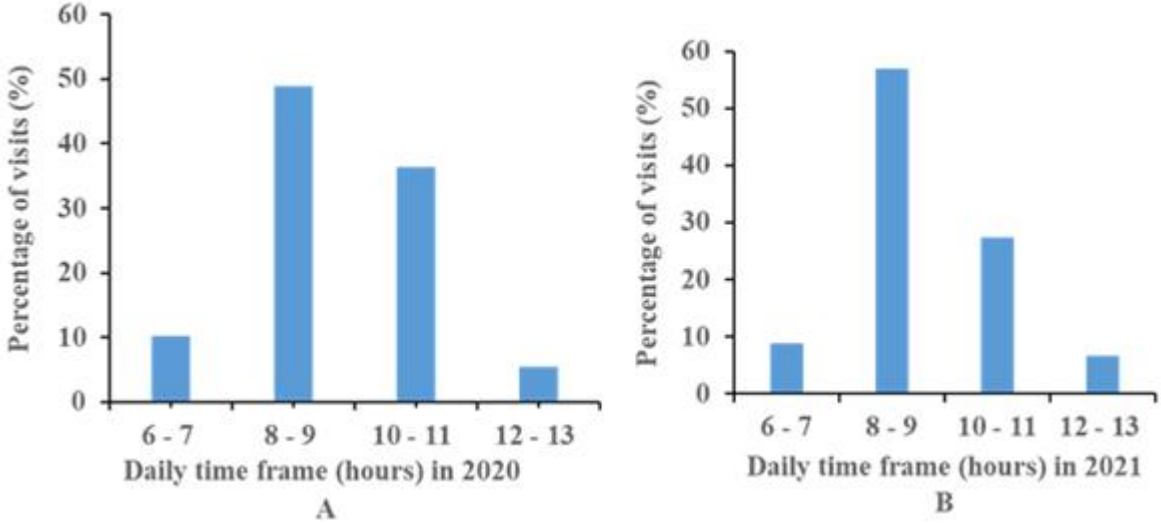

Figure 3: Variations of the number of *Apis mellifera* visits on *Urena lobata* flowers according to the daily time frames in 2020 (A) and in 2021 (B) at dang

Regarding the effect of ambient temperature and the relative humidity on *A. mellifera* visits, it is clear that the effect of these two factors was insignificant throughout the two experimental periods. We found a non significant correlation coefficient between the temperature and the number of *A. mellifera* visits in 2020 (r =-0.14; df = 2; P > 0.05) and in 2021 (r =-0.13; df = 2; P > 0.05) (Figure 4A); we noticed a non significant correlation coefficient between the relative humidity and the number of *A. mellifera* visits recorded in 2020 (r = 0.13; df = 2; P >0.05) and in 2021 (r = 0.37; df = 2; P >0.05) (Figure 4B). In three days of rainfall during our observations in 2020 and 2021, we didn't observe any activity of honeybee workers.

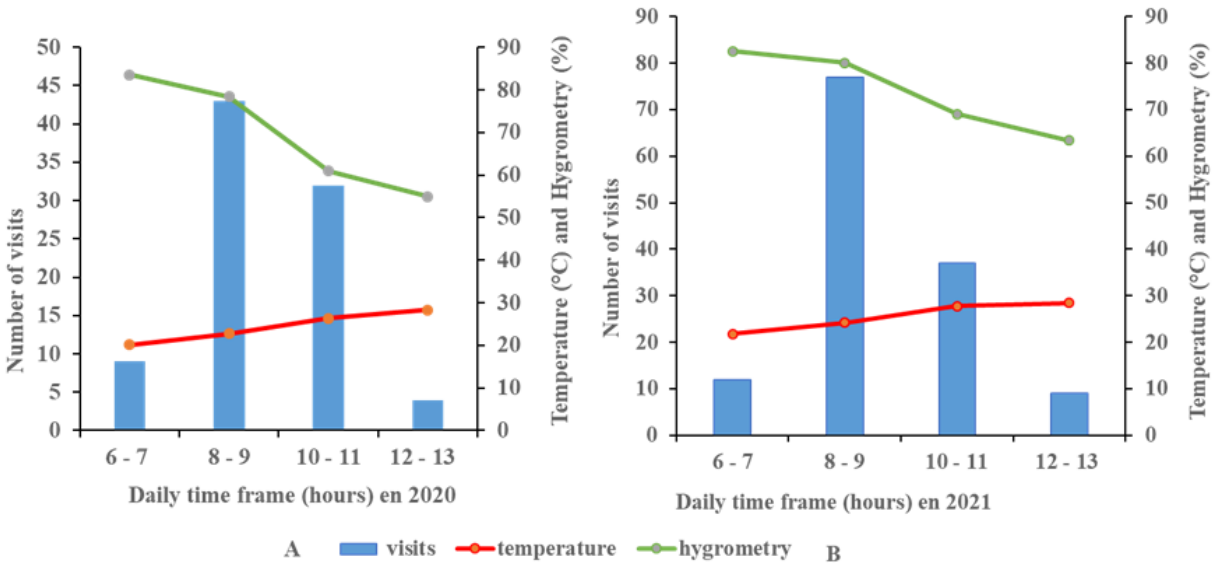

Figure 4: Variations of the temperature, the hygrometry and the number of *Apis mellifera* visits on the flowers of *Urena lobata* according to the daily time frames in 2020 (A) and in 2021 (B) at Dang

In 2020, the highest mean number of *A. mellifera* individuals simultaneous in activity was 1 per flower and 132 per 1000 flowers (n = 61; s = 43; min = 40; max = 240). In 2021, the corresponding figures were 1 per flower and 209 per 1000 flowers (n = 76; s = 72; min = 60; max = 360). For the abundance per 1000 flowers, the difference between the two means was highly significant (t = 42.52; df= 135; P < 0.001). The high abundance of *A. mellifera* individuals per 1000 flowers, and the positive and significant correlation between the number of *U. lobata* flowers and the number of *A. mellifera* visits, highlights the attractiveness of *U. Lobata* nectar and pollen for *A. mellifera*. This attractiveness could be explained by the highest availability and accessibility of these products. The mean duration of *A. mellifera* visit per

U. lobata flower was 4.51 seconds (n = 583; s = 1.48) in 2020 and 4.97 seconds (n = 435; s = 2.23) in 2021. The difference between these two means was significant (t = 3.73; df= 1016; $P < 0.01$). Insects take longer time to obtain their maximum load of nectar and / or pollen on flowers where these resources are easily accessible and available in large quantities [43]. The mean foraging speed was 8 flowers per minute in 2020 (n=397, s=2) as well as in 2021 (n=304; s=1). The difference between these two means is not significant (t =1.54; df= 699; P> 0.05).

3.4 Apicultural value of *Urena lobata*

During the flowering seasons of *U. lobata*, we noted an elaborated activity of *A. mellifera* foragers at the level of its flowers: high abundance of workers per 1000 flowers, good nectar harvest, weak pollen collect and constancy of the foragers to the flowers during foraging bouts. The floral constancy is due to the fact that, workers of honeybees is generally capable to memorize and recognize the shape, colour and odour of the flowers visited during previous foraging trips [44], [45]. The mean concentration in total sugars of *U. lobata* nectar were25.5% (n = 49; s = 2.63) in 2020 and 26.18% (n = 57; s = 2.77) in 2021. The difference between these means is not significant (t = 1.28; ddl= 104; P> 0.05). All these data make it possible to classify *U. lobata* in the category of highly nectariferous and slightly polliniferous bee plants. This Malvaceae could thus be grown to help stabilize *A. mellifera* colonies during the rainy season then to increase honey yield.

3.5 Impact of flowering insects on *Urena lobata* production

During nectar or pollen harvest on *U. lobata* flowers, foraging insects always shook flowers and regularly contacted anthers and stigma, increasing self-pollination and/or cross-pollination possibilities of this plant species. Table 2 gives the fruiting rate, the mean number of seeds per fruit and the percentage of normal seeds in the different treatments of *U. lobata*. It appears from this table that:

- in 2020, the fruiting rates were 100%, 86.70%, 96.07% and 87.75% in treatments 1 to 4, respectively; in 2021, the corresponding figures were 97.50%, 80%, 93.41% and 81.95%in treatment 1' to 4'. The differences between these eight percentages are globally highly significant (χ^2= 44.30; df= 7; $P < 0.001$). The difference between treatments 1 and 2 is highly significant (χ^2= 14.25; df= 1; $P < 0.001$) as well as that between treatments 1' and 2' (χ^2= 15.14; df= 1; $P < 0.001$). Consequently, for the two studied years, the fruiting rate of unprotected flower (treatments 1 or 1') was higher than that of flower bagged (treatments 2 or 2').
- the mean numbers of seeds per fruit were 4.83, 4.83, 4.80 and 4.81for treatments 1 to 4; the corresponding figures were4.93, 4.19, 4.75 and 4.34for treatments 1' to 4'. The differences between these eight means are globally non significant (F = 0.97; df_1= 7; df_2= 865; P > 0.05).
- in 2020, the percentages of normal seeds were 97.07%, 79.55%, 94.47% and 86.90% in treatments 1 to 4, respectively; in 2021, the corresponding figures were 95.05%, 79.92 %, 85.99% and 78.01% respectively. The differences between the eight percentages are globally highly significant (χ^2= 36.48; df= 7; $P < 0.001$). The difference was highly significant between treatments 1 and 2 (χ^2= 14.87; df= 1; $P < 0.001$) as well as between treatments 1' and 2' (χ^2= 10.45; df= 1; P >0.001). Hence, for the two studied years, the percentage of normal seeds from unprotected flowers was higher than that from flowers bagged during their flowering period.

In 2020, the numeric contribution of the anthophilous insects was 13.3% in the fruiting rate and 18.04% in the percentage of normal seeds. In 2021, the corresponding figures were 17.94% and 19.07% respectively.

Table 2: Fruiting rate, mean number of seeds per pod and percentage of normal seeds according to different treatments of *Urena lobata* in 2020 and 2021 at Dang

Years	Treatments	NFS	NFF	FR (%)	Seeds/fruit		TNS	NNS	%NS
					m	*s*			
2020	**1 (FUP)**	120	120	100	4.83	0.31	444	431	97.07
	2 (FBV)	120	104	86.7	4.74	0.30	401	319	79.55
	3 (FVAR)	153	147	96.07	4.80	0.38	706	667	94.47
	4 (FURV)	147	129	87.75	4.75	0.40	565	461	81.59
2021	**1' (FUP)**	120	117	97.50	4.93	0.29	485	461	95.05
	2' (FBV)	120	96	80	4.19	0.41	351	270	76.92
	3' (FVAR)	167	156	93.41	4.79	0.37	757	681	89.99
	4' (FURV)	133	109	81.95	4.68	0.38	523	451	78.01

FUP: Unprotected flowers; **FBV**: Flowers bagged to prevent insect visits; **FVAR:** Flowers bagged, uncovered, visited once by *Apis mellifera* and rebagged; FURV: Flowers protected then unbagged and rebagged without insect visit; **NFS**: number of flowers studies; **NFF**: number of fruits formed; **FR**: fruiting rate; **TNS**: total number of seeds; **NNS**: number of normal seeds; **% NS**: percentage of normal seeds; ***m*:** mean; **s**: standard deviation

3.6 Pollination efficiency of *Apis mellifera* on *Urena lobata*

During pollen and nectar harvest from *U. Lobata* flowers, workers of *A. mellifera* always came into contact with anthers and stigma, increasing the possibilities of *U. lobata* pollination. The percentage of the total number of visits during which foragers came into contact with the stigma of the visited flowers was 80.10% (n = 467) in 2020 and 89.42% (n = 389) in 2021.

The comparison of the fruiting rates (Table 2) showed that the difference was significant between treatment 3 and treatment 4 (χ^2 = 4.65; df= 1; P>0.01) as well as between treatments 3' and 4' (χ^2 = 6.08; df= 1; P >0.01);

The comparison of the mean number of seeds per fruit (Table 2) showed that the difference was not significant between treatments 3 and 4 (t = 1.75; df = 242; P >0.05) and between treatments 3' and 4' (t = 2.33df= 263; P>0.05);

The comparison of the percentages of normal seeds (Table 2) showed that the differences observed were highly significant between treatments 3 and 4 (χ^2= 7.87; df = 1; P <0.001*)* and significant between treatments 3' and 4' (χ^2= 5.31*;* df = 1; P <0, 01).

The contributions of *A. mellifera* in the fruiting rate and the normal seeds via a single flower visit for the two cumulated years were 10.46%and 13.47%, respectively. Consequently, *A. mellifera* is important for *U. lobata* production since its presence can ensure adequate pollination. *Apis mellifera* workers could enhance self-pollination by applying pollen of one flower onto its own stigma [46]. They could provide cross-pollination through carrying pollen with their hair, silk, legs, mouthparts, thorax and abdomen, which is subsequently deposit on to the stigma of other flowers belonging to different plants of the same species (geitogamy) [47].

4. Conclusion

At Dang, *U. lobata* is a plant species that highly benefits from pollination by insects, among which *A. mellifera* is the most important. The worker bees foraged on *U. lobata* flowers throughout its whole blooming period, and intensely harvested nectar and slightly collected pollen. The comparison of fruit and seed productions of flowers bagged and visited once by *A. mellifera* to those of flowers protected from insects then uncovered and rebagged without the visit of insects or any organism underlines the value of this bee in increasing fruit productions as well as seed quality. Based on these results, we recommend the installation of *A. mellifera* colonies at the vicinity of *U. lobata* populations to increase fruit productions. *Urena lobata* should to be grown or protected in the Adamawa Region of Cameroon to increase honey production and to strengthen *A. mellifera* colonies.

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