

Foraging Activity of *Apis mellifera* L. (Hymenoptera: Apidae) on Corn Panicles at Yaoundé, Cameroon

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(✉ Corresponding Author)

Dounia¹✉
Amada Brahim²
Chantal Douka³
Stephan Pierre Elono Azang⁴
Clautin Ningatoloum⁵
Roger Belinga Belinga⁶
Francis Gagni Ankemekom⁷
Fomekong Flavie⁸
Joseph Lebel Tamesse⁹
Fernand-Nestor Tchuenguem Fohouo¹⁰

^{1,2,3,4,5,6,7,8,9,10}Zoology Laboratory, Higher Teacher's Training College, University of Yaoundé I, Yaoundé, Cameroon

¹Email : dounia.nat@gmail.com

²National Committee for Development of Technologies, Ministry of Scientific Research and Innovation (CNDT/MINRESI), Yaoundé-Cameroon

³Department of Biological Sciences, University Adam Barka of Abéché, Abéché, Chad

¹⁰Laboratory of Applied Zoology, Faculty of Science, University of Ngaoundéré, Ngaoundéré, Cameroon

ABSTRACT

To evaluate the impact of *Apis mellifera* (Hymenoptera: Apidae) and other flowering insects on seed production of *Zea mays*, its foraging and pollinating activities were studied in Yaoundé, during the mild rainy season of 2016 and 2017. Treatments included unlimited plants access by all pollinator insects and bagged plants to avoid all visits. For each year of study, observations were made on 12 plants per treatment. *Apis mellifera* foraging behavior and effect of pollinator insects in seed yield were evaluated. Results show that this bee foraged pollen on *Z. mays* panicles during the whole blooming period. The percentage of lines completely filled with seeds, the mean number of seeds per lines and the percentage of normal seeds of unprotected plants were significantly higher than those of plants protected from pollinator insects. Pollinator insects included *A. mellifera* provoked a significant increment of the percentage of lines completely filled with seeds by 26.80% in 2016, 9.90% in 2017, the mean number of seeds per lines by 31.04% in 2016, 18.96% in 2017 and the percentage of normal seeds by 2.01% in 2016 and 2.53% in 2017. The installation of *A. mellifera* colonies and nests of pollinator insects close to *Z. mays* fields is recommended to increase seed yield in the region.

Keywords: *Apis mellifera*, *Zea mays*, Panicles, Pollen, Pollination.

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1. INTRODUCTION

In the agroecosystems, insects in general and Apidae in particular have great ecological and economical importance because they have positive influence on pollination [1]. Insects' pollinators can increase fruit yield and best quality of seeds [2]. The lack of pollinating insects during flowering time can lead to kidney yields fruits and/or seeds for some crops [3]. Maize (*Zea mays* L.) is originated to Mexico [4]. Currently, maize is the most widely grown cereal in the world [5]. This poaceae grows well on a wide variety of soils; his biological cycle varies from 90 to 120 days depending on the type of climate [6]. The cob is still elongated; covered with modified leaves called spathes and can contain up to 500 seeds [7]. Pollination of female flowers is allogamous, but self-pollination is also observed, pollen is produced by male flowers called panicles [6, 7]. All maize in Africa is used for human alimentation; it is also used for animal feed [8]. In the industrial sector, starch extracted from dry corn is used for manufacture of alcohol; the oil produced is used for human diet; manufacture of soaps, and production of biofuels [9]. In Cameroon the floral entomofauna of *Zea mays* is not very well studied. The few studies from the literature are that for Tchuenguem, et al. [7] which indicate that Halictidae visit the panicles and collected pollen. According to Gallai, et al. [10] floral entomofauna of a plant species can vary from one region to another. This work was conducted to study the activity of *A. mellifera* on *Z. mays* panicles and determinate assess of pollinator insects on seeds yields of this Poaceae.

2. MATERIALS AND METHODS

2.1. Site and Biological Materials

The studies were conducted from March to June in 2016 and 2017 (mild rainy season) in the fields located at the campus of Higher Teacher's Training College of University of Yaoundé I (Latitude 10° 62' N, Longitude 14° 33' E and altitude 756 m) in the Center Region of Cameroon. This region belongs to the tropical rain forest agro-ecological zone [11]. The climate is equatorial, guinean-type with four seasons : the peak rainy season (August to November), the peak dry season (November-March), the mild rainy season (March-July) and the mild dry season (July-August); the mean annual temperature is 25°C, while the mean annual relative humidity is 79% [12]. The experimental plot was an area of 600 m². The animal material was represented by insects naturally present in the environment and a colony of *Apis mellifera* (Hymenoptera: Apidae) located in the roof of a building at 5 m from the experimental field. Vegetation was represented by wild species and cultivated plants. The plant material was represented by the seeds of *Zea mays* provided by the Institute of Agricultural Research for Development in Nkolbisson (Yaoundé).

2.2. Planting and Maintenance of Culture

On March 15, 2016 and March 26, 2017, the experimental plot was divided into six sub-plots of (6*6 m²). Seeds were sown on five lines per subplot; each line had six holes and each hole received five seeds. The spacing was 1 m between rows and 1 m on rows. Each hole was 5 cm depth [5]. Two weeks after germination (March 30, 2016 and April 8, 2017), the plants were thinned and only two were left per hole. From thinning at the opening of the first panicle (May 12, 2016 and May 21, 2017), weeding was performed manually as necessary to maintain plot weeds-free.

2.3. Study of the Activity of *Apis Mellifera* on Panicle of *Zea Mays*

Observations were conducted on individually opened flowers each day, from May 16 to 26 in 2016 and from May 24 to June 4 in 2017 at one hour interval from 7 to 16 h (7-8 h, 9-10 h, 11-12 h, 13-14 h, 15-16 h). In a slow walk along all the lines, the identity of all insects that visited panicle of *Z. mays* was recorded. All insects encountered

on panicles were recorded and the cumulated results expressed in number of visits to determine the relative frequency of *A. mellifera* in the anthophilous entomofauna of *Z. mays*. Direct observations of the foraging activity of worker bees on panicles were made. The floral products collected by the foragers were recorded for the same dates and time slots as that of the insect counts. The duration of visits [13] was timed to the same dates and in four time slots (8-9 h, 10-11 h, 12-13 h, 14-15 h). Abundances (larger numbers of individuals simultaneously active) per panicles and per 1000 panicles (A_{1000}) were recorded on the same dates and times lots as that of there registration of the duration of visits. The first parameter was recorded as a result of direct counts. For the abundance per 1000 panicles, honey bees were counted on aknown number of open panicles; $A_{1000} = [(A_x/F_x)* 1000]$, where F_x and A_x are respectively the number of panicle and the number of individual bees actually counted on F_x [13]. During the days of investigation, the temperature and humidity of the study site were recorded every 30 min, from 7 am to 16 pm, using a thermohygrometer installed in the shade.

2.4. Evaluation of the Impact of Pollinator Insects on the yield of Zea Mays

In May 14 and May 22 respectively in 2016 and 2017, 24 plants of *Z. mays* at the bud stage were labeled. 12 of the total plants were allowed for treatment 1 (opened pollination) and 12 others plants belong to treatment 2 (bagged with gauze nets to prevent visitors or external pollinating agents) (figure 1). For each year, three weeks after the withering of the last panicles, the number of seeds formed in the ears of corn for each treatment was counted. The percentage of lines completely filled with seeds, the mean number of seeds per lines and the percentage of normal seeds were then calculated for each treatment. The percentage of lines completely filled with seeds was calculated using the formula: $Pr_1 = \{[(Pr_1 - Pr_2) / Pr_1] * 100\}$, where Pr_1 and Pr_2 are the percentage of line completely filled with seeds in treatment 1 and 2. The percentage of line completely filled with seeds of each treatment (Pr) is $Pr = [(P_2 / P_i) * 100]$, where, P_2 is the number of line completely filled by seeds and P_i the number of line initially set. The mean number of seeds per lines and the percentage of normal seeds were then calculated for each treatment.

2.5. Data Analysis

SPSS soft ware and Microsoft Excel were used for three tests: Student's (t) for comparison of means, correlation coefficient (r) for the study of linear relationship between two variables, Chi-square (χ^2) for the comparison of percentages.

3. RESULTS

3.1. Activity of Apis Mellifera on Zea Mays Panicle

3.1.1. Seasonal Frequency of Visits

Amongst the 1076 and 1627 visits of 8 and 11 insects species recorded on *Z. mays* panicles respectively in 2016 and 2017, *A. mellifera* was the most represented insect with 892 visits (82.91%) in 2016 and 1025 visits (62.99%) in 2017 (Table 1). The difference between these two percentages is highly significant ($\chi^2 = 124.31$; $df = 1$; $p < 0.001$).

3.1.2. Floral Substances Harvested

From our field observations, *A. mellifera* workers were found to collect exclusively pollen on *Z. mays* panicle (Figure 2).

3.1.3. Abundance of Apis Mellifera Workers

In 2016, the highest mean number of *A. mellifera* workers simultaneously in activity was four per panicle ($n = 30$;

$s = 0.21$) and 2832 per 1000 panicles ($n = 30$; $s = 191$). In 2017, the corresponding results were three per panicle ($n = 30$; $s = 1.33$) and 2120 per 1000 panicles ($n = 30$; $s = 102$). The difference between the mean number of bees per 1000 panicles in 2016 and 2017 was highly significant ($t = 68.58$; $df = 58$; $p < 0.001$).

3.1.4. Duration of Visits

In 2016, the mean duration of a visit on *Z. mays* panicle was 46.23 sec ($n = 30$; $s = 12.36$). In 2017, the corresponding figure was 40.50 sec ($n = 30$; $s = 9.86$). The difference between the mean duration of the visit in 2016 and 2017 was highly significant ($t = 7.55$; $df = 58$; $p < 0.001$).

3.1.5. Daily Rhythm of Visits

Apis mellifera workers were active on *Z. mays* panicle from 7 am to 16 pm, with a peak of visits between 11-12 am in 2016 and from 7 am to 14 pm with a maximum of visits between 9-10 am in 2017 (Figure 3). Climatic conditions have influenced the activity of *A. mellifera* workers on *Z. mays* panicles in field conditions. The correlation was positive and significant between the number of *A. mellifera* visit son *Z. mays* panicles and temperature in 2016 ($r = 0.88$; $df = 4$; $p < 0.05$) and in 2017 ($r = 0.56$; $df = 4$; $p < 0.1$). The correlation between the number of visits and the relative humidity of the air was positive and no significant in 2016 ($r = 0.25$; $df = 4$; $p > 0.05$) and negative and significant 2017 ($r = -0.87$; $df = 4$; $p < 0.05$) (figure 3).

3.2. Apicultural Value of Zea Mays

During the mild rainy season, we observed a well elaborated activity of *A. mellifera* workers on *Z. mays* panicles. In particular, there was very good pollen collection and workers faithfulness to its panicles. These data allow to place *Z. mays* in highly polliniferous bee plants.

3.3. Impact of Flower-Feeding Insects in Pollination and Yields of Zea Mays

During pollen harvest, flowering insects of *Z. mays* were regular shakes panicles releasing the pollen which is then transported by the wind to the female flowers. Thus these insects increased the pollination possibilities of this plant species. Table 2 presents the results on the percentage of lines completely filled with seeds, the mean number of seeds per lines and the percentage of normal seeds in different treatments. From this table, we documented the following:

a- The comparison of the percentage of lines completely filled with seeds showed that the difference was highly significant between treatment 1 (opened plants) and treatment 2 (bagged plants) in the first year ($\chi^2 = 9.84$; $df = 1$; $p < 0.001$) and not significant between these two treatments in the second year ($\chi^2 = 2.09$; $df = 1$; $p > 0.05$). Consequently, in 2016 and 2017, the percentage of lines completely filled with seeds of opened plants was higher than that of bagged plants ($\chi^2 = 9.15$; $df = 1$; $p < 0.001$).

b- The comparison of the mean number of seeds per lines showed that the difference was highly significant between treatments 1 and 2 ($t = 169.47$; $df = 152$; $p < 0.001$) in 2016 and in 2017 ($t = 91.06$; $df = 187$; $p < 0.001$). Consequently, in 2016 and 2017, a mean number of seeds per lines on ear of the unprotected plants were higher than that of protected plants.

c- The comparison of the percentage of normal seeds showed that the difference was highly significant between opened plants and protected plants on treatments 1 and 2 in the first year ($\chi^2 = 65.41$; $df = 1$; $p < 0.001$) as well as in the second year ($\chi^2 = 99.82$; $df = 1$; $p < 0.001$). Thus, in 2016 and 2017 the percentage of normal seeds in opened plants was higher than that of protected plants in 2016 and in 2017.

The numeric contribution of pollinating insects on the percentage of lines completely filled with seeds, the mean number of seeds per lines and the percentage of normal seeds were respectively 26.80%, 31.04% and 2.01% in 2016. The corresponding figures were 9.70%, 18.96% and 2.53% in 2017. For the two cumulate years, the numeric contributions were 18.25%, 25.00% and 2.27% for the percentage of lines completely filled with seeds, the mean number of seeds per lines and the percentage of normal seeds respectively. The impact of pollinating insects on seeds yields was positive and significant.

4. DISCUSSION

Apis mellifera was the main floral visitor of *Z. mays* during the observation period. This bee has been reported as the main floral visitor of the panicles of plant in Cameroon [7]. *Apis mellifera* was also shown to be the floral visitors of other plants such as *Glycine max* in Douala [14] *Sesamun indicum* in Bambui [15] *Phaseolus vulgaris* in Ngaoundéré [16] *Vitellaria paradoxa* in Garoua [17] and *Gossypium hirsutum* in Maroua [18]. The peak of the activity of *A. mellifera* on *Z. mays* panicles was located between 9 and 12 am, which correlated with the highest availability of pollen on *Z. mays* panicles. The significant difference between the mean duration of the visit could be attributed to the availability of pollen on the panicles or the variation in the diversity of flowering insects from one year to another. *Apis mellifera* harvested pollen; this could be attributed to the needs of colonies during the corresponding period or because this Poaceae do not produce nectar. This research indicates that *A. mellifera* can provide benefits to pollination management of *Z. mays*. During the collection of pollen on each panicle, *A. mellifera* foragers were always shakes panicles releasing the pollen which is then transported by the wind to the female flowers. The significant contribution of *A. mellifera* in seed yield of *Z. mays* is in agreement in Center Region of Cameroon [7]. The weight of *A. mellifera* played a positive role during pollen collection. Flowering insects shook panicles and could facilitate the liberation of pollen by anthers then transported by the wind from the female flowers for the same plant or the female flowers for another plant of *Z. mays* [19]. The higher production of seeds per lines and that of normal seeds in the treatment with panicles visited by all insects compared to treatment with protected plants showed that *A. mellifera* and another pollinator insect's visit were effective in increasing pollination.

5. CONCLUSION

This study reveals that *Z. mays* is a highly polliniferous bee plant that obtained benefits from the pollination by flowering insects among which *A. mellifera* is the most important. The comparison of seed sets of protected plants to that of plant visited by all insects under scores the value of these pollinator insects in increasing seed productions as well as seed quality. In the Center Region of Cameroon, the installation of *A. mellifera* hive close to *Z. mays* fields is recommended for the increase of theseed yields of this valuable crop.

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Table-1.Diversity of insects on *Zea mays* panicles in 2016 and 2017, number and percentage of visits of different insects at Yaoundé

Insects			2016		2017		Total	
Order	Family	Genus,species,Sub-species	<i>n</i> ₁	<i>p</i> ₁ %	<i>n</i> ₂	<i>p</i> ₂ %	<i>n</i> _{1,2}	<i>p</i> _{1,2} %
Coleoptera		(1 sp.) ^{po}	5	0.42	6	0.36	11	0.40
Diptera	Calliphoridae	(1 sp.) ^{po}	0	0	96	5.90	96	3.55
	Muscidae	<i>Muscadomestica</i> ^{po}	10	0.93	156	9.58	166	6.14
Hymenoptera	Apidae	<i>Apismellifera</i> ^{po}	892	82.91	1025	62.99	1917	70.94
		<i>Xylocopaolivacea</i> ^{po}	0	0	103	6.33	103	3.81
		<i>Amegilla</i> sp. ^{po}	0	0	53	3.25	53	1.96
	Halictidae	<i>Halictus</i> sp. ^{po}	109	10.13	156	9.58	265	9.81
	Eumenidae	<i>Delta</i> sp. ^{po}	36	3.34	15	0.92	51	1.88
	Vespidae	<i>Synagriscornuta</i> ^{po}	0	0	9	0.55	9	0.33
Lepidoptera	Acraeidae	<i>Acraeaacerata</i> ^{rt}	2	0.18	0	0	2	0.08
Nevroptera		(1 sp.) ^{pr}	7	0.65	7	0.43	14	0.51
Orthoptera		(1 sp.) ^{df}	15	1.40	1	0.06	16	0.59
Total	12 species		1076	100	1627	100	2703	100

*n*₁: number of visits on 12 panicles in 10 days. *n*₂: number of visits on 12 panicles in 10 days. *p*₁ et *p*₂: percentages of visits. *p*₁=(*n*₁/1076)*100. *p*₂=(*n*₂/1627) *100. *n*_{1,2}=(*n*₁ + *n*₂). *p*_{1,2}=[(*n*₁ + *n*₂)/2703]*100. *po*:visitor collected pollen. *df*: defoliator. *rt*: rest. *pr*: predator. *sp*:undetermined species.

Table- 2. Percentage of lines completely filled with seeds, mean number of seeds per lines and percentage of normal seeds according to different treatments of *Zea mays* in 2016 and 2017 at Yaoundé

	Year	IMP	CCF	% of lines completely filled with seeds	number of seeds per lines		Normal Seeds	Total Seeds	% Normal seeds
					<i>m</i>	<i>s</i>			
Treatment 1 (opened plants)	2016	12	12	81.11	41.33	3.41	7024	7096	98.98
Treatment 2 (bagged plants)		12	12	59.37	28.50	1.64	5328	5493	96.99
Treatment 1 (opened plants)	2017	12	12	85.10	38.66	4.94	7152	7220	99,05
Treatment 2 (bagged plants)		12	12	76.84	31.33	2.08	5484	5680	96,54

IMP : isolated maize plant ; CCF : corn cob formed



Figure- 1. Plant of *Zea mays* isolated from insects (Dounia, May 30, 2017)



Figure-2. *Apis mellifera* collecting pollen in a panicle of *Zea mays* (Dounia, May 21, 2016)

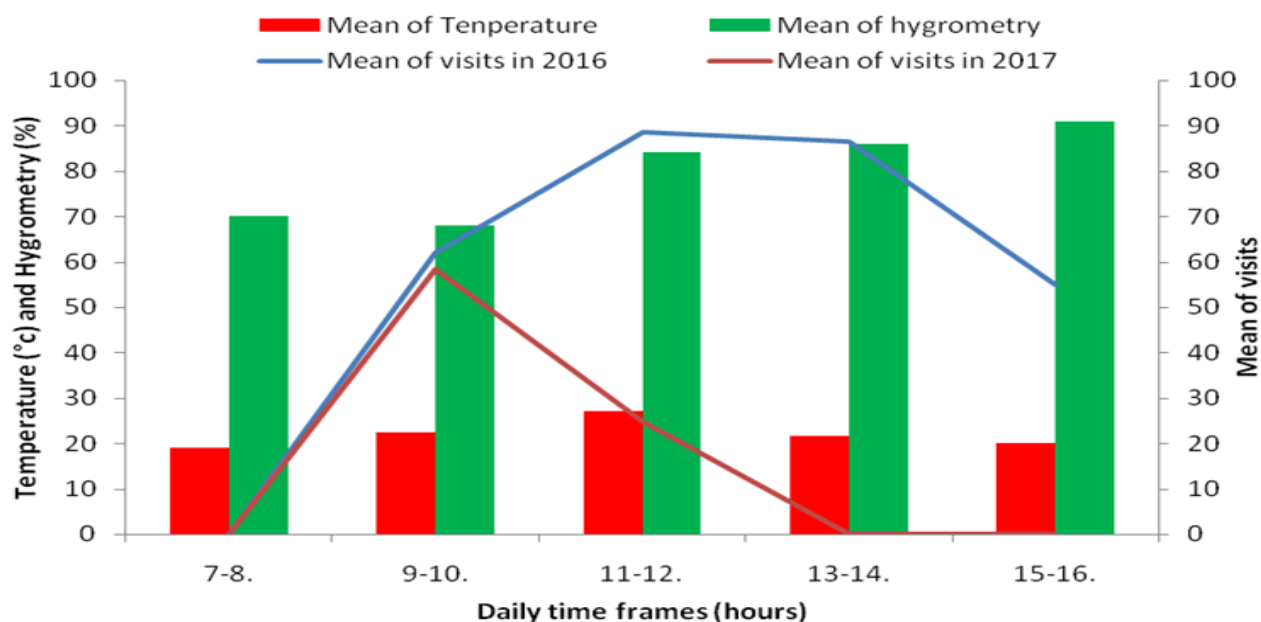


Figure-3. Mean daily temperature and humidity and mean number of visits of *Apis mellifera* on *Zea mays* panicles in 2016 and 2017

Source of figure 3

	7-8.	9-10.	11-12.	13-14.	15-16.
Mean of visits in 2016	0	61,9	88,59	86,59	54,86
Mean of visits in 2017	16.78	58,34	24,87	0	0
Mean of Temperature	19,1	22,4	27,1	21,6	20,1
Mean of hygrometry	70	68	84	86	91

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