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Contribution of Floral Visit of *Apis mellifera* (Apidae) on the Yield of *Cucurbita maxima* (Cucurbitaceae) in Torok and Vogzom in Cameroon

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Abstract

In two locations in Torok (Far North) and Vogzom (North) in Cameroon, during the 2022 agricultural campaign, the flowers of *C. maxima* were observed to study the activity of *Apis mellifera* and evaluate its impact on the fruit and grain yield of this plant. For each site, 90 female flowers at the bud stage were labeled on 36 plants divided into five treatments: 30 female flowers left to pollinate freely (T_1); 30 blooming female flowers isolated from visits by *A. mellifera* (T_0); 10 female flowers each having benefited from a single visit by bees (T_2); 10 female flowers each having benefited from two simultaneous visits by bees (T_3) and 10 female flowers each having benefited from three simultaneous visits by bees (T_4). The fruiting rate, the average number of seeds per fruit and the percentage of mature seeds were compared between these treatments. The results show that among the insect species recorded on the flowers of *C. maxima*; *A. mellifera* occupied the first place in both Torok (48.67%) and Vogzom (49.07%) and collected pollen and nectar every day during the flowering period. Flower visits for nectar collection (78.78% and 67.08%) were more frequent than those for pollen (3.97% and 2.52%) in *A. mellifera* in both Vogzom and Torok. Via its pollinating efficiency on *C. maxima*, the fruiting rate attributable to the pollinating activity of *A. mellifera* was 0% in treatment (T_0) (isolated flowers), 93.33% in treatment (T_1) (free flowers), 43.33% in (T_2) (one visit), 56.66% in (T_3) (two visits) and 73.33% in (T_4) (three visits). The mature fruit rate was 0%

in treatments (T_0) and (T_2), 80.77% in (T_1), 5.88% in (T_3) and 18.19% in (T_4). The average mass and average number of normal seeds per fruit were 4.26 Kg and 255.31 seeds in (T_1), 0.11 Kg and 5.55 seeds in (T_3), and 0.87 Kg and 28.76 seeds in (T_4), respectively.

Subject Areas

Ecology, Environmental

Keywords

Cucurbita maxima, *Apis mellifera*, Pollination Efficiency, Yields, Vogzom

1. Introduction

In many developing countries, agriculture is a sector of activity that employs the majority of the rural workforce [1] [2] and plays a crucial role in the fight against food insecurity [3]. Like other sub-Saharan African countries, Cameroon is an agricultural-based country. This sector largely ensures food self-sufficiency and employs more than 60% of the active population [4]. Despite notable performance in agricultural production, the value added of this sector to Cameroon's GDP has gradually declined, from 44% in 2004 to 17% in 2021 [5]. At the same time, the food insecurity situation has deteriorated, rising from 12.8% in 2019 to 20.4% in 2020 with a national poverty rate of 37.7% [6] [7]. In the face of these challenges, it is important that agricultural development programs consider all factors that can contribute to increased yields [8], including the use of pollinating insects [9] [10] which are responsible for pollinating nearly 85% of flowering plants [11]. For most crops, especially those in the Cucurbitaceae family, the lack of insect pollination can lead to reduced yields and potential economic difficulties for farmers [12]-[14].

Cucurbita maxima or pumpkin is an annual herbaceous plant with long, very vigorous, creeping stems, measuring 3 to 10 meters long and diploid (2n = 40 chromosomes) [15]. It is widely cultivated as a vegetable plant for its fruits, seeds and leaves, all of which are edible. The key factors for good pumpkin production are sufficient sunlight, a warm location and well-fertilized soil with a pH between 6.5 and 7.5 [16] [17]. *Cucurbita maxima* extract has anti-inflammatory and antioxidant properties [18]. Nutritionally, pumpkin is a good source of vitamin A and folic acid, and it is also rich in beta-carotene, vitamin C, and potassium, which are useful in preventing kidney stones [19]. *Cucurbita maxima*, is a monoecious species, the flowers open only one day and their pollination is mainly entomophilous [10] [20]. Several scientific studies have confirmed the dependence of *Cucurbita maxima* on entomophilous pollinators, because their pollen grains are sticky and cannot be transported by the wind [10] [14] [21]-[29]. The floricolous entomofauna and its impact on pollination and yields on a crop can vary in space, in time [30]. It is therefore necessary to conduct studies in Torok and Vogzom

(North and Far North Cameroon) on *Cucurbita maxima* to complete the existing data relating to the Cucurbitaceae family.

Considering its economic, medicinal, nutritional importance and considering the need to maintain and increase its fruit and grain production, we studied the entomophilous pollination of pumpkin or *C. maxima.* The main objective of this study is to contribute to the mastery of the relationships between *C. maxima* and *Apis mellifera* for their optimal exploitation. More specifically, to study the activity of the floricolous entomofauna of *C. maxima*; and to determine the impact of anthophilous insects including *A. mellifera*, on pollination and on the fruit and grain yield of this crop.

2. Location of the Study Site

The observations were carried out in Cameroon at Torok located between latitude (10˚0'0''N) and longitude (15˚0'0''E) for altitude (195 m) in the Far North Region and at Vogzom between latitude (8˚0'0''N) and longitude (15˚0'0''E) for altitude (205 m) in the North Region in 2022 on an area of approximately 400 m^2 each (**Figure 1**). The choice of these sites is justified by the greater number of *C. maxima* producers, the existence of peasant fields of other crops and the guarantee of safety of the experimental plots and the observer. The plant material consisted of pumpkin seeds purchased at the local market. All the insects present in the investigation sites constitute the animal material.

3. Study Methods

3.1. Preparation of the Experimental Plot, Sowing and Maintenance of the Crop

Preparation of plots experimental plots with an area of 400 m^2 each were carried out during the 2022 agricultural season in the two study sites (Torok and Vogzom) and followed the following successive stages: clearing, cleaning, burning and plowing consisted of the formation of ridges of 25 cm in height each and the distance between the ridges is 4 meters. The field was fenced to prevent access to mammalian pests [31]. Sowing was carried out on May 30 and June 2, 2022 and germination occurred one week later, respectively in Torok (Far North) and Vogzom (North). The distance between the pockets is 4 meters taking into account the length of the stems as well as the multi-branched character of this plant [32]-[34].

3.2. Experimental Device

In order to collect data on the diversity of flower-feeding insects associated with *C. maxima*, a so-called random experimental design was used in the two study sites throughout the flowering period (**Figure 2**). Twenty-four plants were chosen at random and divided into two blocks. The female flowers from these two blocks were labeled and two treatments were created depending on whether they were isolated (T_0) or not (T_1) from the foraging activity of flower-feeding insects [30].

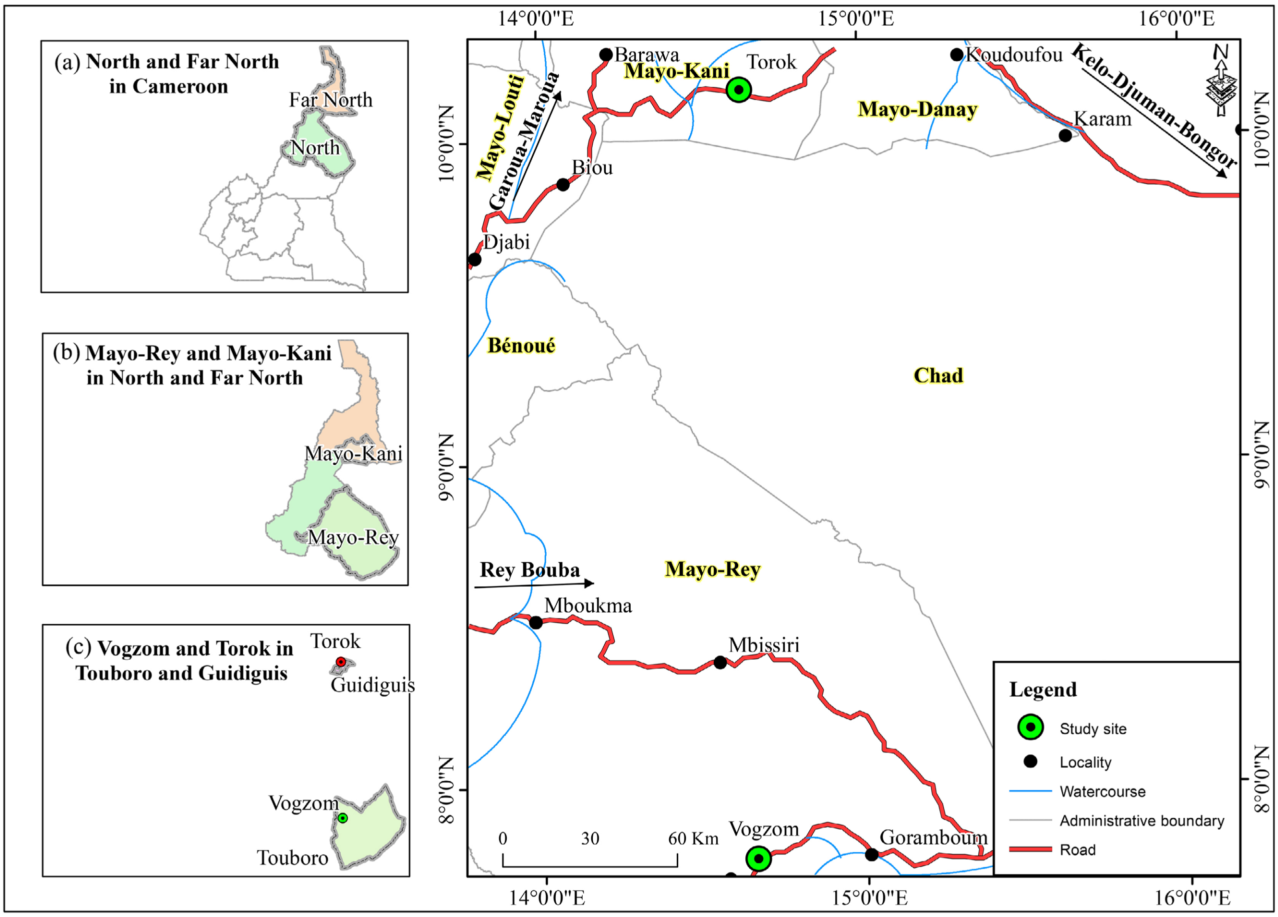

Figure 1. Location map of study sites for crop plots (source of map: INC).

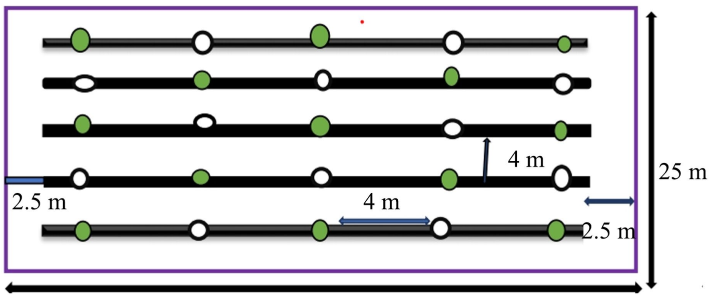

Figure 2. Experimental setup for the different treatments. Legend: Pumpkin plant to which treatments 0, 2, 3, and 4 were applied. Plants to which treatment 1 was applied.

Treatment A (T_1), consists of 12 plants of which 30 female flowers were labeled and left to pollinate freely, *i.e.* accessible to floral visits by bees;

Treatment B (T_0) also consists of 12 plants of which 30 blooming female flowers were isolated from bee visits by mosquito net or gauze bags.

3.3. Technique for Studying Floral Visits Based on the Blossoming of Flowers

Observations were made every day on the flowers of *C. maxima* plants left in free pollination (T_1) or block (A) between 6 a.m. and 1 p.m. (periods corresponding to the beginning and end of insect visits), during its flowering period. The activity of anthophilous insects was recorded during four daily time slots: 6 - 7 a.m., 8 - 9 a.m., 10 - 11 a.m. and 12 - 1 p.m. At each observation time slot, a passage was made once in front of each labeled plant in block A and the number of visiting insects on the open flowers was counted [35]. These visits were brought closer to the daily flowering rate of the flowers, the count of which was taken from the previous protocol in accordance with the recommendations of [30]. The biotic parameters (competing fauna, neighboring flora and climatological (temperature, hygrometry) which influenced insect activities were recorded.

3.4. Technique for Studying Floral Preferences

Floral preferences indicate the attractiveness exerted by floral products (nectar and pollen) on the foraging activity of the listed anthophilous insects. The aim was to note during floral visits, the floral product collected by a given forager. Taking into account the arrangement of floral products (nectar and pollen); when the bee pushed its mouthparts to the bottom of the flower where the nectaries are located, it was a floral visit to collect nectar. When it landed on the anthers and scratched them with its locomotory legs, it was a pollen collection visit [36].

3.5. Studies of the Effectiveness of Bees on Pollination and Growth Parameters of *C. maxima* Fruits

3.5.1. Pollination Efficiency

Additional treatment (C) has been defined allowing the study of the pollination efficiency of *Apis mellifera* (**Figure 3**). The marking, isolation and labeling of female flowers were carried out the day before their blossoming [26]. Very early in the days of their blossoming, the mosquito nets were removed from the female flowers so that they could be visited by *A. mellifera*. They were visited either simultaneously or consecutively by the same individual bee or by their congeners. Once the number of visits defined for the flower is reached, it is protected again. The next day, the mosquito nets were removed, to monitor the evolution of the potential fruits formed until their eventual maturity. The petals emerged made it possible to know precisely the imminent opening of the female flowers considered [32].

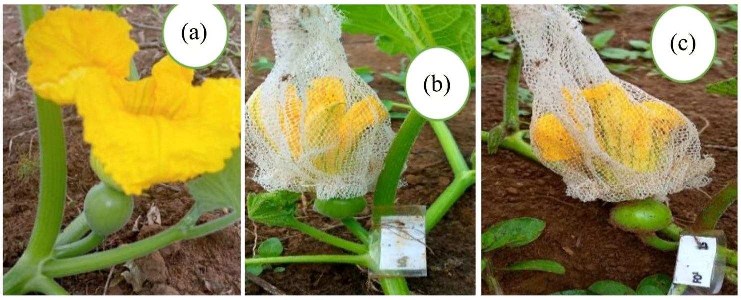

Figure 3. Free female flowers (a); isolated (b) and those having received a bee visit (c).

A treatment C (T_2) which consisted of 10 female flowers each having benefited from a single visit from *A. mellifera*; A treatment C (T_3) which consisted of 10 female flowers each having benefited from 2 simultaneous visits from *A. mellifera* and treatment C (T_4) which consisted of 10 female flowers each having benefited from 3 simultaneous visits from *A. mellifera*. In both sites, the experimental design used in this study was the same.

3.5.2. Impact of Pollinators on the Growth of *C. maxima* Fruits

The growth parameters (diameters and masses) of the fruits per treatment were recorded using a tape measure and a precision electronic balance to determine the different growth phases in volume and weight. These parameters were recorded for both fruits that had not reached physiological maturity and those that had. The diameter (Cm) and mass (Kg) of fruits that had not reached physiological maturity were recorded upon abortion or detachment from the mother plant; as illustrated by **Figure 4** [37].

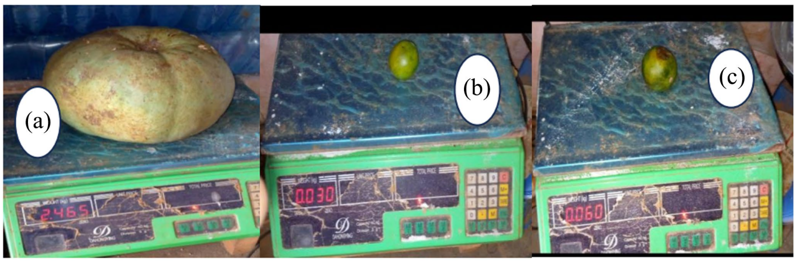

Figure 4. Weighings of fruits from T(C) one visit (b), two visits (c) of *A. mellifera* and T(A) female flowers left free (a).

3.6. Impact of Pollinators on the Fruit and Grain Yield of *C. maxima*

3.6.1. Determination of the Fruiting Rate Attributable to Pollinating Insects

In the 5 treatments, the fruiting rate is determined by [(number of fruits formed/number of female flowers studied) × 100]. The fruiting rate (*% Tfr*) attributable to anthophilous insects is estimated by the formula

$$(\%\,Tfr) = \left\{\left[\left(TA - TB\right)/TA\right] \times 100\right\}$$

where *TA* and *TB* are respectively the fruiting rates in treatment A (female flowers without protection) and in treatment B (female flowers protected from the floral activity of insects) [35].

3.6.2. Calculation of the Pollination Rate Attributable to Pollinating Insects

To calculate the pollination rate attributable to pollinating insects, mature fruits of *Cucurbita maxima* were weighed using a kitchen scale and sectioned using a machete, the total number of seeds per fruit including mature seeds (ms) and immature seeds (is) are counted. The nature of the seeds made it possible to estimate the pollination rate (P): P(%) = {[(ms/ts + is)]/100} [38].

3.6.3. Calculation of Mature Seed Rates Attributable to Pollinating Insects

Just as in the calculation of the fruiting rate due to pollinating insects, the same reasoning is applied for the calculation of the percentage of mature seeds per fruit due to the floral activity of anthophilous insects [35].

3.6.4. Calculation of the Rate of Mature Fruits and Abortion

All mature fruits (F_m) and all female flowers (F_f) are counted, thus allowing the calculation of the rate of mature fruits ($\% M$) by the following formula: ($\% M$) = $\{(F_m/F_f) \times 100\}$ [39]. The rate of loss due to pests ($\% R$) was deduced by the following formula: ($\% R$) = $100 - (\% M)$ [39].

3.7. Data Analysis

Data analysis was done using descriptive statistics (calculation of means, standard deviations and percentages). Four tests were used: 1) ANOVA (F) for comparing means of more than two samples; 2) Student's *t-test* for comparing means of two samples; 3) chi-square (χ^2) for comparing percentages; 4) Pearson's correlation coefficient (r) for studying linear relationships between two variables [40] [41].

4. Results

4.1. Insect Activity on *Cucurbita maxima* Flowers

4.1.1. Frequency of Visits Based on Daily Observation Time Slots

Floral insect activity at Torok begins at 6 a.m. from anthesis or flower blooming and ends at 1 p.m. when the flowers close. The overall peak of insect activity is observed from the second time slot, 8 - 9 a.m. (32.95%), after which floral activity gradually decreases and stops at 12 - 1 p.m. (14.36%). Individual peaks of activity of different insect species per time slot vary from one species to another. The peak activity of *Apis mellifera* is observed at the first observation time slot, 6 - 7 a.m. (48.67%) at Torok, which is marked by a high availability of floral products (Table 1).

Table 1. *Cucurbita maxima* flowers depending on the observation time slots at Torok.

Insects	6 - 7 a.m.		8 - 9 a.m.		10 - 11 a.m.		12 - 1 p.m.		Total
	n	*p*(%)	*n*	*p*(%)	*n*	*p*(%)	*n*	*p*(%)	
Apis mellifera	257	48.67*	150	28.4	100	18.93	21	4	528
Xylocopa inconstant	37	14.17	90	34.48	80	30.65	54	20.68	261
Xylocopa pubescens	25	12.82	75	38.46	50	25.64	45	23.07	195
Xylocopa olivacea	7	16.66	20	47.61	10	23.8	5	11.9	42
Lipotriches collaris	7	16.66	10	23.8	20	47.61	5	11.9	42
Trinchostoma sjostedti	1	8.33	7	58.33	2	16.66	2	16.66	12
Megachile aurifera	15	29.41	18	35.29	9	17.64	9	17.64	51

Continued

Phytomia sp	1	6.66	7	46.66	3	20	4	26.66	15
1 sp	1	8.33	7	58.33	2	16.66	2	16.66	12
Drosophila melanogaster	5	27.77	3	16.66	5	27.77	5	27.77	18
Hypolimnas misippus	8	16.66	20	41.66	10	20.83	10	20.83	48
Papilio demodecus	5	16.66	10	33.33	8	26.66	7	23.33	30
Eurena exima	1	4.76	7	33.33	7	33.33	6	28.57	21
Catopsilia florella	3	20	2	13.33	5	33.33	5	33.33	15
Acraea acerata	10	30.3	10	30.3	3	9.09	10	30.3	33
Total	383	28.94	436	32.95*	314	23.73	190	14.36	1323

Similarly, at the Vogzom site, floral insect activity begins at 6 a.m. from anthesis or flower blooming and ends at 1 p.m. when the flowers close. The overall peak of insect activity is observed from the first time slot 6 - 7 h (43.31%) after which the flower activity gradually decreases and stops at 12 - 13 h (9.91%). This overall peak of activity is influenced by the prominence of *A. mellifera* during this first time slot of observation. The peak of activity of *Apis mellifera* is observed at the first time slot 6 - 7 h (49.07%) also characterized by a high availability of floral products. The individual peaks of activity of different insect species per time slot vary from one species to another (**Table 2**).

Table 2. Variation in the number of insect visits to *Cucurbita maxima* flowers according to observation time slots in Vogzom.

Insects	6 - 7 a.m.		8 - 9 a.m.		10 - 11 a.m.		12 - 1 p.m.		Total
	n	*p* (%)	*n*	*p* (%)	*n*	*p* (%)	*n*	*p* (%)	
Apis mellifera	662	49.07*	449	33.28	152	11.27	86	6.38	1349
Lasioglossum sp.	19	32.75	37	63.79*	1	1.72	1	1.72	58
Monolepta intermedia	-	-	22	27.16	27	33.33	32	39.51*	81
Monolepta bioculata	-	-	18	26.08	19	27.54	32	46.38*	69
Drosophila melanogaster	31	35.63*	23	26.43	21	24.14	12	13.80	87
Total	712	43.31*	549	33.40	220	13.38	163	9.91	1644

n: number of visits; *p*: percentage of visits: (*n*/*A*) × 100; A: total number of visits = 1644; *: peak of visits.

Overall, the activities of flower-feeding insects were influenced by several factors, including climatology. Flower visits by insects were higher in the morning, when the temperature was low (20.03˚C) and the relative humidity was high (80.36%). However, flower visits by insects gradually decreased with increasing temperature and decreasing relative humidity. High temperature was detrimental to the foraging activity of insects on pumpkin flowers (**Figure 5**).

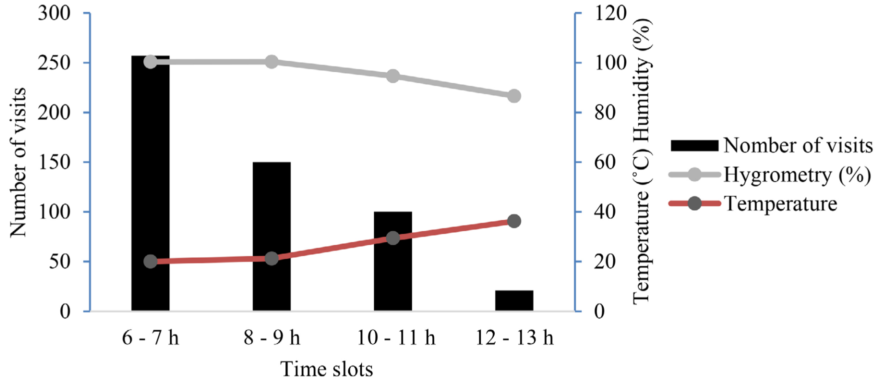

Figure 5. Daily variation of insect floral visits as a function of temperature and relative humidity at the two sites.

4.1.2. Abundance of Visiting Insects

The average abundance of foragers per 1000 flowers ranged from 31 in *A. mellifera* to 5 in *Xylocopa olivacea* in Torok (Far North) and approximately 959 in *A. mellifera* to 182 in *Lasioglossum* sp in Vogzom in the North. The high abundances of *A. mellifera* on 1000 flowers highlight the good nectar attractiveness and the large landing surface of *Cucurbita maxima* flowers. **Table 3** illustrates the relative results on the abundance of insect visits to *Cucurbita maxima* flowers in Torok and Vogzom.

Table 3. Abundance of Apideae per 1000 flowers according to Torok and Vogzom.

Insects	Torok (Far North)					Vogzom (North)				
	NVE	m	s	min	max	NVE	m	s	min	max
Apis mellifera	59	31.42	16.11	64	625	67	958.54	676.92	111	2667
Xylocopa inconstant	30	6	1.30	1	12					
Xylocopa olivacea	15	5	10	1	11					
Lasioglossum sp.						50	182.22	89.11	111	444

4.1.3. Floral Products Collected

Of the 528 and 1349 visits of *Apis mellifera* studied, respectively in Torok (Far North) and Vogzom (North), 78.78% and 67.08% of the visits were devoted primarily to nectar collection. On the other hand, 17.23% and 30.4% of the visits were devoted to the simultaneous collection of pollen and nectar, compared to 3.97% and 2.52% of the visits devoted only to pollen collection. In Torok (Far North), the 261 and 195 visits of *Xylocopa inconstant* and *Xylocopa olivacea* studied were devoted to the exclusive collection of nectar. 55.17% and 44.82% to the respective collection of nectar and pollen, out of 58 visits of *Lasioglossum sp.* studied has Vogzom in the North. The results of the visits related to the collection of nectar (**Figure 6**) and pollen (**Figure 7**) of *Cucurbita maxima* are shown in **Table 4**.

Figure 6. *Apis mellifera* nectarivorous.

Figure 7. *Apis mellifera* pollinivore.

Table 4. Floral preferences of Apidae on *Cucurbita maxima*.

Insects observed	NVE	Nectar		Nectar and Pollen		Pollen	
		NVN	%	NVPN	%	NVP	%
Apis mellifera	528	416	78.78	91	17.23	21	3.97
Xylocopa inconstant	261	261	100.00				
Xylocopa olivacea	195	195	100.00				
Torok (Far North)							
Apis mellifera	1349	905	67.08	410	30.4	34	2.52
Lasioglossum sp.	58	32	55.17			26	44.82
Vogzom (North)							

Legend: NVE = Number of visits studied; NVN = Number of visits devoted to nectar collection; NVPN = Number of visits devoted to nectar and pollen collection; NVP = Number of visits devoted to pollen collection; min: minimum and max: maximum.

4.2. Pollination Efficiency and Influence of Pollinators on *C. maxima* Fruit Growth as a Function of Treatment

Among the flower-eating insects active on *C. maxima*, *Apis mellifera* mainly carried pollen from flower to flower on one or more pistillate flowers carried by the same plant. They could therefore intervene in geitonogamy (transport of pollen grains from a male flower to a female flower carried by the same pumpkin plant) or in xenogamy (transport of pollen grains from a male flower of plant A to a female flower carried by another pumpkin plant B). However, the visits which favored the pollination of female flowers are those linked to the simultaneous collection of nectar and pollen which is 17.23% and 30.04% respectively in Torok and Vogzom in the context of this study.

The average diameter varies from 16.57 cm in treatment T_1, to 0.52 cm in treatment T_3 and 6.26 cm in treatment T_4. The average mass of a fruit is 4.26 kg in treatment T_1, 0.11 kg in treatment 3, and 0.87 in treatment T_4. The abortion rate is 100% in treatments T_0, T_2, T_3 and it is 75% in T_4. The growth parameters of the formed fruits increase with the intensity of pollination; the more bee visits there are on the female flowers, the better the characteristics of the formed fruits and vice versa. The growth parameters of the fruits between the different treatments are illustrated in Table 5.

Table 5. Comparison of diameter and mass of mature fruits from different treatments.

Treatments	Diameter (cm)	Mass (Kg)	Aborted fruits	
			N	TA (%)
T_0 (Isolated flowers)	-	-	30	100
T_1 (Free Flowers)	16.57 ± 1.04	4.26 ± 1.12	2	7.15
T_2 (Faruv)	-	-	1	100
T_3 (Fardv)	0.52 ± 0.1	0.11 ± 0.02	4	100
T_4 (Fartv)	6.26 ± 0.21	0.87 ± 0.16	6	75.00

Legend: NFM: number of mature fruits; TA: abortion rate; Faruv: flowers having received a single visit; Fardv: flowers having received two visits; Fartv: flowers that received three visits.

4.3. Impact of Pollinators on Fruit and Grain Yields of *Cucurbita maxima*

At the Torok site (Far North), the fruiting rate was 76.67% in treatment A, 0% in treatment B and 26.66% in treatment C. The overall comparison indicates a significant difference between treatments A, B and C ($\chi^2 = 40.25$; df = 2; $p < 0.05$) and between treatments A and C ($\chi^2 = 15.02$; df = 1; $p < 0.05$).

And in Vogzom (North), the fruiting rate was 93.33% in treatment A, 0% in treatment B and 43.33% in treatment C. The overall comparison indicates a significant difference between treatments A, B and C ($\chi^2 = 52.77$; df = 2; $p < 0.05$) and between treatments A and C ($\chi^2 = 17.33$; df = 1; $p < 0.05$).

The average number of mature seeds per fruit was 255.31 ± 51.02 and 252.33 ± 38.02 in treatment (A) in Vogzom (North) and Torok (Far North) respectively, and zero in treatment (B) in both sites since there was no fruit formation in these two treatments. The percentage of mature seeds is high in treatment A, around 96.6% and 98.23% in Torok and Vogzom respectively.

The pollination rate is deduced through the ratio between the total number of mature seeds (NGM) obtained on the total number of sheaths (NTG) which reflects the total number of ovules obtained. This rate is [(2925/3028) × 100] = 96.59% and [(6521/6638) × 100] = 98.23% in treatment A in Torok and Vogzom respectively. This high rate reflects the fact that good pollination leads to good fertilization and an increase in seed yield and good quality fruits in *C. maxima.*

Although the flowers in treatment (A) received bee visits, it was found that some female flowers failed to form fruits with a rate of 6.67% and 23.33% respectively in Vogzom and Torok. The fruit and grain yield of *Cucurbita maxima* in Torok and Vogzom according to the different treatments is recorded in Table 6.

Table 6. Pumpkin fruit and seed yields in Torok and Vogzom.

Parameters studied	Treatment A		Treatment B		Treatment C	
	Torok	Vogzom	Torok	Vogzom	Torok	Vogzom
Number of female flowers studied	30	30	30	30	30	30
Number of fruits formed	23	28	0	0	8	13
Fruits formed (%)	76.67	93.33	0	0	26.66	43.33
Number of mature fruits obtained	12	26	0	0	0	2 (Fartv)
Ripe fruits (%)	52.17	92.85	0	0	0	15.38
Total number of seeds obtained	3028	6638	0	0	0	84
Number of mature seeds obtained	2925	6521	0	0	0	30
Mature seeds obtained (%)	96.60	98.23	0	0	0	35.71
Number of immature seeds obtained	103	117	0	0	0	54
Immature seeds obtained (%)	3.40	1.76	0	0	0	64.28
Average number of mature seeds per fruit	252 ± 38	255 ± 51	0	0	0	15
Abortion rate (%)	48.00	7.15	100.00	100.00	100.00	85.00

Fartv: Flowers that received three visits.

There is a positive and significant regression equation between fruit mass and diameter ($y = 102.57x + 36.418$) with a coefficient of determination $R^2 = 0.89$ (*ddl* = 1.19; $p < 0.05$). This coefficient of determination indicates that 89% of the variation in the number of mature seeds influences the mass of the fruits obtained. Overall, the larger the fruit, the higher the number of mature seeds it generally contains. Figure 8 below illustrates the linear regression equation between fruit mass and the number of mature seeds contained in each fruit.

The average weight of a berry whose female flowers were left freely accessible to bees was 4.26 ± 1.12 kg at both sites. The total number of fruits and their masses obtained per site in this study were around 100 (426 kg) and 70 (298.2 kg) fruits respectively at Vogzom (North) and Torok (Far North). From the experimental fields, a predicted yield of 10.65 t/ha in Vogzom and 7.45 t/ha in Torok can be extrapolated. One of the reasons for the difference in the predicted yield in this study is that there is a beehive next to the experimental plot, unlike at the Torok site. The existence of this hive favored optimal pollination of the female flowers of *C. maxima* in Vogzom.

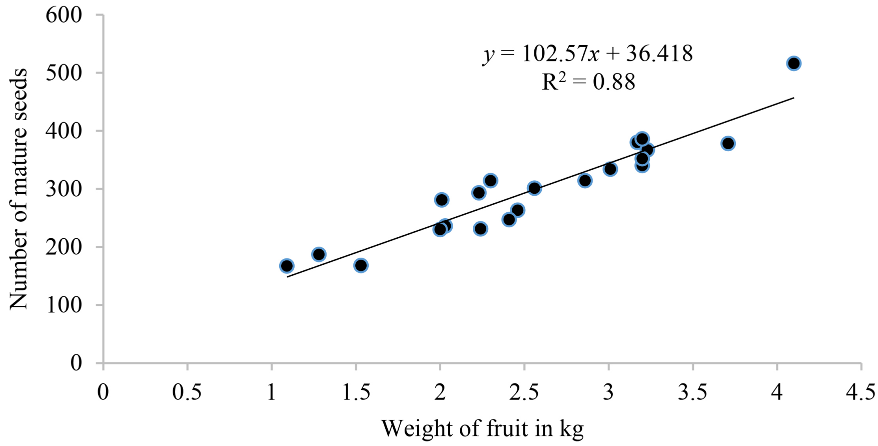

Figure 8. Linear relationship between fruit mass and number of mature seeds.

5. Discussion

Several insects were identified as active on the flowers of *C. maxima* with a preponderance of *Apis millifera* whose peak visits were observed between 6 - 7 a.m (48.67%) in Torok and (49.07%) in Vpgzom. Thus, the peak of bee activity in the two sites on the flowers of *C. maxima* is generally correlated with the greater availability of floral resources such as nectar and pollen, these results corroborate those of [10] [42] [43].

The high abundances of *A. mellifera* on 1000 flowers of *Cucurbita maxima* (31.42 ± 16.11) in Torok and (958.54 ± 676.92) in Vogzom highlight the good attractiveness of the nectar and the large landing surface of the flowers of this plant. These results corroborate those of Jacob-Remacle [44] whose workers use the pheromone during foraging to mark interesting food sources, with a view to directing other foragers there [10] [28] [45] [46]. In entomophilous plants, including Cucurbitaceae, nectar is the main product sought by bees. Visits that effectively promoted pollination were those linked to the simultaneous collection of nectar and pollen; in this study, they were around 30.4% and 17.23% respectively in Vogzom and Torok [27] [47]. Pollination requires the transfer of pollen through the bees' integument. The pollen grain retained by the bees' hairs is the most conducive to pollination [45].

The optimal yield of mature fruits and grains was obtained in treatment T_1 (free flowers), while it was zero in treatment T_0 (female flowers isolated from bee activities) in both sites. These results are in agreement with those of [10] [37] [48] [49], the more pollen grains a female flower receives, the more potential it has to transform into a large fruit containing many mature seeds as seed. These correlations explain the fact that effective entomophilous pollination results in the production of good quality fruits and seeds. Furthermore, poor pollination of female flowers results in a reduced yield and poor-quality fruits. This explains why in treatments T_2, T_3, and T_4, in Vogzom as in Torok, the abortion rate is high and the fruits that reach maturity are not of good quality. The production of *Cucurbita maxima* therefore depends on optimal pollinating activity of domestic bees [20] [22]-[24]. The forecast yield per hectare of fruit is 10.65 t/ha and 7.45 t/ha respectively in Vogzom and Torok, obtained by extrapolation from that of the observation plots. These predicted yields are lower than those obtained in France, which reached 20 - 30 t/ha in open fields in organic farming of *Cucurbita maxima* [50]. Cordova [22] mentions that several factors can influence agricultural yield including: variety, climate, cropping system, soil characteristics and availability of pollinators. The experimental plots of two sites in this study have a pH 5.3 of the soil so, which is slightly acidic and poor in organic matter which could explain the lower yield obtained compared to the results of other authors. According to Deepa *et al.* [17] soil with a pH between 6.5 and 7.5 is favorable for maximum production of *C. maxima*.

6. Conclusion

The floricolous entomofauna associated with the cultivation of *Cucurbita maxima* in Vogzom as in Torok is not very diverse overall. The pollination of the female flowers of *C. maxima* is ensured by insects and particularly by *Apis mellifera* which played an important role in the fertilization of this crop. The visits of *A. mellifera* which directly favored pollination are those linked to the simultaneous harvesting of nectar and pollen which are of the order of 91 (17.23%) and 410 (30.4%) respectively in Torok and Vogzom. Experiments have shown that the more a female flower receives floral visits from bees, the more pollen grains it receives and the more fruit and seed production is ensured. Thus, the minimum number of bee visits to the female flowers of the pumpkin which guarantees the yield of this crop is on average three visits in the context of this study. All 30 female flowers protected from insect visits systematically aborted. Overall, honey bee activity determines the production of the best quality *Cucurbita maxima* fruits and seeds. In *C. maxima* farms, the absence of bee flower-growing activity results in zero yield; this is the case for 30 female flowers that were exempted from bee visits. The predicted yield per hectare in fruit is 10.65 t/ha and 7.45 t/ha respectively in Vogzom and Torok in the framework of this study. These important results of the activity of *Apis mellifera* on the yield of fruits and seeds of *C. maxima*, suggest to us the need to conserve the colonies of this biodiversity by practices of organic agriculture and beekeeping.

Conflicts of Interest

The authors declare no conflicts of interest.

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