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Pollination efficiency of *Apis mellifera* Linnaeus 1758 (Hymenoptera, Apidae) on *Mimosa pudica* Linnaeus 1753 (Fabaceae) inflorescences at Yassa (Douala - Cameroon)

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Abstract
To evaluate impact of *Apis mellifera* workers, on pod and seed set of *Mimosa pudica,* its foraging and pollinating activities were studied in Douala, for two seasons (May-June 2014 and 2015). Two treatments, differentiated according to inflorescences were protected from insects activities or not. The pollination and behavior of foragers were studied. Individuals from 13 species of insects were recorded visiting *M. pudica* inflorescences. *Xylocopa torrida* was the most frequent followed by *Apis mellifera*. This honey bee intensely and exclusively foraged for pollen. Results show that *A. mellifera* foraging result the number of fruit per inflorescence by 10.04 % and 4.31 %, the number of seeds per fruit by 2.92 % and 4.57 % and the increase of the percentage of the normal seeds by 10.03 % and 4.30 % respectively in 2014 and 2015. Conservation of *A. mellifera* nests close to *M. pudica* plants could be recommended to improve pods and seeds production.

Keywords: *Apis mellifera*, *Mimosa pudica*, pollen, pollination

1. Introduction

Mimosa pudica is a plant originating tropical America and widely naturalized around the world [1]. The root extract of this plant is used against snake bites in India [2] and in wound healing processes [1]. Preliminary data on *M. pudica*- pollinating insects relations show that *Apis mellifera* harvests the pollen of this Fabaceae [3-6]. According to our knowledge, there are no in-depth data on the relationship between this plant species and the flowering insects. Before this study, literature is scant on the relationships between the honey bee and many plant species in Cameroon. Nevertheless, in this country, owing to increasing demand for hive products such as honey and pollen, beekeeping needs to be developed. Highest quantities of pollen marketed in Cameroon came from the Adamawa region which has a climate particularly favourable to the proliferation of bees; the Littoral region is hihgly concerned by the problem of low beekeeping production [7].

Bees in particular usually increase the fruit and seed yields of many plant species, through pollination of flowers during foraging [8-13, 6, 14].

The main objective of this research undertaken in Douala in 2014 and 2015 was to contribute to the knowledge of the relationships between honey bees and *M. pudica*. This knowledge is essential for an efficient management of these plants. For each plant species, specific objectives were: (1) the registration of the activity of *A. mellifera* on *M. pudica* inflorescences; (2) the evaluation of the apicole value of this plant; (3) the evaluation of the impact of flowering insects on pollination, on fruits and seeds yields of this Fabaceae, and (4) the estimation of the pollination efficiency of *A. mellifera* on *M. pudica*.

2. Materials and Methods

2.1 Study site and Biological Material

The experiment was carried out twice, from May to June 2014 and from May to June 2015 at Yassa, in the neighborhood of Douala in the Littoral Region of Cameroon. The climate of this region was classified by Suchel [15] as equatorial climate of Guinean type, coastal Cameroonian subtype, characterized by a short dry season (December to February) and a long rainy season (March to November). Rainfalls are abundant and regular while the air temperature is relatively high and stable with a monthly average of 28 °C [15].

The annual rain fall is about 4000 mm. The mean annual station temperature is 26.7°C, while the mean annual relative humidity is 100%. Plants chosen for observations were located at three km away in diameter, centered on experimental field. This hive is located at 4°00-469'N, 9°48-648'E and 15 m above sea level. The number of honeybee colonies located in this area varied from 1 in May 2014 to 2 in June 2015. The vegetation was represented by ornamental hedge and native plants of the equatorial forests.

2.2 Estimation of the frequency of *Apis mellifera* visiting inflorescences of *Mimosa pudica*

From 1st to 2nd June 2014, 60 quadrats of 1 m^2 of flowering *M. pudica* were made. Out of these plants, 290 inflorescences with flowers at the bud stage were labelled among which 120 were left unattended (treatment 1) and 120 bagged (treatment 2) to prevent visitors. On June 1st 2015, 290 inflorescences of *M. pudica* with flowers at the bud stage were labelled among which 50 were left for unlimited visits (treatment 3). The frequency of *A. mellifera* in the inflorescences of *M. pudica* was determined based on observations on inflorescences of treatment 1 and treatment 3, every day, from June 2nd to June 15th 2014 and from June 2nd to June 15th 2015, at 6 – 7h, 7 – 8h, 8 – 9h, 9 – 10h. In a transect walks along all labelled inflorescences treatment 1 and treatment 3, the identity of all insects visiting *M. pudica* was recorded. Specimens of all insect taxa were caught with insect net and conserved in 70% ethanol for subsequent taxonomy determination. All insects encountered on inflorescences were registered and the cumulated results expressed in number of visits to determine the relative frequency of *A. mellifera* in the anthophilous entomofauna of *M. pudica*.

In addition to the determination of the floral insects' frequency, direct observations of the foraging activity on flowers were made on insect pollinator fauna in the experimental field. The floral products (pollen) harvested by *A. mellifera* during each floral visit were recorded based on its foraging behavior. Pollen gatherers scratched the anthers with their mandibles or legs. In the morning of each sampling day, the number of opened flowers carried by each labelled inflorescence was counted. During the same days, as for the frequency of visits, the duration of individual flower visits was recorded (using a stopwatch) for the following time frames: 6 – 7h, 7 – 8h, 8 – 9h, 9 – 10h. Moreover, the number of pollinating visits during which the bee came into contact with the stigma, the abundance of foragers or the highest number of individuals foraging simultaneously on a flower or on 1000 flowers [16] and the foraging speed as the number of flower visited by a bee per min as described by [3] were measured. The disruption of the activity of foragers by competitors or predators and the attractiveness exerted by other plant species on *A. mellifera* were also assessed.

During each daily investigations period, a mobile thermo-hygrometer was used to register the temperature and the relative humidity in the experimental site.

2.3 Evaluation of the effect of *A. mellifera* and other insects on *Mimosa pudica* yields

This evaluation was based on the impact of flowering insects on pollination, the impact of pollination on fructification of *M. pudica*, and the comparison of yields (mean number of fruit per inflorescence, mean number of seed per fruit and percentage of normal seeds) of treatment X (unlimited Inflorescences) and treatment Y (bagged inflorescences). The mean number of fruit per inflorescence due to the influence of foraging insects (F_{ri}) was calculated by the formula: $F_{ri} = \{[(Fr_X - Fr_Y) / Fr_X] * 100\}$ where Fr_X and Fr_Y were the mean number of fruit per inflorescence in treatment X and treatment Y. The mean number of seeds per fruit and the percentage of normal seeds per fruit were then calculated for each treatment. The impact of flowering insects on seed yields was evaluated using the same method as mentioned above for mean number of fruit per inflorescence [16].

2.4 Assessment of the pollination efficiency of *Apis mellifera* on *Mimosa pudica*

Parallel to the constitution of treatments 1 and 2, 50 inflorescences were isolated (treatment 5) as those of treatment 2. Parallel to the constitution of treatments 3 and 4, 50 inflorescences were isolated (treatment 6) as those of treatment 4. Between 7 am and 13 pm of each observation date, the gauze bag was delicately removed from each inflorescence carrying new opened flowers, the inflorescence were observed for up to 20 minutes and then protected again.

The contribution (Fr_a) of *A. mellifera* in the fructification was calculated by the formula: $Fr_a = \{[(Fr_Z - Fr_Y) / Fr_Z] * 100\}$, where Fr_Z and Fr_Y are the mean number of fruit per inflorescence in treatment Z (bagged inflorescences and flowers visited exclusively by *A. mellifera*) and treatment Y (bagged inflorescences). At maturity, fruits were harvested from treatment 5 and treatment 6 and the number of fruit per inflorescence counted. The mean number of seeds per fruit and the percentage of normal seeds were then calculated for each treatment. The impact of *A. mellifera* on seed yields was also evaluated using the same method as mentioned above for number of fruit per inflorescence [16].

2.5 Data analysis

Data were analyzed using descriptive statistics, student's t-test for the comparison of means between two samples, correlation coefficient (r) for the study of the association between two variables, chi-square ($\chi 2$) for the comparison of percentages using SPSS statistical software and Microsoft Excel programs.

3. Results

3.1 Frequency of *Apis mellifera* in the floral entomofauna of *Mimosa pudica*

In table 1, showing the 212 and 189 visits of 11 and 12 insect species recorded on runner bean flower, respectively in 2014 and 2015, *A. mellifera* was the second most represented insect with 53 visits (25.00%) and 54 visits (28.57%), respectively in 2014 and 2015. The difference between these two percentages is not significant ($\chi^2 = 0.65$; $df = 1$; $P > 0.05$). (**Table 1**) *A. mellifera* was active on *M. pudica* inflorescences from 7 am and 13 pm, with a peak of visits between 10 am and 11 am in 2014 as well as in 2015 (**Table 2**).

3.2 Activity of *Apis mellifera* on *Mimosa pudica* inflorescences

3.2.1 Floral products harvested

From our field observations, *A. mellifera* workers were found to collect pollen on *M. pudica* flowers. Pollen collection was intensive and regular. From 212 visits recorded in 2014, 212 (100.00%) were devoted to exclusive pollen harvest; whereas in 2015, from 189 visits recorded, 189 (100.00%) were devoted to exclusive pollen harvest (Figure 1). Pollen was harvested all scheduled time frame long.

3.2.2 Rhythm of visits according to the flowering stages
Visit was most numerous on the experiment plot when the number of inflorescences carrying opened flowers was highest (Figure 2 A and B). Furthermore, a positive and very highly significant correlation was found between the number of *M. pudica* opened flowers and the number of *A. mellifera* visits in 2014 ($r = 0.90$; $df = 10$; $P < 0.001$) as well as in 2015 ($r = 0.92$; $df = 9$; $P < 0.001$).

3.2.3 Daily rhythm of visits
A. mellifera foraged on *M. pudica* inflorescences throughout the whole daily blooming period, with a peak of activity situated between 10 and 11 am (table 2). Climatic conditions influenced the activity of *A. mellifera* in the field of *M. pudica* (table 2). In 2014, the correlation was positive and not significant ($r = 0.52$; $df = 3$; $P < 0.05$) between the number of *A. mellifera* visits on *M. pudica* inflorescences and the temperature, while it was negative and not significant ($r = -0.49$; $df = 3$; $P < 0.05$) between the number of visits and relative humidity. In 2015, the correlation was negative and not significant ($r = -0.39$; $df = 3$; $P < 0.05$) between the number of *A. mellifera* visits on *M. pudica* flowers and the temperature, while it was positive and highly significant ($r = 0.99$; $df = 3$; P < 0.05) between the number of visits and relative humidity (Figure 3 C and D).

3.2.4 Abundance of *Apis mellifera*
In 2014, the highest mean number of *A. mellifera* simultaneous in activity was 1 per inflorescence ($n = 212$; $sd = 0$) and 33.76 per 1000 flowers ($n = 59$; $sd = 18.91$; maxi = 100). In 2011, the corresponding numbers were 1 (n = 189; s = 0) and 33.24 ($n = 51$; $sd = 22.02$; maxi = 117.65). The difference between the mean number of foragers per 1000 flowers in 2014 and 2015 is not significant ($t = 0.69$; $P > 0.05$).

3.2.5 Duration of visits per inflorescence
In 2014, the mean duration of a visit was 2.99 seconds (n = 275; sd = 2.75), with a maximum of 39 sec for pollen collection. In 2015, the corresponding numbers were 3.05 sec ($n = 213$; $sd = 3.08$) with a maximum of 40 sec for pollen harvest. The difference between the duration of the visit to harvest pollen in 2014 and 2015 is highly significant ($t = 2.47$; $P > 0.05$).

3.2.6 Foraging speed of *Apis mellifera* on *Mimosa pudica* inflorescences
On the experimental plot of *M. pudica*, *A. mellifera* visited between 2 and 15 inflorescences/min in 2014 and between 2 and 12 inflorescences/min in 2015. The mean foraging speed was 22.66 inflorescences/min ($n = 79$; $sd = 6.46$) in 2014 and 24.54 inflorescences /min ($n = 61$; $sd = 7.5$) in 2015. The difference between these two means is highly significant ($t = 9.04$; $P < 0.001$).

3.2.7 Influence of neighboring flora
During the observation period, flowers of many others plant species growing near *M. pudica* were visited by *A. mellifera*, for nectar (ne) and/or pollen (po). Amongst these plants were *Bidens pilosa* (Asteraceae, ne and po), *Brachiaria brizantha* (Poaceae, po), *Senna mimosoides* (Fabaceae, ne and po), *Zea mays* (Poaceae, po), *Psidium guajava* (Myrtaceae, po), *Manihot esculenta* (Euphorbiaceae, ne and po), *Mangifera indica* (Anacardiaceae, ne), *Elaeis guineensis* (Arecaceae, ne and po), *Oxalis barrelieri* (Oxalidaceae, ne et po), *Mimosa invisa* (Fabaceae, po), *Arachis hypogaea* (Fabaceae, po) and *Glycine max* (Fabaceae, ne).
During one foraging trip, an individual bee foraging on *M. pudica* was not observed moving from *M. pudica* to the neighboring plant and vice versa. During *M. pudica* flowering periods, a well elaborated activity of *A. mellifera* as well as other bee species was registered on its inflorescences. In particular, there was a high density of bee workers on that plant, very good pollen harvest and workers faithfulness to its inflorescences. These data point out the very good attractiveness of *M. pudica* floral products to *A. mellifera*. It appears from those data that our studied plant species could be classified in one category of apicole plants: highly polleniferous plant species.

3.3 Impact of *Apis mellifera* and others anthophilous insects' activity on pollination and on the fruit and seed yields of *Mimosa pudica*
During pollen harvest on *M. pudica*, foraging insect always check inflorescences and regularly contacted anthers and stigma. The flowering insect increased the pollination possibility of *M. pudica*. The comparison of the number of fruit per inflorescence (Table 3) shown that the differences observed are very highly significant between treatments 1 and 2 ($t = 1121.71$; $df = 3872$; $P < 0{,}001$) and treatments 3 and 4 ($t = 912.98$; $df = 3704$; $P < 0{,}001$). The difference between the treatments 1 and 3 was highly significant ($t = 223.06$; $df = 5075$; $P < 0.001$).
Consequently, in 2014, the number of fruit per inflorescence of unprotected inflorescences (treatment 1) was higher than that for protected inflorescences (treatment 2); whereas in 2015, the number of fruit per inflorescence of the unprotected inflorescences (treatment 3) was higher than that of protected inflorescences (treatment 4).
The percentage of number of fruit per inflorescence was 22.24 % for treatment 1 and 10.31 % for treatment 2 in 2014; the difference between these two treatments is very highly significant ($t = 1121.71$; $df = 3872$; $P < 0{,}001$); b) the percentage of number of seeds per fruit was 3.14 % for treatment 1 and 2.99 % for treatment 2 in 2014; the difference between these two treatments is very highly significant ($t = 779.98$; $df = 11975$; $P < 0.001$); c) the percentage of normal seeds was 96.41 % for treatment 1 and 85.17% for treatment 2 in 2014; the difference between these two treatments is very highly significant ($\chi 2 = 492.27$; $df = 1$; $P < 0.001$).
The percentage of number of fruit per inflorescence was 20.42 % for treatment 3 and 10.72 % for treatment 4 in 2015; the difference between these two treatments is very highly significant ($t = 912.98$; $df = 3704$; $P < 0{,}001$); b) the percentage of number of seeds per fruit was 3.13 % for treatment 3 and 2.92 % for treatment 4 in 2015; the difference between these two treatments is very highly significant ($t = 328.05$; $df = 6050$; $P < 0.001$); c) the percentage of normal seeds was 97.25 % for treatment 3 and 91.31% for treatment 4 in 2015; the difference between these two treatments is very highly significant ($\chi 2 = 199.59$; $df = 1$; $P < 0.001$).

3.4 Pollination efficiency of *Apis mellifera* on *Mimosa pudica*
On all visited flowers, *A. mellifera* contacted anthers and carried pollen. With this pollen, worker bees flew frequently from inflorescences to inflorescences. *A. mellifera* came into contact with visited inflorescences during 100% of visits.

Thus this bee highly increased the pollination possibilities of *M. pudica* inflorescences.

The comparison of the number of fruits per inflorescence (Table 3) showed that the differences observed were highly significant between the treatments 2 and 5 ($\chi^2 = 22.36$; $df = 1$; $P < 0.001$) and treatments 4 and 6 ($\chi^2 = 246.51$; $df = 1$; $P < 0.001$). The difference between the treatments 5 and 6 was significant ($\chi^2 = 7.35$; $df = 1$; $P < 0.05$).

Therefore, in 2014, the number of fruits per inflorescence of inflorescences protected and visited exclusively by *A. mellifera* (treatment 5) was higher than that of flowers protected during their opening period (treatment 2); similarly, in 2015, the number of fruits per inflorescence of inflorescences protected and visited exclusively by *A. mellifera* (treatment 6) was higher than that of inflorescences protected during their opening period (treatment 4).

The comparison of the percentages of normal seeds (Table 1) has shown that the differences were highly significant between treatments 2 and 5 ($\chi^2 = 83.49$; $df = 1$; $P < 0.001$) and treatments 4 and 6 ($\chi^2 = 47.50$; $df = 1$; $P < 0.001$). The difference between treatments 5 and 6 was not significant ($\chi^2 = 159.49$; $df = 1$; $P < 0.001$).

Consequently, in 2014, the percentage of normal seeds of inflorescences protected and visited exclusively by *A. mellifera* (treatment 5) was higher than that inflorescences protected during their opening period (treatment 2); in 2015, the percentage of normal seeds of inflorescences protected and visited exclusively by *A. mellifera* (treatment 6) was higher than that of inflorescences protected during their opening period (treatment 4).

The percentage of the number of fruits per inflorescence due to *A mellifera* activity was 30.92% in 2014 and 29.15% in 2015. For all the inflorescences studied, the percentage of the number of fruits per inflorescence attributed to the influence of *A. mellifera* was 30.04 %.

The percentage of the normal seeds due to *A. mellifera* was 6.82 % in 2014 and 5.60% in 2015. For all the inflorescences studied, the percentage of the number of seeds per pod attributable to influence of *A. mellifera* was 6.21%.

In short, the influence of *A. mellifera* on fruit and seeds yields was positive and higher significant.

Table 1: Diversity of insects visiting *Mimosa pudica* inflorescences in 2014 and 2015, number and percentage of insects visits.

Insects			2014		2015	
Ordre	**Family**	**Genus and Species**	n_1	p_1 (%)	n_2	p_2 (%)
Diptera	Muscidae	*Musca domestica*	2	0.94	1	0.53
	Syrphidae	(sp.1)	10	4.72	5	2.65
		(sp.2)	-	-	6	3.17
Hymenoptera	Apidae	*Apis mellifera*	53	25	54	28.57
		Xylocopa sp.	16	7.55	15	7.94
		Xylocopa olivacea	9	4.25	17	8.99
		Xylocopa torrida	79	37.26	63	33.33
	Halictidae	*Halictus* sp.	-	-	4	2.12
		Lasioglossum sp.	21	9.91	13	6.88
		Leuconomia granulata	8	3.77	6	2.83
	Megachilidae	*Chalicodoma* sp.	6	2.83	2	1.06
		Megachile sp. 1	5	2.36	3	1.58
		Megachile sp. 2	3	1.42	-	-
Total			212	100	189	100
Number of species			11 species		12 species	

n1: number of visits on 120 inflorescences in 11 days, n2: number of visits on 120 inflorescences in 10 days, p1 and p2: percentages of visits, $p1 = (n1 / 212) * 100$, $p2 = (n2 / 189) * 100$; comparison of percentages of *A. mellifera* visits for two years: $\chi 2 = 0.65$; $df = 1$; $P > 0.05$; NS.

Fig 1: *Apis mellifera* collecting pollen on *Mimosa pudica* inflorescences at Yassa.

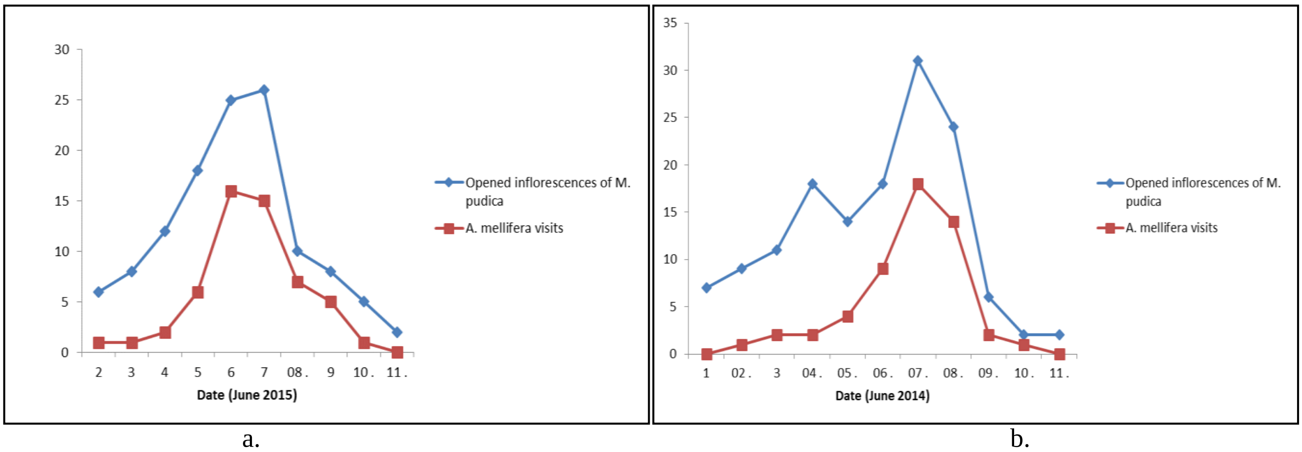

Fig 2: Seasonal distribution of the number of *Mimosa pudica* opened inflorescences and the number of *Apis mellifera* visits in June 2014 (A) and June 2015 (B) at Yassa.

Table 2: Frequence visits of *Apis mellifera* on *Mimosa pudica* inflorescences according to daily observation periods at Yassa in 2014 and 2015.

Years	Daily periods (hours)								
	6 - 7		8 - 9		10 - 11		12 - 13		Total number of visits (A)
	n	*P* (%)	n	*P* (%)	n	*P* (%)	n	*P* (%)	
2014	2	3.77	11	20.75	30pk	56.61	10	18.87	53
2015	1	1.85	12	22.22	33pk	61.11	8	14.82	54
Total	3	2.81	23	21.48	63pk	58.86	18	15.85	107

P: Percentage of visits (n/A)*100; pk : peak of activities.

Table 3: *Mimosa pudica* yields in different Treatments.

Years	Treatments	Nf/i		Ns/f		Nsfr	Nns	Pns
		m	*Sd*	*m*	*sd*			
2014	1(Fi)	22,24	10.21	3.14	0.46	8309	8011	96.41
	2(Pi)	10,31	05.10	2.99	0.55	3668	3124	85,17
2015	3(Fi)	20,42	10.47	3.13	0.47	7724	7512	97.25
	4(Pi)	10,72	04.54	2.92	0.68	3725	3401	91.31
2014	5(Iv *A. mellifera*)	23,50	9.81	3.08	0.41	3041	2879	94.67
2015	6(Iv *A. mellifera*)	20,56	06.42	3.06	0.42	3342	3189	95.42

Fi : free inflorescences, **Pi** : protected inflorescences, **Iva**: inflorescences visited exclusively by *A. mellifera*, **Nf/i** : number of fruits per inflorescence, **Ns/f** : number of seeds per fruit, **Nsfr** : number of seeds formed, **Nns** : number of normal seeds, **Pns** : percentage of normal seeds.

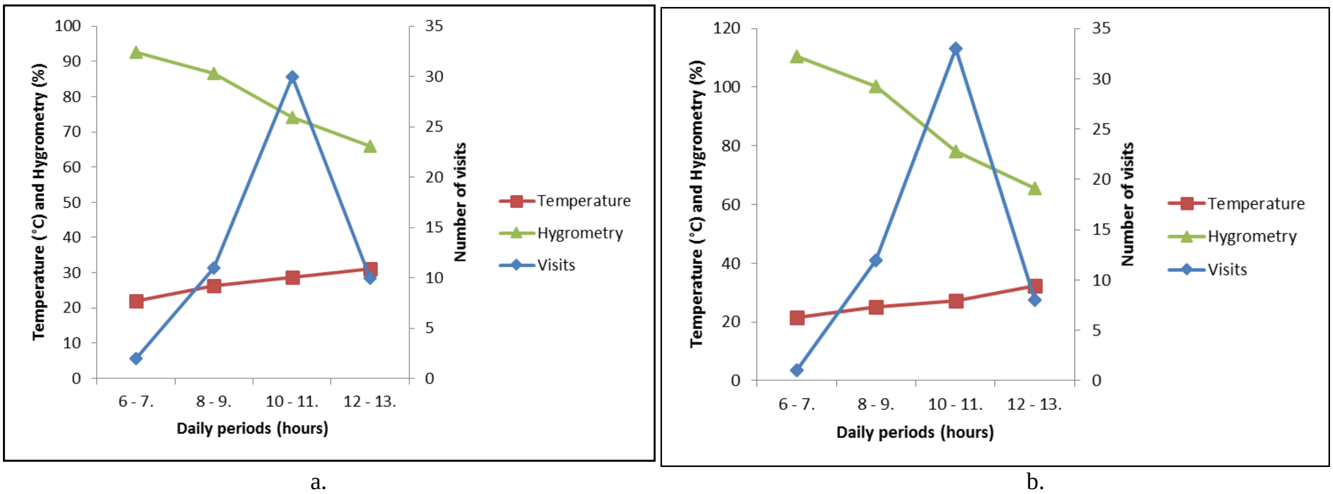

Fig 3: Daily distribution of *Apis mellifera* visits on 120 *Mimosa pudica* inflorescences over 11 days in 2014 (C) and 10 days in 2015 (D), mean temperature and mean humidity of the study site.

4. Discussion

4.1 Activity of *Apis mellifera* on *Mimosa pudica* inflorescence

Results obtained from these studies indicated that bee *A. mellifera* was the main floral insect frequent on *M. pudica*. during the observation periods. The significant difference between the visit frequencies of *A. mellifera* and those of other insects can be explained by the strategies adopted by this bee that consist of the recruiting of a great number of workers for the exploitation of an interesting nutritional source [17-21]. 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.

The significant difference between the percentages of *A. mellifera* visit for the two years of study could be explained by the presence of the nest of this insect near the experimental plot in 2015.

An activity peak of *A. mellifera* has been observed on *M. pudica* inflorescences in the morning. This peak could be linked of the period to highest availability of the pollen on *M. pudica* flowers

The high abundance of *A. mellifera* foragers on 1000 flowers and the positive and significant correlation between the number of *M. pudica* inflorescencess bloom and number of *A. mellifera* visits, underscore the attractiveness of *M. pudica* pollen with respect to this bee. The attractiveness for *M. pudica* pollen could be partially explained by its high production compared to a range of 15 - 75 % in which fail most of the plant species [22].

The significant difference observed between the duration of pollen harvest visits could be explained by the accessibility of each of these floral products. Pollen is produced by the anthers, which are situated on the top of the stamen and are thus easily accessible to *A. mellifera* [23].

The fact that an individual bee exploiting *M. pudica* plot was not observed visiting another plant species indicates that *A. mellifera* shows flowers constancy for the flowers of this plant species.

4.2 Impact of *Apis mellifera* activity on the pollination and yields of *Mimosa pudica*

During the collection of pollen on each inflorescence, *A. mellifera* workers regularly come into contact with the stigma. They could thus provoke auto-pollination by applying pollen of one flower on its own stigma.

The same results were found in southwestern Brazil on *Couepia uiti* flowers [4], in Dang-Ngaoundéré *Anona senegalensis*, *Croton macrostachyus*, *Psorospermum febrifugum* and *Syzygium guineense* var. guineense flowers [24], *Phaseolus vulgaris* [12], *Callistemon rigidus* [25], in South Africa on *Cyrtanthus breviflorus* flowers [26]; in Ngaoundéré on *Ximenia americana* flowers [27], in Yaoundé on *Phaseolus coccineus* flowers [28] and in Maroua [13].

Apis mellifera foragers were also able to carry pollen with their furs, legs and mouth accessories. They could consequently carry the pollen from a flower of one plant to stigma of another flower of the same plant (geitonogamie) or to that of another plant (xénogamie). This last form of pollination is as probable as allogamy exist in *M. pudica* [29-31].

The intervention of *A. mellifera* in the pollination of *M. pudica* is seemingly more real than its density per 1000 flowers and its foraging visits are high. Moreover, its daily period of intense activity which is situated in the morning hours coincides with the optimal receptive period of the stigma of *M. pudica* [29].

The positive and significant contribution of *A. mellifera* in the fruit and seeds yields of *M. pudica* is justified by the action of this worker bee on pollination. Our results agreed with those obtained in Great Britain [30] and United State of America [32] which showed that *Phaseolus coccineus* flowers produce less seeds per pod in the absence of insect pollinators.

The numeric contribution of *A. mellifera* to the yields of *M. pudica* through its pollination efficiency was significantly higher than that of all insects on the exposed inflorescences except for *Xylocopa torrida*. This shows on one hand that *A. mellifera* is one of the principal insect pollinators of *M. pudica* and on the other hand that many insect that visit *M. pudica* inflorescences benefits from this Fabaceae, but did not have any influence on pollination and yields of the plant species. This result confirmed other findings reported by [4, 28, 25, 12, 13, 33, 6] with *A. mellifera* bee specie. The weight of *A. mellifera* played a positive role: when collecting pollen, *A. mellifera* shacked flowers; this movement could facilitate the liberation of pollen by anthers, for the optimal occupation of the stigma.

5. Conclusion

From our observations, *M. pudica* is a highly polliniferous bee plant that benefits from pollination by the insect, among which *Apis mellifera* is one of the most important. The comparison of fruits and seeds set of unprotected inflorescences with that of inflorescences visited exclusively by *A. mellifera* underscores the value of this bee in increasing fruit and seed yields as well as seed quality. The study thus shows investment management of *A. mellifera* interms of nest provision at proximity of *M. pudica* field is worthy while for growers.

6. Acknowledgements

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7. References

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