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Diversity of Floricultural Insects and their impact on the Productivity of *Cucurbita Maxima Dusch* (Cucurbitaceae) in the Sudano-Sahelian Zone of Cameroon

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Abstract

Purpose: This study aims to assess the biodiversity of *Cucurbita maxima* pollinators with a view to optimising the expected results, in a context of efficient and sustainable agriculture in Cameroon.

Methodology: In Vogzom (North), and in Torok (Far North) in 2022, *Cucurbita maxima* flowers (Cucurbitaceae) were observed in order to evaluate agronomic parameters, identify the floricultural entomofauna and the pollinating activity of Apidae. For the characterization of the floricultural entomofauna in Vogzom and Torok, five treatments of 30 female flowers each were established according to whether they were protected from visits by *Apis mellifera* (T0) or benefited from one visit (T2), two (T3), three visits (T4) each or were free (T1). A recognition code was assigned to each visiting species of *Cucurbita maxima* flowers and a few individuals of each species were captured and retained for later identification. The data collected was codified and encoded in the Excel spreadsheet of the Microsoft Office 2019 program. The normality test of the different variables was done by the Shapiro-Wilk test at the 5% significance level. The Tukey test was used for the comparison of means when the p-value was > 5% and otherwise, the nonparametric Kruskal-Wallis test was used.

Finding: The floricultural entomofauna associated with pumpkin consists of five species in Vogzom and fourteen species in Torok. Apidae (82.06%) were in the majority; represented by *Apis mellifera* (82.06%) in Vogzom. Similarly in Torok, Apidae (77.55%) were in the majority, represented by *Apis mellifera* with a relative abundance of 40.5%. The daily activity of the Apidae was effective between 6 a.m. and 1 p.m. with a morning peak of activity (6 a.m. to 7 a.m.) in both sites. Floral visits to collect nectar (74%) were more important than those devoted to pollen (26%) in *A. mellifera*. In Vogzom as well as in Torok. The fruiting and mature fruit rates as well as their average mass vary according to the number of successful insect visits by the female flowers.

Contributions to theory, policy and practice: Overall, the fruit and seed production of *Cucurbita maxima* is closely dependent on the pollinating activity of the Apidae; without it, no fruit or seed is formed, as the pumpkin is neither parthenocarpic nor apomictic. Obtaining optimal pumpkin yields is conditioned by the conservation and protection of pollinator biodiversity.

Keywords: *Cucurbita Maxima, Productivity, Pollination, Food Security, Sudano-Sahelian*

1. Introduction

Many insects visit the flowers, which are a source of sweet and protein food for them (Guerriat, 1996). They are responsible for the pollination of more than 80% of cultivated plants (Klein *et al*., 2007) and represent the most numerous and efficient pollinators (Philippe, 1991). The floral activity of pollinating insects promotes the reproduction of angiosperms and leads to an increase in the quantity and quality of the yields of plant species (Pesson & Louveaux, 1984 and Klein *et al*. 2007). Crop pollinating insects are in the process of accelerated dieback throughout the world (Haubruge *et al*., 2006). However, they are an essential link in the food chain, for the survival of several wild and cultivated plant species. According to the FAO (2005), each state must develop a policy for the protection and conservation of pollinating insects; This requires a good knowledge of plant-pollinator networks. Thus, in several countries, pollinating insects of several plant species are known and their activity meticulously exploited (Jacob-Remacle, 1989). It is well known in the literature that the activity of floricultural entomofauna associated with spontaneous or cultivated plant species usually leads to increased fruit and/or grain yields via pollination (Jacob-Remacle, 1989).

Given its economic importance, the preciousness of its fruits in the human diet and considering the need to maintain and increase its fruit and seed production, we studied the entomophilous pollination of pumpkin or *Cucurbita maxima.* The general objective of this study is to contribute to the knowledge of the relationships between *Cucurbita maxima* and its antophilic insects in order to optimize the expected results, in a context of efficient and sustainable agriculture in Cameroon. Specifically, to evaluate the diversity of flowering insects of *Cucurbita maxima* and the substances collected in order to determine the pollinating potential and their impact on the fruit and seed yield of this crop.

2. Literature Review:

In Cameroon, studies on the pollination of Cucurbitaceae have only focused on pistachio or *Cucumeropsis mannii* (Azo'o & Messi, 2012), watermelon or *Citrullus lanatus* and wild cucumber *Cucumis sativus* (Azo'o *et al*., 2014 and 2017). Despite this work, additional information is not yet exhaustive on the knowledge of the relationships between several plant species growing in Cameroon and their pollinating insects (Tchuenguem, 2010b). For the moment, no studies have been carried out on the pollination of pumpkin in this country.

3. Materials and Methodology

3.1. Sites, study stations and biological materials

Investigations took place in Torok, in the district of Guidiguis, Far North region, and in Vogzom, in the district of Touboro, in the North region of Cameroon in 2022 (fig. 1). The choice of these observation sites is justified by the large number of *Cucurbita maxima* producers, the existence of farmers' fields of other crops and the guarantee of safety of the experimental plots and the observer. The plant material consisted of pumpkin seeds bought at the local markets. All the insects present in the investigation sites constitute animal material.

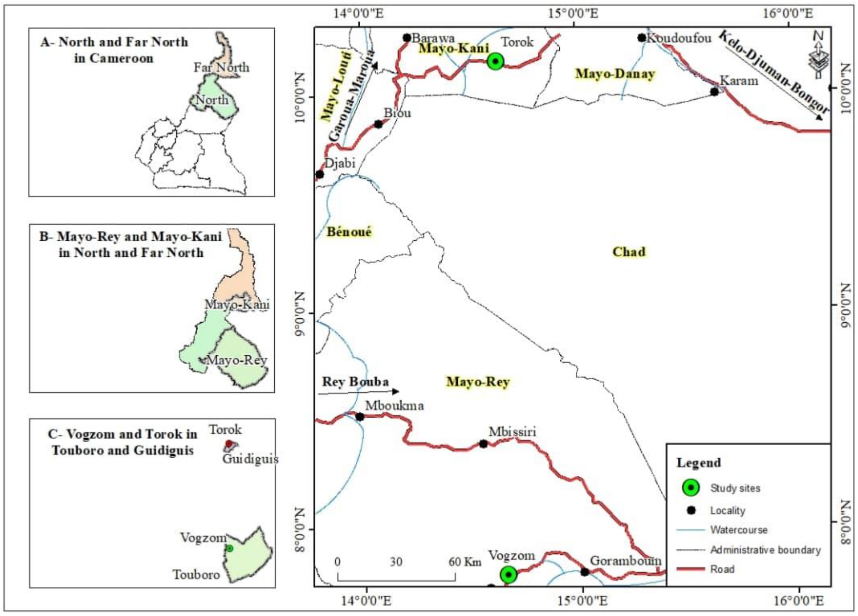

Figure 1: Location map of the Torok and Vogzom study sites

3.1.1. Experimental Devices

The study of the activity of antophilic insects on *C. maxima* was carried out from a randomized experimental design and took place during the entire flowering period during the production season of the year 2022. 30 plants were chosen on a random basis and divided into two blocks. The female flowers from these two blocks are labelled and two treatments are made up depending on whether or not they are isolated from the foraging activity of the flowering insects: treatment A and treatment B each constituted 30 female flowers. Overall, the marking and isolation of female flowers in Batch B was carried out the day before they opened. The next day after they were isolated, the mosquito nets were removed, allowing the evolution of the potential fruit formed to maturity to be followed.

3.2. Method

3.2.1. Diversity of the flower-dwelling entomofauna of *Cucurbita maxima*

3.2.1.1. Collection of data on the flowery entomofauna of *Cucurbita maxima.*

Observations are made every day on the flowers of the plants left in free pollination between 6 a.m. and 1 p.m. (periods corresponding to the beginning and end of insect visits), during the flowering period of the plant species under study. The activity of the antophilic 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 time slot of observation, the number of visiting insects was carried out, the number of visiting insects was passed in front of each labelled plant in block (A) and counted on the open flowers. The cumulative results of the different counts are expressed by the number of visits (Tchuenguem *et al*., 2004). Based on the data on the floricultural entomofauna, some ecological parameters (Shannon, Jacrd and Piélou equitability indices) were evaluated in order to assess the species richness of the insects in the two study sites.

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3.2.1.2. Variations in insect flower visits according to the rate of flowering of *Cucurbita maxima* flowers.

Each day, the cumulative visits of the antophilic insects that are listed as active on the flowers of the plant species by time slot are listed. These visits are brought closer together at the daily rate of the blossoming of the unisexual flowers, the count of which is derived from the previous protocol.

1. Average duration of floral visit and floral preferences and influence of abiotic factors on forager activity.

This is the time it takes for the insect to collect a product (pollen and/or nectar) from a flower (Jacob-Remacle, 1989). The duration of a visit corresponds to the value read on the stopwatch when the insect left the flower (Tchuenguem *et al*., 2004).

Floral preferences indicate the attractiveness of floral products (nectar and pollen) on the foraging activity of the anthophile insects listed (Messi & Tchuemguem, 1994).

The temperature and humidity of the study station were recorded twice per daily observation time slot using a portable thermo-hygrometer and their average values were calculated (Azo'o *et al*., 2021).

3.2.2. Method for evaluating the performance of *Cucurbita maxima*

3.2.2.1. Pollination efficiency studies

Treatment C (T2) which consisted of 30 female flowers each of which had benefited from a single visit from a major insect. Treatments D (T3) which consisted of 30 female flowers that each benefited from 2 simultaneous visits of major insects. Treatment E (T4) consisted of 30 female flowers, each of which benefited from 3 simultaneous visits of major insects.

Figure 2: Free female flower (Hebri,2022)

Figure 3: Isolated female flower (Hebri,2022)

3.3. Data analysis and Processing

3.3.1. Analysis and processing of data on the impact of pollinators on the yield of *Cucurbita maxima.*

3.3.1.1. Forager density

The density of foragers (A) is the largest number of individuals simultaneously active on a given number of flowers (Jacob-Remacle 1989). It is expressed by the ratio between the number of foragers counted (Ax) and the number of flowers in bloom (Fx) at time x. For practical reasons, this ratio is multiplied by 100 or 1000, which gives the number of individuals observed for 100 or 1000 flowers present at a given time (Pierre *et al*., 1997). The corresponding formula is therefore A = [(Ax/Fx) x 100 or 1000] (Tchuenguem *et al*., 2004).

3.3.1.2. Fruiting rate due to pollinators

In the 6 treatments constituted, the fruiting rate [(number of fruits formed/number of female flowers studied) x 100] is calculated. The fruiting rate (*%Tfr*) attributable to antophilic insects is estimated by the formula (*%Tfr*) = {[(*TA* – *TB*)/*TA*] x 100} where *TA* and *TB* are respectively the fruiting rates in treatment A (female flowers without protection) and in treatment B (female flowers protected from insect floral activity) (Tchuenguem *et al*., 2004).

3.3.1.3. Pollination rate due to pollinating insects

The mature fruits of *Cucurbita maxima* are weighed by a kitchen scale; opened with a machete and the number of mature seeds (Gm) and immature seeds (Gi) are counted. The nature of the seeds allows us to estimate the pollination rate (P): P (%) = {[(Gm/Gm + Gi)] /100} according to Gingrass *et al*. (1999). In addition, a linear relationship can be established between the mass of each fruit and the number of mature seeds counted to assess the relationship between these two parameters Nerson, (2002).

3.3.1.4. Rates of mature seeds attributable to pollinators

As with the calculation of the fruiting rate due to pollinating insects, the same reasoning is applied to the calculation of the percentage of mature seeds per fruit due to the floral activity of antophilic insects (Tchuenguem *et al*., 2004).

4. Results

4.1. Biological diversity of insects on *Cucurbita maxima* flowers.

At the order level, the flowering insects of the pumpkin in Vogzom were divided into three main orders. The order Hymenoptera is predominant with 85.58% of the total number of visits, the order of Coleoptera with 9.13% of the relative abundance and the order of Diptera with only 5.29% of the number of visits. The flowering insects of the pumpkin have been grouped into 4 families; they are classified as follows in descending order of their relative abundance: the family Apidae (82.06%), the family Leaf beetles (9.13%), the family Drosophila (5.29%) and the family Haicelidae (3.52%). Five species of antophilic insects have been identified active on the flowers of *Cucurbita maxima*. The honey bee *A. mellifera* is prominent with a relative abundance of visits of 82.06%; this bee is the only representative of the family Apidae. The other species are in descending order of their relative abundance: *Drosophila melanogaster* (5.29%), *Monolepta intermedia* (4.93%), *Monolepta bioculata* (4.20) and *Lasioglossum* sp. (3,52%). Overall, the flower-dwelling entomofauna of *Cucurbita maxima* in Vogzom (Touboro, Cameroon) is poorly diversified and largely dominated by the activity of *A. mellifera*.

On the other hand, in Torok, the floricultural entomofauna of *Cucurbita maxima* is divided into three orders of unequal importance due to the variation in their relative abundance. The order

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of hymenoptera is dominating with 82.3% of the total number of visits, followed by lepidoptera and diptera with a relative abundance of 11.1% and 3.4% respectively. As far as the family is concerned, the floricultural insects are divided into 9 families and dominated by the apidae, with a relative abundance of 77.55% of the total number of visits, followed respectively by the halictidae (4.1%), meachilidae (3.9%), nymphalidae (3.6%), pieridae (2.7%), acraeidae (2.5%), papilionidae (2.3%), syrphilidae (2.00%) and finally drosophilidae (1.4%). Fourteen species of antophilic insects have been recorded active on the flowers of *Cucurbita maxima*. *Apis mellifera* is dominant with a relative abundance of 40.5%, while *Trinchostoma sjostedti* is the lowest (0.9%) of the total number of visits. Overall, the flower-dwelling entomofauna of *Cucurbita maxima* in Torok (Far North) is diverse and dominated by the activity of *Apis mellifera*. The results of the biological diversity of the flowering entomofauna associated with *Cucurbita maxima*, Vogzom (North) and Torok (Extreme-North) are reported in Table I below.

4.1.1. Index of diversity of entomofauna between the two sites

The Shannon diversity index calculated at the two sites was respectively H' = 2.70p at Torok (Far North) and H' = 1.03 at Vogzom (North). Species diversity is low at Vogzom (North) H' < 3 compared to Torok (Far North) which is average (2 < H' < 4). The site of Torok (Far North) is thus rich in flowering species of pumpkin more than the site of Vogzom (fig. 40.).

The calculated values of the Pielou equitability, linked to the Shannon index, confirm the fluctuations between these values of the diversity index. The equitability values show an almost equal variation in the two sites.

In addition, the Simpson index proves that the probability of two individuals taken at random being different species is low. The low values of the indices in intercropping (0.2) as well as in non-associated crops (0.15) and 0.28 in shrub savannahs show that they are poor in biodiversity. This low diversity is the consequence of human activities developed in the fields, in particular with the abusive use of chemical inputs.

4.2 Insect activity at the flower level *Cucurbita maxima*

4.1.2. Rhythm of visits according to the rhythm of blooming of the flowers of *Cucurbita maxima*

Overall, the number of insect visits varies depending on the number of blooming flowers. In the Far North, as in the North, the bell-shaped curve shows that the number of flowers in bloom increases and reaches a peak and then decreases until wilting. It is important to note that the higher the number of flowers, the higher the number of insect visits. It also emerges from these figures that there is a positive and significant correlation between the number of flowers in bloom and the abundance of visitors to Torok in the Far North ($r = 0.93$; *ddl* = 14; $P < 0.001$) as well as in Vogzom in the North ($r = 0.92$; *ddl* = 4; $P > 0.01$). These correlations highlight the good attractiveness of the nectar of the flowers of this Cucurbitaceae to foragers.

Figure 4 illustrates the relationship between the number of *Cucurbita maxima* flowers blooming per day and the corresponding number of insect flower visits.

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Table I. Number and percentage of visits of the different insects recorded at the level of *Cucurbita maxima* flowers in 2022 (Cameroon).

Floricultural insects			**Torok (Far North)**		**Vogzom(North)**	
Order	Family	Genus and Species	*n1*	*f1 (%)*	*n2*	*f2 (%)*
Hymenoptera	Apidae	*Apis mellifera*	528	40,5	1349	82,06
		Xylocopa inconstans	261	19,7		
		Xylocopa pubescens	195	14,7		
		Xylocopa olivacea	42	3,2		
	Total Apidae	4	1026	77,55	1349	82,05
	Halictidae	*Lipotriches collaris*	42	3,2		
		Lasioglossum sp.			58	3,52
		Trinchostoma sjostedti	12	0,9		
	Total Halictidae	3	54	4,1		
	Megachilidae	*Megachile aurifera*	51	3,9		
	Total Megachilidae	1	51	3,9	58	3,52
Total Hymenoptera	4	8	1089	82,3	1407	85,58
Coleoptera	Chrysomelidae	Monolepta intermedia			81	4,93
		Monolepta bioculata			69	4,2
	Total Chrysomelidae	2			150	9,13
Total Coleoptera	1	2			150	9,13
Diptera	Syrphidae	*Phytomia sp.*	15	1,1		
		1 sp.	12	0,9		
	Total Syrphidae	*2*	27	2,00		
	Drosophilidae	Drosophila melanogaster	18	1,4	87	5,29
	Total Drosophilidae	1	18	1,4	87	5,29
Total Diptera	2	3	45	3,40	87	5,29
Lepidoptera	Nymphalidea	*Hypolimnas misippus*	48	3,6		
	Total Nymphalidea	1	48	3,6		
	Papilionidea	*Papilio demodecus*	30	2,3		
	Total Papilionidea	1	30	2,3		
	Pieridae	*Eurema exima*	21	1,6		
		Catopsilia florella	15	1,1		
	Total Pieridae	2	36	2,7		
	Acraeidae	*Acraea acerata*	33	2,5		
	Total Acraeidae	1	33	2,5		
Total Lepidoptera	4	5	147	11,1		
Total		**14**	**1323**	**100,0**	**1644**	**100**

p = (n/1644) x 100 = Percentage of visits; n = number of visit

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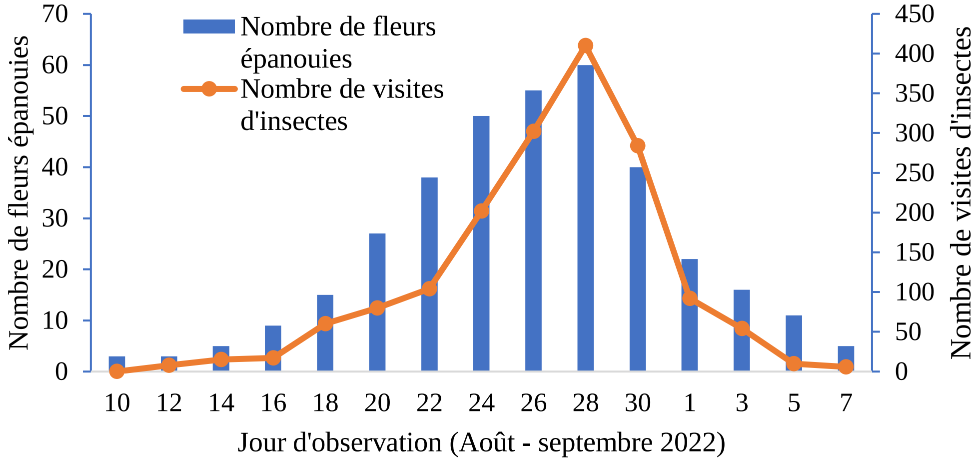

Figure 4: Variation in the number of visits according to the number of flowers in bloom

4.1.2.1.Absolute abundance of visiting insects

The greatest number of individuals simultaneously active on a flower was 2 in *A. mellifera* and one in all other insects at the two sites, respectively. The average abundance per 1000 flowers varied from 31 in *A. mellifera* to 5 in *Xylocopa olivacea* in Torok (Far North) and from 958 in *A. mellifera* to 182 in *Lasioglossum sp* in Vogzom in the north. The optimal value of the density of foraging insects corresponded to the month of peak flowering of the plant species studied, which is the month of August in the Sudano-Sahelian zone of Cameroon. Tables II and III below present the results relating to the abundance of visits of two Apidae on the flowers of *Cucurbita maxima* in Torok (Far North) and Vogzom (North).

Table II. Abundance of foragers of some insects per flower, ***Cucurbita maxima*****, in Torok (Far North) and Vogzom (North).**

Parameters studied / Insects	Torok (Far North)				Vogzom (North)			
	n	*m ± s*	*mini*	*maxi*	*N*	*m ± s*	*mini*	*maxi*
Apis mellifera	65	2.03 ± 0.79	1	4	67	2.26 ± 1.45	1	4
Xylocopa inconstans	36	1.03 ± 0.18	1	2				
Xylocopa olivacea	48	1.00 ± 0.00	1	1				
Lasioglossum sp.					50	1.04 ± 0.19	1	2

n : number of timed visits; ***m*** : mean; ***S*** : standard deviation; ***mini*** : minimum; ***Max:*** maximum.

Table III. Average abundance of foragers of some insects per 1000 flowers in Torok (Far North) and Vogzom (North).

Parameters studied / Insects	Torok (Far North)				Vogzom (North)			
	n	*m ± s*	*mini*	*maxi*	*N*	*m ± s*	*mini*	*maxi*
Apis mellifera	59	31.42 ± 16.11	64	625	67	958.54 ± 676.92	111	2667
Xylocopa inconstans	30	6 ± 1.30	1	12				
Xylocopa olivacea	15	5 ± 10	1	11				
Lasioglossum sp.					50	182.22 ± 89.11	111	444

Legend: *n* = sample; *m* = mean; *s* = standard deviation; *mini* = minimum; *max* = maximum

Figure 5: *Cucurbita maxima* flower foraged by several workers (Hebri, 2022)

4.1.2.2.Average duration of visits of Apidae per flower

The duration of visits was recorded in Apidae for both nectar and pollen collection visits. Pollen was collected from male flowers and nectar from both sexes, male and female flowers. The average duration of a visit per *Cucurbita maxima flower* varies according to the floral product harvested and for each floral product, depending on the species of insect and depending on the site.

On female flowers in the Torok site (Far North) the average duration of a visit varies from 6.15 (n = 134; s = 2.42) seconds in *Xylocopa inconstants* at 4.24 (n = 379; s = 2.42) seconds in *Apis mellifera*. Comparison of the mean length of visits between the two insect species on female flowers indicates a significant difference (t = 11.93; ddl = 208; P < 0.05). In Vogzom in the North, on female flowers, the average duration of a visit varies from 315.06 (n = 19; s = 146.30) seconds in *Lasioglossum* sp. 13.35 (n = 698; s = 20.56) seconds in *Apis mellifera*. Comparison of the mean length of visits between the two bee species on female flowers indicates a significant difference (t = 9.31; ddl = 145; P < 0.05).

On male flowers in the Torok site (Far North), the average duration of a visit varies from 5.28 (n = 34; s = 3.02) second in *Xylocopa olivaceae* at 3.80 (n = 1491; s = 1.86) seconds in *A. Mellifera*; Comparison of the mean length of visits between the two bee species on male flowers indicates a significant difference (t = 9.31; DDL = 145; P < 0.05). The same pattern in Vogzom (North) the average duration of a visit varies from 12.57 (n = 36; s = 3.02) second in *Lasioglossum* sp. and 4.11 (n = 651; s = 1.83) seconds in *A. Mellifera*; The comparison of the average length of visits between the two insect species indicates a significant difference (t = 9.31; DDL = 145; P < 0.05). Overall, the average values of the Apidae visit time are higher for nectar collection than for pollen. The values for the average length of visits for nectar or pollen collection are reported in Tables IV and V below.

Table IV. Average duration of a visit of the Apoidea species on the female flowers of *Cucurbita maxima* in Torok (Far North) and Vogzom (North).

Study sites / Insects	Torok (Far North) *N*	*m* ± s	*Mini*	*maxi*	Vogzom (North) *N*	*m* ± s	*Mini*	*maxi*
Apis mellifera	379	4.24 ± 1.29	1	7	698	13.35 ± 20.56	1	125
Xylocopa inconstans	134	6.15 ± 2.42	1	8				
Xylocopa olivacea	38	2.11 ± 1.21	1	6				
Lasioglossum sp.					19	315.06 ± 146.30	5	2340

Table V Average duration of visit of Apidae on male flowers of *Cucurbita maxima* in Torok (Far North) and Vogzom (North).

Study sites / Insects	Torok (Far North) *N*	*m* ± s	*Mini*	*maxi*	Vogzom (North) *N*	*m* ± s	*mini*	*maxi*
Apis mellifera	1491	3.80 ± 1.86	1	10	651	4.11 ± 1.83	1	5
Xylocopa inconstans	34	5.28 ± 3.41	1	8				
Xylocopa olivacea	51	2.04 ± 0.43	1	5				
Lasioglossum sp.					36	12.57 ± 3.02	1	54

4.1.2.3.Floral products harvested

Out of 528 and 1015 visits *Apis mellifera* studied in Torok (Far North) and Vogzom (North of the North) respectively**)**, 416 (78.78%) and 681 (67.09%) were devoted primarily to nectar collection (Figure 7), 91 (17.23%) and 305 (30.04%) to simultaneous pollen and nectar collection, 21 (3.97%) and 29 (2.85%) to exclusive pollen collection (Figure 8). In Torok, the 261 and 195 visits of *Xylocopa inconstans* and *Xylocopa olivacea* studied were devoted exclusively to the exclusive collection of nectar. 32 (55.17%) and 26 (44.82%) to the collection of nectar and pollen, out of 58 visits to *Lasioglossum sp.* at Vogzom.

With the exception of *Apis mellifera* which selectively and alternately collects pollen and nectar from the male flowers of *Cucurbita maxima* during the same visit, the results obtained illustrate that: the honey bee is fonder of nectar than pollen on the flowers of *C. maxima*. Data on the proportion of removals of the two floral products by Apidae are given in Table VI below.

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

Floral Products / Insects observed	NVE	Nectar NVN	%	Nectar and Pollen NVPN	%	Pollen NVP	%
Apis mellifera	528	416	78,78	91	17,23	21	3,97
Xylocopa inconstans	261	261	100,00				
Xylocopa olivacea	195	195	100,00				
Torok (Far North)							
Apis mellifera	1349	681	67,09	305	30,04	29	2,85
Lasioglossum sp.	58	32	55,17			26	44,82
Vogzom (North)							

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Legend: NVE = Number of visits studied; NVN = Number of visits devoted to nectar harvesting; NVPN = Number of visits devoted to the collection of nectar and pollen; NVP = Number of visits dedicated to pollen collection

Fig*ure* 6: Apis mellifera nectarivore

Figure 7: *Apis mellifera* pollinivore

4.1.3. Influence of some abiotic factors on the antophilic activity of foragers

Flower visits by flowering insects are more important in the morning, when the temperature is low (19.9°C) and the relative humidity high (84.81%). However, insect flower visits gradually decrease with increasing temperature and decreasing relative humidity. Overall, insect flower visits are strongly correlated with variations in air temperature and relative humidity. The linear regression is negative and significant between temperature and number of visits (y = -0.0147x + 30.95) with a high coefficient of determination (R^2 = 0.9734; ddl = 1, 3; $P < 0.05$) (Figure 9). The high temperature is detrimental to the insects foraging activity on pumpkin flowers.

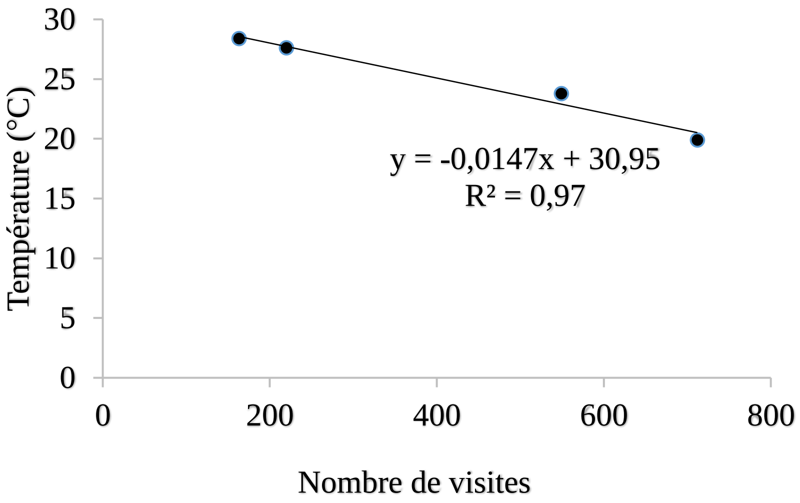

Figure 8: Linear regression equation between the number of visits and temperature

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4.2. Yield evaluation due to pollinating insects of *Cucurbita maxima*

4.2.1. Impact of insects on pollination *C. maxima*

When collecting pollen and/or nectar from a *C. maxima* flower, insects were frequently found in contact with the anthers and stigma. Some insects carried the pollen of the plant species studied from flower to flower (with the help of mouthparts and fur) on one or more pistillate flowers borne by the same plant. They could therefore intervene in geitonogamimy (transport of pollen grains from a male flower to a female flower carried by the same melon plant) or in xenogamy (transport of pollen grains from a male flower from plant A to a female flower carried by another melon plant B). As a result, these insects were actively involved in the cross-pollination of *Cucurbita maxima*.

For each of the two sites, in apidea (*Apis mellifera*, *Xylocopa inconstans*, *Xylocopa olivacea*); the frequency of contact between the stigma and the anthers during foraging was 100%. While in *Lasioglossum sp.*, the frequency of visits with insect-stigma contact was 90.47% and 88.88% with anthers. Table VII shows the frequency of contact between insects and the stigma of pumpkin flowers, for which the duration of visits per flower was recorded.

Table VII. Number and frequency of contacts between insects, anthers and stigma during floral visits of *Cucurbita maxima* in Torok (Far North) and Vogzom (North).

Insects	Number of visits studied	Visits with stigmatic contact		Number of visits studied	Visits with anther contact	
	n	N	(%)	n	Number	(%)
Apis mellifera	640	640	**100,00**	1491	1491	**100,00**
Xylocopa inconstans	261	261	**100,00**	34	34	**100,00**
Xylocopa olivacea	195	195	**100,00**	51	51	**100,00**
Torok (Far North)						
Apis mellifera	1349	1349	**100,00**	651	651	**100,00**
Lasioglossum sp.	84	76	**90,47**	36	32	**88,88**
Vogzom (North)						

4.2.2. Fruit and seed yields of *Cucurbita maxima*

C. maxima flowers that do not benefit from insect floral visits (Treatment B) abort and fall off. Only the flowers that benefited from insect floral visits (Treatment A and C) produced fruits and seeds as future seeds. The floral activity of insects on the flowers of *C. maxima* conditions the fruit and seed production of this plant species. In 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 (x^2 = 40.25; *ddl* = 2; P < 0.05) and between treatments A and C (x^2 = 15.02; *ddl* = 1; P < 0.05). And in Vogzom (North), the fruiting rate is 93.33% in treatment A, 0% in Traitemen B and 43.33% in treatment

C. The overall comparison indicates a significant difference between treatments A, B and C (x^2 = 52.77; *ddl* = 2; $P < 0.05$) and between treatments A and C (x^2 = 17.33; *ddl* = 1; $P < 0.05$)

The mean number of mature seeds per fruit was 255.31 ± 51.02 and 252.33 ± 38.02 in Treatment A in Torok (Far North) and Vogzom (North) respectively and zero in Treatment B at both sites since there was no fruit formation in these two treatments. From Tables VIII and IX below, the pollination rate is deduced through the ratio between the total number of mature seeds (NGM) obtained to the total number of sheaths (NTG) which reflects the total number of ovules obtained. This rate is [(2925/3028) x 100] = 96.59% [(6521/6638) x 100] = 98.23%. Respectively in Torok and Vogzom. This high rate reflects the fact that good pollination leads to good fertilization and an increase in seed and fruit yield in *Cucurbita maxima.* Bees are therefore responsible for improving fruit and seed yields in pumpkins.

The fruiting rate and number of mature seeds were zero in the T0 control treatment in which the female flowers were exempted from insect flower visits. This rate is 93.33% and 98.23% respectively in the T1 treatment whose flowers are kept in open pollination. The fruiting rate attributable to Apidae is {[(93.33 – 0.00)/93.33] x 100} = 100%. Similarly, the percentage of mature seeds attributable to honey bee pollinator activity is {[(93.33 – 0.00)/93.33] x 100} = 100%. The mean mass of mature fruit in the two sites was 4.26 kg. Overall, Apidae in general and the honey bee in particular contribute to the maintenance of fruit and seed production of *Cucurbita maxima*. The fruit and seed yield of *Cucurbita maxima* in Torok and Vogzom according to the different traitements.et recorded in tables VIII and IX below.

Table VIII. Fruit and pumpkin seed yields in Torok (Far North).

Parameters studied	**Treatment A**	**Treatment B**	**Treatment C**
Number of flowers studied	30	30	30
Number of fruits formed	23	0	8
Percentage of fruit formed (%)	76,67	0	26,66
Number of mature fruits obtained	12	0	0
Percentage of fruit that has reached maturity (%)	52,17	0	0
Total number of seeds obtained	3028	0	0
Number of mature seeds obtained	2925	0	0
Percentage of mature seeds obtained (%)	96,60	0	0
Number of immature seeds obtained	103	0	0
Percentage of immature seeds obtained (%)	3,40	0	0
Average number of mature seeds per fruit	252 ± 38	0	0
Abortion rate (%)	48	100	100

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Table IX. Fruit and seed yields of *Cucurbita maxima* in Vogzom (North).

Parameters studied	Treatment A	Treatment B	Treatment C
Number of flowers studied	30	30	30
Number of fruits formed	28	0	13
Percentage of fruit formed (%)	93,33	0	43,33
Number of mature fruits obtained	26	0	2 (Fbtvi)
Percentage of fruit that has reached maturity (%)	92,85	0	15,38
Total number of seeds obtained	6638	0	84
Number of mature seeds obtained	6521	0	30
Percentage of mature seeds obtained (%)	98,23	0	35,71
Number of immature seeds obtained	117	0	54
Percentage of immature seeds obtained (%)	1,76	0	64,28
Average number of mature seeds per fruit	255 ± 51	0	15
Abortion rate (%)	7,15	100	85

Legend : **(Fbtvi)** : female flowers, each of which benefited from 3 simultaneous visits of insects.

4.2.2.1.Linear relationship between fruit mass and number of mature seeds

Figure 11 below illustrates the linear regression equation between fruit mass and the number of mature seeds contained in each fruit. It can be seen from this figure that there is a positive and significant regression equation between these two parameters (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 usually contains.

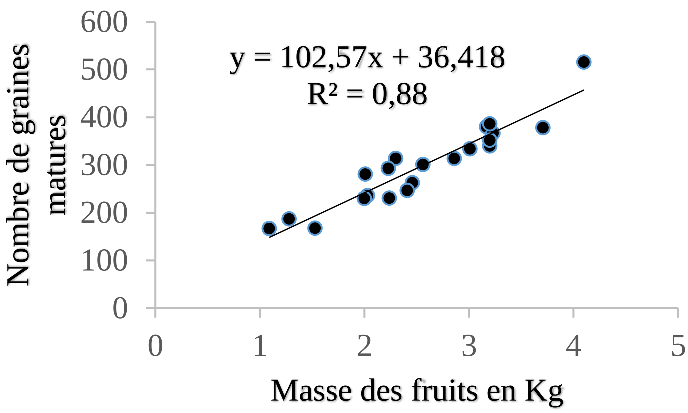

Figure 9 **:** Linear relationship between fruit mass and number of mature seeds

5. Discussion

The identification of pollinating insects on *Cucurbita maxima* in the Sudano-Sahelian zone of Cameroon has shown that the floricultural entomofauna associated with this crop is low in Vogzom (North) and diversified in Torok. It is represented by only 3 orders, 4 families and 5 species in Vogzom, while in Torok it is made up of 3 orders but 14 families and 29 species. The work of other authors on other cultivated plant species of Cucurbitaceae or not has recorded a relatively high number of species of flowering insects. Azo'o (2014) recorded 38 insect species on the flowers of *Citrullus lanatus*, 35 on *Cucumeropsis mannii* and 14 on *Abelmoschus esculentus* in Yaoundé. Overall, the floricultural entomofauna varies from one plant species to another, with variations in the number of species identified and the different species obtained.

The results of this work also indicate the prominence of Apidae in the floricultural entomofauna of pumpkin with two species, namely, *Apis mellifera* and *Lasioglossum* sp in Vogzom and *Apis mellifera*, *Xylocopa inconstans*, *Xylocopa pubescens*, *Xylocopa olivacea* in Torok. Of these insect species at both sites, *A. mellifera* comes out on top with a relative abundance of 82.06% and 40.5% respectively in Vogzom and Torok. Honeybees are known as the main flowering and pollinating insects of several other Cucurbitaceae species: *Cucurbita moschata* Canto-Aguilar & Parra-Tabla., (2000), *Cucumis sativus* (Gingrass *et al*., 1999; Calin *et al*., 2008).

The activity of Apidae in general and *A. mellifera* in particular is predominant in the morning from dawn and ends at midday (before 1 p.m.). It is known in the literature that pumpkin flowers, like other Cucurbit species such as watermelon, have an ephemeral lifespan (Philippe, 1991; Petersen *et al*., 2013 and Bomfim *et al.*, 2016); thus, they produce a lot of nectar in the morning from the anthesis. In addition, the peak of bee activity on the flowers of plant species is generally correlated with the greater availability of floral resources such as nectar and pollen, which explains the principle of optimal foraging that characterizes social bees (Pierre, 1997). *Apis mellifera* appeared mainly as a nectarivore on the flowers of *Cucurbita maxima* in the observation site at Torok and Vogzom. The results of this study indicate that 78.78% and 67.09% of the visits were devoted to the collection of nectar in Torok and Vogzom respectively. Similar results have been obtained on bee foraging activity on other Cucurbit species such as the watermelon *Citrullus lanatus* (Cordova, 1990 and Knapp *et al*., 2018) and *Cucumeropsis mannii* (Azo'o & Messi, 2012).

The results of this study show that there is a positive and significant correlation between the daily rhythm of flower bloom and the rhythm of floral visits of insects in general and Apidae in particular. This correlation highlights a second aspect that illustrates the principle of optimal supply or forage that characterizes the Apidae, particularly *A. mellifera* (Pierre, 1997). According to Faegri & Pijl (1979), the availability of floral resources plays an important role in bee foraging and pollination. These data underlie Fretwell & Lucas' (1970) theory of the ideal free distribution, which states that pollinator abundance follows the spatial distribution of flower densities in the field. Similar results have been obtained by several authors on several plant species, such as (Tchuenguem *et al*., 2009a) on *Helianthus annus* and (Djonwangwé *et al*., 2011) on *Ximenia americana.* This work also highlights the high quantity of male flowers compared to female flowers in the site of Torok and Vogzom. This predominance of the number of male flowers over the number of female flowers suggests the wide availability of pollen, which is advantageous for the pollination of female flowers.

The high abundances of *A. mellifera* on 1000 flowers highlight the good attractiveness of the nectar and the large landing surface of *Cucurbita maxima* flowers. Indeed, it is known that in *A. mellifera*, during foraging, workers use the pheromone to mark interesting food sources, with a view to directing other foragers to them (Jacob-Remacle, 1990). In addition, the experimental site in Vogzom was located near an apiary, hence the large deployment of workers on *Cucurbita maxima* flowers.

During their visits to the staminate flowers of *Cucurbita maxima*, honeybees in general came into contact with the anthers and passively collected pollen with their thick fur. Passing over the female flowers, the foragers came into contact with the stigmas and induced pollination of the female flowers visited. Vaissière *et al*. (1998) report that in entomophilous plants from which Cucurbitaceae originate (Klein *et al*. 2007), pollination requires the transfer of pollen through the bee seed coat.

Cucurbita maxima , like all other Cucurbitaceae, is a self-compatible and inter-compatible plant species and the pollen grains of this crop are not anemophilic, i.e. cannot be carried by the wind (Cordova, 1990). Only bees *A. mellifera* were found to be suitable for interfloral transport of its pollen, which favoured fertilisation in this plant species in both Torok and Vogzom. The significant activity of honey bees from the blossoming of the flowers coincides with the period of maturity of the stamens and receptivity of the stigmata of Cucurbitaceae (Philippe, 1991). In fact, in Cucurbits, when the flowers are open, the pollen is dehiscent and the stigma receptive for at least two hours (Philippe, 1991).

The optimal fruit yields obtained in the T1 treatment (free flowers) compared to those obtained in the T0 treatment in the two sites are therefore attributed to the pollinating activity of the bees on the flowers of *Cucurbita maxima*. According to Jean-Prost (1987), the more pollen grains a flower receives, the more potential it has to transform into a large fruit containing many seeds; This explains the positive and significant linear regression between the mass of the fruits obtained and the number of mature seeds they contain. These correlations explain the fact that efficient entomophilous pollination results in good quality fruit. In addition, poor pollination of female flowers leads to a reduced yield and poor quality fruit. This explains why in T2, T3, and T4 treatments, in Vogzom as in Torok, the abortion rate is high and the ripe fruits are not of good quality (low average mass and small diameter). A good production of *Cucurbita maxima* therefore depends on optimal pollinating activity of honeybees. The dependence of Cucurbitaceae on entomophilous pollination for fruit and seed production is well established by the results of several studies, in particular (Free, 1993; Stanghellini *et al*., 2002; Njoroge *et al*., 2004).

From the experimental fields, a projected yield of 10.65 t/ha in Vogzom and 7.45 t/ha in Torok was obtained by extrapolation. These optimal yields are lower than that obtained by (Polacchi *et al.*, 1982) which reached 5 – 40 t/ha with an average of 18 t/ha on the same species of *Cucurbita*. Cordova (1990) mentions that several factors can influence agricultural yield, including: variety, climate, cropping system, soil characteristics and the availability of pollinators.

Conclusion

Cucurbita maxima is a free-boding monoecious fruit of the Cucurbitaceae family. Among the insect species recorded on the flowers of this plant species, *Apis mellifera* seems to have played an important role in the pollination of *Cucurbita maxima*. Indeed, with a relative abundance of around 82.06% and 40.5%, this species transported the pollen grains of the male flowers to the stigma of the female flowers. Experiments have shown that the more a female flower receives floral visits from bees, the more pollen grains she receives and the more fruit and seed production is assured. Thus, the number of bee visits to the female flowers of the pumpkin guarantees the yields of this crop. Female flowers protected from insect visits have systematically aborted. Overall, honey bee activity conditions the fruit and seed production of *Cucurbita maxima*. On farms with *C maxima*, the absence of bee floricultural activity leads to zero yield.

Recommendation: Fund research to make an inventory of all pollinating insects of different crops in Cameroon, and finally develop a reliable policy aimed at the enhancement and conservation of the biodiversity of potential pollinators in Cameroon.

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