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Impact of *Amegilla calens* and *Apis mellifera* Pollination on *Gossypium hirsutum* var. QR_1302 Flowers at Tchabbal-Mounguel (Ngaoundéré, Cameroon)

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Abstract

The investigations were carried out from September 10 through October 13, 2017 at Tchabbal-Mounguel. On *Gossypium hirsutum* flowers, investigations were done on many aspects of the pollination services of *Amegilla calens* and *Apis mellifera*. *G. hirsutum* flowers were observed to study the activity of *A. calens* and *A. mellifera* and to evaluate their impacts on fruits and seed yields of this Malvaceae. The treatments consisted of 120 flowers left for free pollination, 120 flowers protected from insects using gauze bag nets, 200 protected flowers and visited exclusively by *A. calens* and *A. mellifera* and 100 protected flowers then opened and closed without any visit of insects or any other organisms. The results show that on cotton flowers, foragers of *A. calens* and *A. mellifera* highly collect nectar and pollen on its flowers. The highest mean number of individuals simultaneously active per 1000 flowers is 587 for *A. calens* and 526 for *A. mellifera*. Through their pollinating efficiency, *A. calens* and *A. mellifera* caused a significant increase in the fruiting rate by 7.00% and 17.33%, the number of seeds per fruit by 44.20% and 18.32% and the normal seeds by 47.78% and 5.66% respectively. Therefore, the conservation of the nests of *A. calens* and colonies of *A. mellifera* around *G. hirsutum* plantations are to be recommended to improve the fruit and seed yields of this Malvaceae.

Keywords

Bees, Pollination Efficiency, Cotton Plant, Yield

1. Introduction

Gossypium hirsutum L., commonly known as cotton, is an economically important plant species, mostly known for being the leading source of natural fiber. Over 90% of the worldwide cotton production comes from cultivars of *G. hirsutum* [1]. It is one of the major cash crops cultivated in three Northern Regions of Cameroon [2]. Cotton is a plant species with wild, feral, and semi-domesticated populations [3]. Its flowers are white at the beginning of the day and hermaphrodite. They stay open between 8 and 11 hours [4] [5]. Anthesis occurs in the morning, soon after the flowers are completely open, and the stamens begin to release pollen afterward [4]. The mating system of cotton has been the major topic of several studies; however, the majority of them have described it as predominantly autogamous and self-pollinated [1]. Flowers of *G. hirsutum* produce pollen and nectar that attract pollinators.

The role of insects as pollinators of cotton was first reported by [6]. However, it is known worldwide that honeybees are important in affecting qualitative and quantitative improvement of crop yields [7] [8] [9] [10]. Thus, insect pollination can play an important role in maintaining sustainable and profitable agriculture with minimized disruptions to the environment [11]. Furthermore, increases in cotton production, seed production, and fiber quality have been linked with visits by *Apis mellifera* and wild bees [12] [13].

Therefore, despite the rich bee fauna associated with cotton flowers in different regions of the world [12] [13] [14] [15] [16], few studies have been conducted to evaluate the role of bees in cotton pollination in Cameroon [2] [17] [18], and farmers are generally unaware of the potential benefits of bee pollination for crop production. Given the economic importance of cotton, and despite the important role of bees in the production of cotton [17] [18], bee pollination is still largely ignored by farmers and is absent in agricultural programmes of the Government.

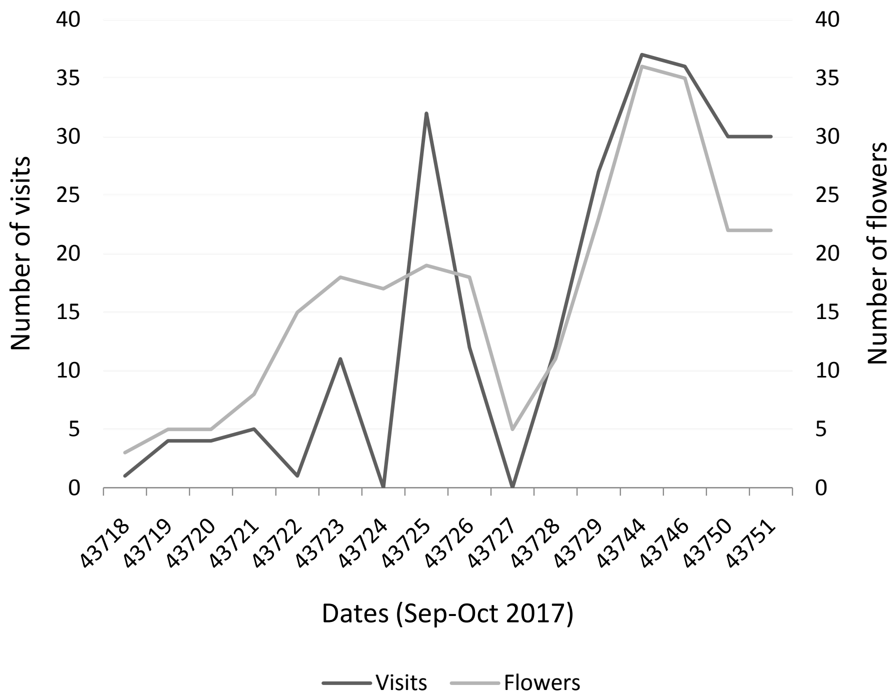
The present research was conducted to investigate the role of bees in general and *Amegilla calens* and *A. mellifera* in particular in the pollination of *G. hirsutum* and thus to enhance the yield of this crop. Moreover, this work is a contribution to the understanding of the relationship between *A. calens, A. mellifera* and *G. hirsutum* for their sustainable management in Cameroon. Specifically, it consists to 1) determine the place of *A. calens* and *A. mellifera* among the flowering insects *G. hirsutum*; 2) study the activity of these bees on the flowers of the Malvaceae; 3) determine the impact of these two Apidae on pollination and fruit and seed yields of this plant and 4) estimate their pollination efficiency on this plant species.

2. Material and Methods

2.1. Study Site, Experimental Field, and Biological Material

Investigations were conducted at Tchabbal-Mounguel (latitude: 7˚33'23.4''N, longitude: 13˚33'19.7"E, altitude: 1376 m asl), Ngaoundéré III Subdivision, Vina Division, Adamaoua Region in Cameroon.

In an experimental plot of 437 m² made of 8 subplots (8 m long over 4.3 m large), seeds of *G. hirsutum* var. QR1302 (**Figure 1**) were seeded. Except for *A. mellifera*, the majority of insects observed on *G. hirsutum* flowers were naturally present in the experimental field environment.



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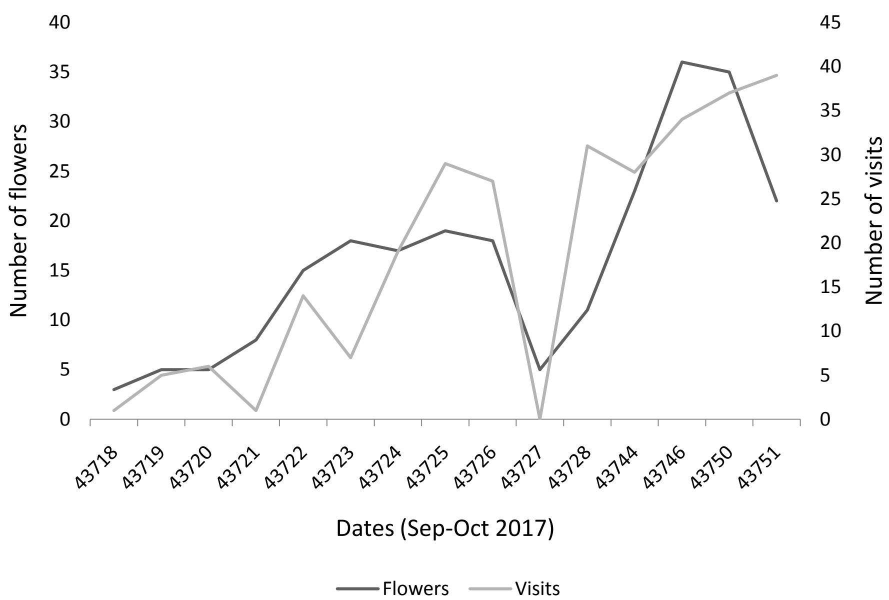


(B)

Figure 1. Variation in the number of visits of *Amegilla calens* (A) and *Apis mellifera* (B) and the number of open flowers of *Gossypium hirsutum* according to daily observations.

2.2. Methods

2.2.1. Experimental Field, Seeding, and Maintenance of the Crop

On May 24, 2017, soil was stirred, and 8 subplots were made with six lines each. Each line was made of 15 holes. The spacing was 70 cm between lines and 50 cm between two successive holes of the same line. Five seeds were seeded per hole in each subplot of the experimental plot. Two weeks after germination, the weak plants were removed and two most vigorous ones were left per hole. From germination (occurred on May 29th) to the blooming of the first flower (September 10th), the field was regularly weeded and after the appearance of the first flowers, weeding was carefully performed by hand.

2.2.2. Experimental Treatments on Cotton Plants' Flowers

For the field work, 540 flowers were labeled and four treatments were set up.

Treatment 1 made of 120 flowers labeled at bud stage and left opened for free pollination at blooming.

Treatment 2 made of 120 labeled flowers at buds stage and protected from insects using gauze bag nets.

Treatment 3 made of 200 flowers labeled at bud stage and protected from insects' visits as those of treatment 2, then opened for a single visit of *A. calens* or *A. mellifera*.

Treatment 4 made of 100 flowers labeled at bud stage and protected from insect visits, then opened and closed without any visit of flowering insect or any other organism.

2.2.3. Place of *Amegilla calens* and *Apis mellifera* within the Flowering Insects of *Gossypium hirsutum*

On flowers of treatment 1, observations were done every day, during the plant's flowering period, from September 10th to October 13th, 2017, according to six-time periods (7 - 8 h, 9 - 10 h, 11 - 12 h, 13 - 14 h, 15 - 16 h and 17 - 18 h). We pass once on each flower during each time slot. At each passage, the different insects encountered on the bloomed flowers were caught and kept in 70% ethanol (for further identification in the laboratory) and counted and the results expressed by the number of visits. For this treatment, we considered all flowering insects not only the two species of bees studied. Data obtained made it possible to determine the frequency of visit for each insect species (F_i), using the following formula: $F_i = (V_i / V_I) * 100$, with V_i = number of visits of the insect I on the flowers of the treatment 1 and V_I the number of visits of flowering insects on the same flowers.

2.2.4. Study of the Activity of *Amegilla calens* and *Apis mellifera* on Flowers of *Gossypium hirsutum*

From September 10th to October 13th, 2017, daily observations were done on its flowers. Floral resources (nectar and pollen) harvested by flowering insects have been therefore recorded. Products collected were systematically recorded during the registration of the duration of visits per flower, and a distinctive sign was then done on the corresponding visit.

Abundance per flower was recorded following direct counts. For the abundance per 1000 flowers (A_{1000}), the number of foragers was counted on a known number of bloomed flowers. The abundance per 1000 flowers is calculated using the following formula: $A_{1000} = \left[\left(A_x / F_x\right) \times 1000\right]$, where F_x and A_x are respectively the numbers of open flowers and the number of foragers counted on corresponding flowers at the moment x [19]. This parameter was recorded during the same dates as for the frequency of visits for six periods: (6 - 7 h, 8 - 9 h, 10 - 11 h, 12 - 13 h, 14 - 15 h, and 16 - 17 h).

The duration of visits per flower is the time spent by foragers to collect a floral product from a flower [20] [21] [22]. This parameter was recorded during the same dates and time slots as for the abundance of foragers. At least five values per time slot were taken, when the activity of these two bees allowed it.

The foraging speed is the number of flowers visited by an individual insect in one minute [20]. During this observation, when *A. calens* returns to a flower already visited, the count is done as a new flower visited [20] [21] [22].

The influence of neighboring flora was evaluated by direct observations in the field. We noted (for each foraging trip) the number of times *A. calens* or *A. mellifera* flew from a flower of *G. hirsutum* to the flowers of other neighboring plant species and vice-versa. During our fieldwork, temperature and hygrometry of the study station were recorded throughout the observation period every 30 minutes, from 6 am to 6 pm, using a hand thermo-hygrometer (Techno Line WS 9119).

2.2.5. Evaluation of the Relationship between the Flowering Rhythm of *Gossypium hirsutum* and the Rhythm of *Amegilla calens* and *Apis mellifera*

Bloomed flowers of treatment 1 were counted from the beginning of the flowering of the first flower to the wilting of the last flower. Data obtained were compared with the number of visits of *A. calens* and *A. mellifera* on the corresponding flowers.

2.2.6. Assessment of the Impact of Flowering Insects Including *Amegilla calens* and *Apis mellifera* on *Gossypium hirsutum* Yields

Parallel to the installation of treatment 1, treatment 2 was set up. The fruiting rate due to the influence of flowering insects (P_i) was evaluated using the following formula: $P_i = \left\{\left[\left(F_1 - F_2\right)/F_1\right] * 100\right\}$ where F_1 and F_2 are the fruiting rate in treatments 1 (free flowers) and 2 (protected flowers) respectively. For a treatment x, the fruiting rate (F_x) is: F_x = [(number of fruits formed/number of labeled flowers)] × 100] [19].

The percentage of seed per fruit due to the influence of flowering insects (P_g) was calculated using the following formula: $P_g = \left\{\left[\left(g_1 - g_2\right)/g_1\right] * 100\right\}$ where g_1 and g_2 are the mean seed counts per fruit in treatments 1 and 2, respectively [19].

The percentage of normal seeds attributable to the influence of flowering insects (P_n) was calculated using the following formula: $P_n = \left\{\left[\left(P_{n1} - P_{n2}\right)/P_{n1}\right] * 100\right\}$ where P_{n1} and P_{n2} are the percentages of normal seeds from treatments 1 and 2 respectively [19].

2.2.7. Estimation of the Pollination Efficiency of *Amegilla calens* and *Apis mellifera* on *Gossypium hirsutum*

Parallel to the implementation of treatments 1 and 2, 300 flowers at buds stage were labeled and two treatments were made: Treatments 3 and 4.

The flowers of treatment 3 visited exclusively by *A. calens* correspond to treatment 3a and those exclusively visited by *A. mellifera* belong to treatment 3b.

As soon as a flower of treatment 3 had bloomed, the gauze bag net was gently removed during the daily period of optimum activity and the flower left opened for free pollination and was observed for one to ten minutes, to note the possible visit of *A. calens* or *A. mellifera*. As soon as one of these bees visit the flower, it was directly rebagged with the same gauze bag net and was no longer handled. Flowers of treatment 3 that have not been visited by one of the Apidae during the corresponding time of observation, have been incorporated into treatment 4.

For treatment 4, as soon as each flower has blossomed, the gauze bag net was carefully removed and was observed for one to ten minutes, avoiding any visit of insects or other organisms. After this manipulation, the flower was protected again and was no longer handled.

At the maturity, fruits set of treatments 3 and 4 were harvested and the percentage of fruiting rate was calculated. The number of seeds per fruit was counted and the percentage of normal seeds calculated for each treatment. The fruiting rate, the percentage of normal seeds and the percentage of normal seeds due to *A. calens* and *A. mellifera* were respectively calculated in the same way as those of the flowering insects.

2.3. Data Analysis

Data were analyzed using descriptive statistics (means, standard deviations, and percentages) and four tests: 1) Student's t-test for comparing the mean of two samples; 2) chi-square (χ^2) for the comparison of percentages; 3) Pearson (r) correlation coefficient for the study of linear relationships between two variables; 4) ANOVA (F) for the comparison of means of more than two samples. We also used the Excel 2010 software.

3. Results

3.1. Place of *Amegilla calens* and *Apis mellifera* within the Flowering Insects of *Gossypium hirsutum*

From a total of 490 recorded visits of six bee species counted on flowers of treatment 1, *A. mellifera* ranked first with 33.88% of visits followed by *Ceratina* sp. (24.69%) and two species of *A. calens* each having 15.31% (**Table 1**).

3.2. The Rhythm of Visits According to the Daily Observation Time Frame

Table 2 shows the visitation rate of *A. calens* and *A. mellifera* according to the

Table 1. Flowering insects counted on *Gossypium hirsutum* flowers, in Tchabbal-Mounguel in 2017, its number and percentage of visits.

Order	Family	Genus Species,	*n*	*P* (%)
Hymenoptera	Apidae	*Amegilla* sp. (Po)	75	15.31
		Amegilla calens (Ne, Po)	75	15.31
		Apis mellifera (Ne, Po)	166	33.88
		Ceratina sp. (Ne, Po)	121	24.69
	Halictidae	*Lasioglusum* sp. (Ne, Po)	47	9.59
		Lipotriches sp. (Ne, Po)	6	1.22
Total		**6 species**	**490**	**100**

n: number of visits on 120 flowers of treatment 1 in 15 days of observation; *p*: percentage visits = (*n*/201) × 100; sp.: non identified species; Ne: nectar; Po: pollen.

Table 2. Distribution of *Amegilla calens* and *Apis mellifera* visits on *Gossypium hirsutum* flowers according to the daily time slots.

Insects	Daily time frames (hour)												Total number of visits (A)
	6 - 7		8 - 9		10 - 11		12 - 13		14 - 15		16 - 17		
	n	*p* (%)	*n*	*p* (%)	*n*	*p* (%)	*n*	*p* (%)	*n*	*p* (%)	*n*	*p* (%)	
Amegilla calens	2	2.86	43	61.43•	23	32.86	2	2.86	-	-	-	-	70
Apis mellifera	7	6.25	57	50.89•	41	36.61	6	5.36	1	0.89	-	-	112
Total	**9**	**4.95**	**100**	**54.95•**	**64**	**35.16**	**8**	**4.40**	**1**	**0.55**	**-**	**-**	**182**

n: number of visits; *p*: percentage of visits = (*n*/*A*) × 100; •: daily pic of visits; -: no visit.

daily time frame. It appears from this table that the activity of these two Apidae begins in the morning around 7 h and decreases sharply around 13 h for *A. calens* and around 15 h for *A. mellifera* with a peak of activity between 8 and 9 h.

3.3. The Rhythm of Visits According to the Number of Bloomed Flowers

Figure 1 illustrates the rhythm of visits of *A. calens* (Figure 1(A)) and *A. mellifera* (Figure 1(B)) according to the number of bloomed flowers. It appears that the number of visits of *A. calens* and *A. mellifera* is proportional to the number of bloomed flowers. There is a positive and very highly significant correlation between the number of visits of *A. calens* ($r = 0.85$, $df = 13$, $P < 0.001$) and *A. mellifera* ($r = 0.81$, $df = 13$, $P < 0.001$) and the number of bloomed flowers.

3.4. Foraging Activity of *Amegilla calens* and Apis Mellifera on *Gossypium hirsutum* Flowers

3.4.1. Harvested Floral Products

Of the 48 recorded visits of *A. calens*, 60.41% were devoted to pollen harvest and 39.58% for nectar. From the 166 visits of *A. mellifera*, 35.56% were for pollen collection and 64.44% for nectar (Table 2). Therefore, on *G. hirsutum* flowers, we could affirm that these bee species concentrated their visits in collecting different resources, pollen for *A. calens* and nectar for honeybee.

3.4.2. Abundance of Foragers

The largest number of *A. calens* and *A. mellifera* foragers simultaneously active on *G. hirsutum* flowers is 1 for each bee. Table 3 presents data on the abundance of each bee species per 1000 flowers. This table shows that the mean abundance per 1000 flowers was 526.71 for *A. mellifera* and 586.53 for *A. calens*; the difference between these two means is not significant ($t = 1.12$, $df = 188$, $P > 0.05$).

3.4.3. Influence of Some Climatic Factors

Figure 2 shows the variations in mean ambient temperature, mean ambient humidity and the number of insect visits on the flowers of *G. hirsutum* according to the daily time slots of observation. It can be seen from this figure that there is no correlation between temperature and the number of insect visits ($r = 0.54$; $df = 4$; $P > 0.05$). Similarly, there is no correlation between the number of visits and the humidity ($r = -0.45$; $df = 4$; $P > 0.05$).

3.4.4. Duration of Visits per Flower

Table 4 presents data concerning the duration of visits of *A. calens* and *A. mellifera* according to the floral products harvested on this Malvaceae. It appears that the mean duration of one visit per flower was 327.68 sec for nectar harvest and 321.34 sec for pollen with *A. calens*; the difference between these two means is not significant ($t = 1.12$, $df = 188$, $P > 0.05$). The corresponding values for *A. mellifera* were 38.41 sec for nectar harvest and 35.15 sec for pollen; the difference between these two means is not significant ($t = 0.85$, $df = 147$, $P > 0.05$).

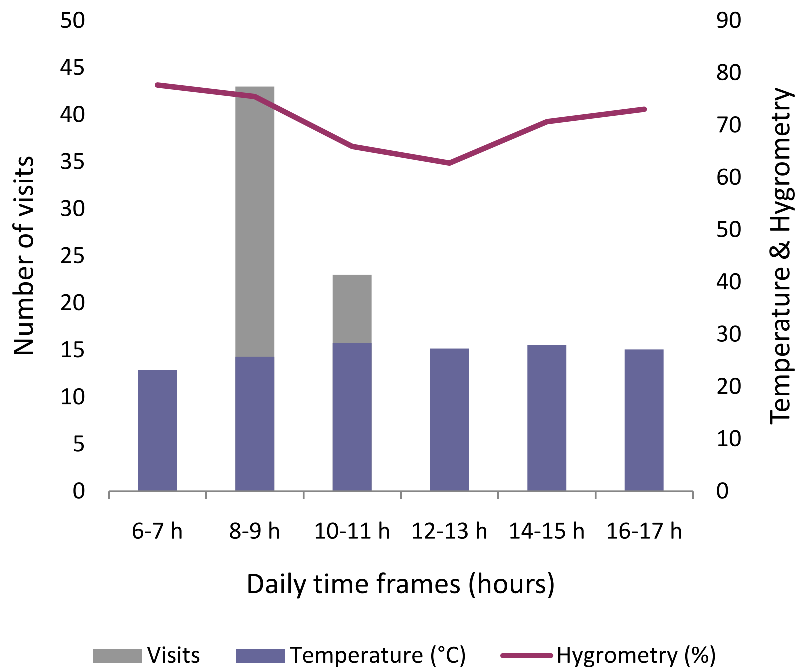
Table 3. Abundance of *Amegilla calens* and *Apis mellifera* workers per 1000 flowers on *Gossypium hirsutum*.

Insects	Abundance of foragers					Comparison of means		
	1000 flowers (A_{1000})							
	n	*m*	*s*	*mini*	*maxi*	***t* - cal**	***df***	***P*-value**
Amegilla calens	91	586.53	423.62	33.33	2000	1.12	188	$P > 0.05$
Apis mellifera	99	526.71	292.30	111.11	1000			

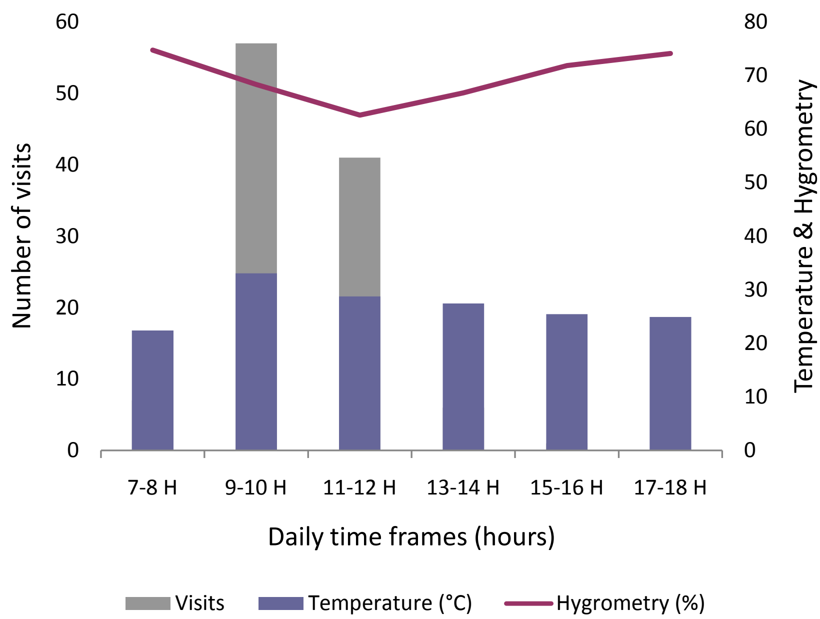
Table 4. Duration of *Amegilla calens* and *Apis mellifera* foragers visits on *Gossypium hirsutum* flowers based on floral products collected.

Insects	Floral products	Duration of one visit per flower (sec)				
		n	*m*	*s*	*mini*	*maxi*
Amegilla calens	Nectar	19	327.68	209.30	18	600
	Pollen	29	321.34	297.13	21	1000
Apis mellifera	Nectar	96	38.41	21.70	6	109
	Pollen	53	35.15	22.65	5	105

n: number of recorded visits; *m*: mean; *s*: standard deviation; *maxi*: maximum; *mini*: minimum.



(A)



(B)

Figure 2. Daily variations in temperature, relative humidity and number of visits of *Amegilla calens* (A) and *Apis mellifera* (B) on *Gossypium hirsutum* flowers.

3.4.5. Foraging Speed

The mean speed was 2.29 flowers/min (n = 31, s = 2.36) for *A. calens* and 5.07 flower/min (n = 46, s = 4.80) for *A. mellifera*. The difference between the two means is highly significant (t = 3.33, df = 145, P < 0.01).

3.4.6. Apicultural Value of *Gossypium hirsutum*

During the flowering period of *G. hirsutum*, there was an intense activity of *A.*

mellifera workers on its flowers. This activity has resulted in a high daily frequency of visits, a high harvest of nectar and pollen and a strong fidelity of foragers to flowers. This result highlights the attractiveness of cotton flowers products to *A. mellifera*. Therefore, the cotton plant could be classified among the very highly nectariferous and highly polliniferous bee plant species. As such, the Malvaceae can be therefore cultivated and preserved to stabilize bee colonies at the end of the rainy season in Cameroon.

3.5. Impact of *Amegilla calens* and *Apis mellifera* on the Pollination of *Gossypium hirsutum*

During nectar and/or pollen harvest on the flowers, foragers of *A. calens* and *A. mellifera* were in regular contact with the anthers and the stigma of this plant. Table 5 presents data on the number of visits and the frequencies of *A. calens* and *A. mellifera* foragers in contact with stigma and/or anther. It appears from this table that all visits (100%) of each bee species were in contact with the anthers and the stigma of the Malvaceae. Through this action, each bee could directly intervene in the self and cross-pollination of cotton.

3.6. Yields of *Gossypium hirsutum*

Table 6 summarizes data on the yield from different treatments. This table shows

Table 5. Number and frequency of contacts between *Amegilla calens*, *Apis mellifera*, anthers and stigma during flower visits.

Insects	Visits followed with anthers contact				Visits followed with stigma contact			
	Nectar		Pollen		Nectar		Pollen	
	n	*p* (%)	*n*	*p* (%)	*n*	*p* (%)	*n*	*p* (%)
Amegilla calens	96	100	53	100	96	100	53	100
Apis mellifera	19	100	29	100	19	100	29	100

Table 6. Fruiting rate, mean number of seeds per fruit and percentage of normal seeds according to different treatments set on *Gossypium hirsutum* flowers.

Treatments	NFE	NCF	TF (%)	Seed/fruit			NTG	NGN	% GN
				n	*m*	*s*			
1 (Fl)	120	116	96.67	97	25.39	6.17	2463	2298	93.30
2 (Fpi)	120	106	88.33	55	21.29	5.28	1171	981	83.77
3a (FvAm)	177	167	94.35	48	25.54	6.09	1226	1131	92.25
3b (FvAp)	152	127	83.55	97	22.03	4.93	2049	1882	91.85
4 (Fpnv)	271	209	77.12	114	19.75	4.50	2252	1955	86.81

Fl: Free pollination; **Fpi**: Protected flowers from insects visits; **FvAm**: Protected flowers and opened for exclusive visit of *Amegilla calens*; **FvAp**: Protected flowers and opened for exclusive visit of *Apis mellifera*; **Fpnv**: Protected then opened flowers without any single visit; **NFE**: Number of studied flowers; **NCF**: number of formed fruits; **TF**: fruiting rate; **NTG**: total number of seeds; **NGN**: number of normal seeds; **% GN**: percentage of normal seeds.

that the fruiting rate was 96.67%, 88.33%, 94.35%, 83.55% and 77.12% in treatments 1, 2, 3a, 3b and 4 respectively. The overall difference between these 5 percentages is very highly significant ($\chi^2 = 41.33$, $df = 4$, $P < 0.001$). The difference is significant between treatments 1 and 2 ($\chi^2 = 6.01$, $df = 1$, $P < 0.05$), very highly significant between treatments 3a and 4 ($\chi^2 = 23.56$, $df = 1$, $P < 0.001$), then between treatments 3b and 4 ($\chi^2 = 182.38$, $df = 1$, $P < 0.001$).

The mean number of seed per fruit was 25.39, 21.29, 25.54, 22.03 and 19.75 in treatments 1, 2, 3a, 3b and 4 respectively. The difference between these 5 means is very highly significant (F = 19.48, $df1 = 1$, $df2 = 402$, $P < 0.001$). The difference is significant between treatments 1 and 2 ($t = 3.29$, $df = 150$, $P < 0.05$), then between treatments 3b and 4 ($t = 2, 67$, $df = 143$, $P < 0.05$) and very highly significant difference between treatments 3a and 4 ($t = 5.88$, df = 160, $P < 0.001$).

3.7. Impact of Flowering Insects on *Gossypium hirsutum* Yields

The fruiting rate, the percentage of the mean number of seeds per fruit and the percentage of normal seeds due to the impact of flowering insects were 8.62%, 16.14%, and 10.21% respectively. The influence of these insects on fruiting, on the mean number of seeds per fruit and the percentage of normal seeds was positive. It means that cotton flowers have benefited from the visits of flowering insects leading to good production.

3.8. Pollination Efficiency of *Amegilla calens* and *Apis mellifera* on *Gossypium hirsutum* Flowers

The fruiting rate, the percentage of the mean number of seeds per fruit and the percentage of normal seeds due to the activity of *A. calens* were 18.26%, 22.67%, and 5.90% respectively. The fruiting rate, the percentage of mean seed per fruit and the percentage of normal seed due to honeybee activity were 7.70%, 10.35%, and 5.49% respectively. Both bee species have increased the fruiting rate by 12.98%, the mean number of seeds per fruit by 16.51% and the percentage of normal seeds by 5.70%.

4. Discussions

From our observations, a total of six bee species were recorded on this Malvaceae's flowers, *A. calens* and *A. mellifera* being among the most frequent. [10] did the same observations where they found that an Apidae (*Apis cerana cerana*) was the most dominant visiting insects in China. In Australia [23] and Cameroon [17] [18] [24] [25], *A. mellifera* was the most frequent flowering insect on cotton plant flowers. The high frequency of visits of these two insects on flowers of this plant could be explained by the good attractiveness and accessibility of the floral products of this plant to bees.

The peak of activity of these two Apidae between 8 am and 9 am is linked to the daily periods of greater availability of the floral products of this Malvaceae. According to [26], nectar represents a key link between insect-pollinated plants and their pollinators. Therefore, a large number of studies on cotton plant species have examined the effects of nectar, pollen, and number of flowers on pollinator attraction [18] [27] [28] [29] [30]. However, the reduced activity on flowers after 13 h for *A. calens*, and 15 h for *A. mellifera* could be explained by the decrease in the quantity and quality of floral products. According to [31], by making floral rewards available to pollinators at different times of the daily cycle, plants might be able to "select out" a subset of pollinators from the broad taxonomic array potentially available in the environment. Therefore, the foraging activity of pollinators could be influenced by abiotic factors such as ambient temperature, wind velocity, and solar radiation and biotic factors include predation and competitive interactions among flowering insects. It is known that nectar serves as the main carbohydrate source for bees and consequently, the total caloric value, as well as the rate of calorie uptake. This floral product nutritional value is an important aspect for bees [30]. Moreover, the flower structure, color, and scent are other aspects of attraction of bees on flowers. Therefore, for [28], the foraging activity of bees can differ according to flower height, and also to body size of the foragers.

The visits of these two Apidae are far more numerous on this plant when the number of bloomed flowers is higher. The positive and significant correlations between these two parameters highlight the good attractiveness of the pollen and nectar of this Malvaceae vis-à-vis of the foragers. Moreover, it is known that increase in flower number and size on a plant species cause increased visitation by flowering insects. The high abundance observed by 1000 flowers of *A. calens* and the honeybee highlights this attractiveness. According to [28], the sugar content of nectar alone is an appropriate quantitative metric of crop attractiveness. Moreover, it is known that bees especially honeybees through the communication (round and waggle dances) can inform foragers when a food source is very close to the hive (less than 50 meters) or more than 150 meters from the hive [32].

As a highly nectariferous bee plant, *G. hirsutum* can be grown and protected to increase honey production during its blooming and therefore, to maintain the colony for the dry season.

During their foraging activity, *A. calens* and *A. mellifera* have increased the pollination possibilities of this Malvaceae. During this activity, the thorax and abdomen of each bee are in contact with the anthers and the stigma thereafter. It scrapes the anthers with their hind legs, mandibles and abdominal hair (for *Amegila* sp.) to collect pollen. This facilitates the release of pollen at the anther, and therefore, facilitates the optimal occupation of the stigma by pollen grains. An optimal pollen load on the stigma would be favorable for fruit and seed formation. [26] noted that fruit growth and development is mainly dependent on pollination. Thus, the significant increase in fruiting rate, the number of seeds per fruit and the percentage of normal seeds due to *A. calens* and *A. mellifera* are the consequence of the activity of these bees on visited flowers.

This study shows that insect pollination services are very important for cotton production in Cameroon and should, therefore, be advertised to the main actors, the farmers, and rural populations. In particular, as the cotton plant is the main cash crop widely cultivated in the northern regions of Cameroon and of economic importance for the farmers, cotton plant is also an important bee plant and as such an irreplaceable habitat for pollinators. However, due to agricultural intensification and the misuse of agrochemical products like insecticides, pesticides, and herbicides, bee pollination services are at increased risk.

This paper proposes the integration of an environmentally friendly activity of farmers and the strong partnership between pollination ecologists and farmers for sustainable development. Moreover, it suggests and strongly encourages the practice of organic farming to protect and improve the efficiency and efficacy of pollinators on crops. As a nectariferous and polliniferous bee plant species, the cotton plant can be cultivated and protected to increase the production of honey and thus, contribute effectively to the rural and economic development of the region of Adamaoua.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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