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Mazi Sanda
University of Ngaoundéré, Faculty of Science, Department of Biological Sciences, B.P.:454 Ngaoundéré, Cameroon

Kingha Tekombo BM
University of Ngaoundéré, Faculty of Science, Department of Biological Sciences, B.P.:454 Ngaoundéré, Cameroon

Deli Kodji Pra
University of Ngaoundéré, Faculty of Science, Department of Biological Sciences, B.P.:454 Ngaoundéré, Cameroon

Faibawa E
University of Ngaoundéré, Faculty of Science, Department of Biological Sciences, B.P.:454 Ngaoundéré, Cameroon

Tchuenguem Fohouo FN
University of Ngaoundéré, Faculty of Science, Department of Biological Sciences, B.P.:454 Ngaoundéré, Cameroon

Brückner D
Forschungsstelle für Bienenkunde, Universität Bremen, FB2, Postfach 33 04 40, 28334 Bremen, Germany

Correspondence
Mazi Sanda
University of Ngaoundéré, Faculty of Science, Department of Biological Sciences, B.P.:454 Ngaoundéré, Cameroon

Role of pollinators in enhancing pod and seed set of *Arachis hypogaea* Variety 28-206 (Fabaceae) at Tchabal-Mounguel (Ngaoundere, Cameroon)

Mazi Sanda, Kingha Tekombo BM, Deli Kodji Pra, Faibawa E, Tchuenguem Fohouo FN and Brückner D

Abstract
Flowers of *Arachis hypogaea* were observed at Tchabal-Mounguel, in 2017 in order to study the activity of major pollinators and to evaluate their impact on pod and seed yields. Investigations focused on two treatments differentiated by the presence or absence of protection on flowers. Insect's foraging behavior, pollinator activity, fruiting rate, number of seeds per pod, and percentage of normal seeds were evaluated. The mean duration of one visit per flower varies from 18.67 sec to 68.32 sec; the mean foraging speed varies from 1.99 flowers/min to 5.15 flowers/min. By comparing the yield of unprotected flowers to those protected from insect visits, it appears a significant increase in fruiting rate of 15.09%, mean seed per pod of 3.94%, percentage of seed per pod of 24.81% and the percentage of seed weight of 9.09% due to flowering insects. To improve pod and seed yields of *A. hypogaea*, it is advisable to construct nesting sites for Halictidae in or near the fields of this Fabaceae.

Keywords: *Arachis hypogaea*, flowering insect, flower, pollen

1. Introduction
The production of cultivated or spontaneous plants, the quality of fruits or seeds consumed by humans depend on pollinators [1]. In fact, 90% of the 250 000 species of angiosperms in the world depend on entomophilous insects [2]. Nevertheless, the majority of African farmers are unaware that in the absence of pollinating insects or in the presence of an insufficient number of these arthropods during flowering, yields may be greatly reduced or null [3]. At the global level, the value of the pollination service is estimated at 100215 billion CFA Francs [4].
In Cameroon, the relationships between several Fabaceae and their pollinating insects are more and more known due to works done for several years, particularly in the Adamaoua Regions [5-10], from the Center [11-15] and the Far North [16-18]. Despite these important works, the interactions between many plants grown in Cameroon and their anthophilous insects remain unknown. In order to ensure the continuity of studies on the pollination of Fabaceae, we studied the relationship between a plant widely cultivated and consumed in Cameroon, *Arachis hypogaea* Linnaeus 1753 and its flowering insects.
Arachis hypogaea commonly called peanut is a legume native to Brazil [19]. This plant is grown in all tropical, subtropical and some European countries [20]. In Cameroon, it is grown for its seeds that are used as food for humans and its leaves are used to feed livestock [19]. The mean annual production of groundnut seeds in this country is estimated at 536187 tons / year for an area of 377496 hectares with a yield of 1.42 tons / hectare [21].
Before our work, the flowering entomofauna of *A. hypogaea* was studied in particular in Malawi [22], in Israel by Carmin (quoted by [23]), in Egypt [24] and in Cameroon [11, 9]. It is known that the flowering entomofauna and its impact on pollination and plant yields vary in space and time [25], it is therefore, important to further the investigations on the relationship between *A. hypogaea* and its flowering insects in Cameroon, to supplement the existing data for this country. Moreover, flowering insects and its pollinating impact of *A. hypogaea* variety 28 - 206 has not been addressed in previous works.
The main objective of this work was to contribute to the understanding of the relationships between *A. hypogaea* and its flower visiting insects, for their optimal management in Cameroon.

It has four specific objectives

- inventory of the flowering insects of *A. hypogaea* var. 28 – 206;
- study the activity of these insects on this Fabaceae flowers;
- estimate the apicultural value of this plant species;
- evaluate the impact of flowering insects on pod and seed yields of this legume.

2. Material and Methods

2.1 Study site, experimental field and biological material

Investigations were conducted at Tchabbal-Mounguel (latitude: 7° 33'23.4"N, longitude: 13° 33'19.7"E, altitude: 1376m asl), Ngaoundéré III Subdivision, Vina Division, Adamaoua Region in Cameroon. This Region is located between the 6th and 8th degrees of North latitude and between the 11th and 15th degrees of East longitude and belongs to Guinean high savanna ecological zone [26].

The climate is Sudano-Guinean, mild and fresh, characterized by two seasons: a rainy season (April to October) and a dry season (November to March).

The mean monthly temperature varies from 19.42 °C (December) to 24.08°C (March); the mean monthly humidity varies from 47% (February) to 83% (August); the monthly rainfall varies from 0 mm (December and January) to 360.2 mm (August); the duration of monthly sunstroke varies from 104.58h (August) to 310.56h (December) [27]. In an experimental field of 157.5 m2, the seeds of *A. hypogaea* var. 28-206 (Figure 1) were sown. Except for *Apis mellifera*, the majority of insects observed on *A. hypogaea* flowers were from naturally occurring insects.

2.2 Methods

2.2.1 Preparation of the experimental field, sowing and weeding

From the 26th April to 10th May 2017, an experimental plot of 157.5 m^2 was cleared, fenced and plowed and divided into 9 subplots of 3 m long, 1.5 m wide and 10 cm high each. The spacing between the subplots was 1 m. The seeds of *A. hypogaea* were sown on May 13, 2017 on ten lines per subplot at a rate of one seed per hole. The spacing between the plants on and between the lines was 15 cm.

From the germination (May 19th) to the blossoming of the first flower (June 16th), the field was regularly weeded with hoe. Weeding was performed manually as necessary to maintain plots weed-free.

2.2.2 Determination of the breeding system of *Arachis hypogaea*

Few days before flowering, two treatments were constituted: treatment 1: 600 plants belonging to three subplots were left unprotected (free pollination) and on which no insect was captured, treatment 2: 600 plants belonging to three subplots that have been protected with mesh cages (1 mm^2 mesh) to prevent insects' visits.

At harvest, the number of pods formed was counted on each plant of treatments 1 and 2. For each treatment, the fruiting index (*Ifr*) was calculated as follow: $Ifr = (F2 / F1)$, where *F2* is the number of pods formed and *F1* the number of flowers initially set [28].

The allogamy rate (*TC*) from which derives the autogamy rate (*TA*) was expressed as the difference in fruiting indices between treatment *X* (unprotected plants) and treatment *Y* (protected plants) according to [29]: $TC = \{[(IfrX - IfrY) / IfrX] * 100\}$, where *IfrX* and *IfrY* are respectively the fruiting indices in unprotected and protected subplots; $TA = (100 - TC)$.

2.2.3 Study of the activity of flowering insects on *Arachis hypogaea* flowers

Observations were done every day, from the blooming of the first flowers until the fading of the last flower, according to six time slots: 6-7 am; 8-9 am; 10-11 am; 12-1 pm; 2-3 pm; 4-5pm. At each passage and according to the time slot, insects encountered on blooming flowers of treatment 1 were identified and counted. Data on frequency of visits of various identified flowering insects made it possible to determine the place of each insect in *A. hypogaea* entomofauna, according to the following formula: $Fi = (Vi / VI) * 100$, with *Vi* = number of visits of insect *i* on flowers of treatment 1 and *VI* the number of visits of all insects on same flowers [28].

Floral product (pollen) collected by insects was noted during the same dates and time slots as for the frequency of visits. An insect that scratches the anthers of a flower with its mandibles and metathoracic legs is a pollen harvester and in this case, pollen grains can be observed its transport organs.

2.2.4 Abundance of foragers

Abundance per flower was recorded following direct counts. For the abundance per 1000 flowers (A_{1000}), foragers were counted on a known number of flowers. A_{1000} was calculated using the following formula: $A_{1000} = [(A_x / F_x) * 1000]$, where F_x and A_x were respectively the number of open flowers and the number of visitors counted on open flowers of treatment 1 at *x* moment [25]. This parameter was recorded according to the following time slots 7-8 am, 9am -10 am, 11 am-12 pm, 1pm-2pm, 3pm-4pm and 5pm-6pm, with at least six values per time slot, when foragers' activity allowed it.

2.2.5 Duration of visits per flower

The duration of visits per flower is the time an insect spent on a flower to collect pollen [25]. The stopwatch is set to zero and as soon as an insect lands on a flower the stopwatch was lunched and it was stopped as soon as the insect leaves it. The duration of the visit corresponds to the value read on the stopwatch [25]. Data were recorded during the same dates and daily time slots as the abundance of visits.

2.2.6 Foraging speed

It is the number of flowers visited per minute [39]. The stopwatch was lunched as soon as an insect lands on a flower and stopped as soon as it is out of sight; concomitantly, the number of flowers visited is counted. The foraging speed (*Fs*) is calculated according to the formula:

$Fs = (F_i / d_i) * 60$ where d_i is the duration given by the stopwatch and F_i is the number of flowers corresponding to d_i [25].

The influence of the fauna was systematically recorded during the same time of visits per flower. Each interrupted visit was noted and the author was identified.

Temperature and hygrometry of the station were recorded every 30 minutes, from 6am to 6pm throughout the period of investigations using a portable thermo-hygrometer (Tecno Line WS 9119) installed in the shade. The effects of wind, sunshine, cloud and rain were also recorded.

2.2.7 Estimation of the apicultural value of *Arachis hypogaea*

As in other works [13, 15, 32], the apicultural value of *A.*

hypogaea was evaluated using data on: the flowering and the attractiveness of the workers of *A. mellifera* vis - à - vis the pollen.

2.2.8 Evaluation of the impact of the flowering insects on the yields

It was based on the

- impact of flowering insects on pollination;
- impact of flowering insect on fruiting;
- comparison of fruit (fruiting rate) and seed (mean number of seeds per pod and percentage of normal seeds) yields from unprotected flowers (T1) to those protected from insects (T2) [28].

The fruiting rate (*Pi*) due to the influence of flowering insects was calculated using the formula: $Pi = \{[(F1 - F2) / F1] * 100\}$ where *F1* and *F2* are the fruiting rates in treatments 1 (free flowers) and 2 (protected flowers) respectively. For treatment x, the fruiting rate (Fx) is: *Fx* = [(number of fruits / number of flowers) * 100] [25].

The percentage (*P*) of the number of seeds per pod due to the influence of flowering insects was calculated using the formula: $P = \{[(g1 - g2) / g1] * 100\}$ where *g1* and *g2* are the mean number of seed per pod in treatments 1 and 2 respectively [25].

The percentage (*Pn*) of normal (well developed) seed due to the influence of flowering insects was calculated as follow: $Pn = \{([Pn1-Pn2) / Pn1] * 100\}$ where *Pn1* and *Pn2* are the percentages of normal seeds from treatments 1 and 2 respectively [25].

2.3 Data analysis

As in other works [7, 33, 32], data analysis was done using descriptive statistics (means, types and percentages), Student's t-test for comparison of two means, khi- square ($\chi 2$) for the comparison of percentages, Pearson's Coefficient of Correlation (*r*) for the study of linear relationships between two variables and ANOVA (*F*) to compare means of more than two samples. We also used Excel 2016 software.

3. Results

3.1 Reproductive mode of *Arachis hypogaea*

On *A. hypogaea*, 15994 and 14661 flowers were studied in treatments 1 and 2 respectively. The fruiting index was 0.53 in treatment 1 and 0.45 in treatment 2. Thus, TC = 15.09% and TA = 84.91%. Therefore, *A. hypogaea* var. 28 - 206 has a mixed mating system allogamous - autogamous, with predominance of autogamy.

3.2 Place of each insect in *Arachis hypogaea* entomofauna

From June 16 to August 13, 2017, 416 visits of nine species of insects belonging to three orders and seven families were recorded on 15994 flowers of treatment 1. Table 1 presents the list of these insects with their percentages of visits. This table indicates that Hymenoptera are the most important order with 83.18% of 416 visits. They most represented family was Halictidae, among which *Lasioglossum* sp. 1 ranked first with 76.44%. Coleoptera and Lepidoptera were poorly represented with 8.41% of visits each.

The high frequency of visit of Halictidae on flowers could be explained by the good attractiveness of its pollen vis - à – vis of these insects, its accessibility, availability and also by the presence of their nests in the experimental field of the Fabaceae.

During the period of investigation, temperature, humidity, rain and wind more or less influenced the activity of insects on flowers. We found that there is no correlation between the number of insects and the temperature ($r = 0.71$, $df = 4$, $P > 0.05$) on the one hand and the number of visits and hygrometry ($r = - 0.56$, $df = 4$, $P > 0.05$) in others.

Table 1: Flowering insects recorded on *Arachis hypogaea* flowers at Tchabal-Mounguel in 2017, number and percentage of visits of different insects

Insects			Visits	
Ordre	**Famille**	**Genre et Espèce**	***n***	***P* (%)**
Coleoptera	Chrysomelidae	(sp.) (flower eater)	32	7.69
	Lagriinae	*Lagriavillosa* (flower eater)	2	0.48
	Meloidae	*Coryna* sp. (flower eater)	1	0.24
	Total Coleoptera	3	35	8.41
Hymenoptera	Apidae	*Apis mellifera* (po)	4	0.96
	Formicidae	*Polyrachis* sp.(po)	17	4.10
	Halictidae	*Lasioglossum* sp. 1 (po)	318	76.44
		Lasioglossum sp. 2 (po)	7	1.68
	Total Hymenoptera	4	346	83.18
Lepidoptera	Pieridae	*Eurema* sp. 1 (look for nectar)	29	6.97
		Eurema sp. 2 (look for nectar)	6	1.44
	Total Lepidoptera	2	35	8.41
Total		9 species	416	100

n= number of visits on 15994 flowers in 58 days; ***P***: pourcentage of visits=(***n***/ 416)* 100 ;sp.: undetermined species; po : pollen harvest

3.3 Rhythm of visits according to daily time frames

Insects' visits were abundant on *A. hypogaea* flowers in the morning, with a daily pic of activity situated between 10 am and 11 am. This daily period could correspond to the time of day when pollen is released in large quantities and accessible to insects. Between 6:00 am and 7:00 am, no insect visits were recorded. This period of the day could correspond to the time of day when the flowers of this Fabaceae are not yet well bloomed (Table 2).

Table 2: Number of insects' visits on *Arachis hypogaea* flowers according to daily time frames of observation at Tchabal-Mounguel in 2017

Insect species	Daily Periodes (hour)								
	8 – 9		10 – 11		12 – 13		14 – 15		T
	n	***P* (%)**	***n***	***P* (%)**	***n***	***P* (%)**	***n***	***P* (%)**	
Apis mellifera	1	25	1	25	2	50*	-	-	4
Chrysomelidae	3	9.38	29	90.62*	-	-	-	-	32
Coryna sp.	-	-	1	100*	-	-	-	-	1
Eurema sp. 1	1	3.45	15	51.72*	8	27.59	5	17.24	29
Eurema sp. 2	1	16.64	3	50*	-	-	2	33.33	6
Lagriavillosa	2	100*	-	-	-	-	-	-	2
Lasioglossium sp. 1	59	18.55	194	61.01*	62	19.50	3	0.94	318
Lasioglossium sp. 2	4	57.14*	1	14.29	2	28.57	-	-	7
Polyrachis sp.	1	5.58	16	100*	-	-	-	-	17
Total	72	17.31	260	62.50*	74	17.79	10	2.40	416

n: number of visits of insect per time frames during 58 days of observation; ***P*** : Pourcentage of visits = (***n*** / **T**) * 100; **T** : total number of visits of insect per time frames during 58 days of observation; * : Daily peak of visits

3.4 Rhythm of visits according to the rhythm of flowering

The number of insect visits is proportional to the number of opened flowers of *A. hypogaea*. We found a positive and highly significant correlation (r = 0.52, df = 25, P <0.01) between the number of opened flowers and the number of insect visits. This positive and highly significant correlation demonstrates the good attractiveness of this Fabaceae's pollen to insects (Figure 1).

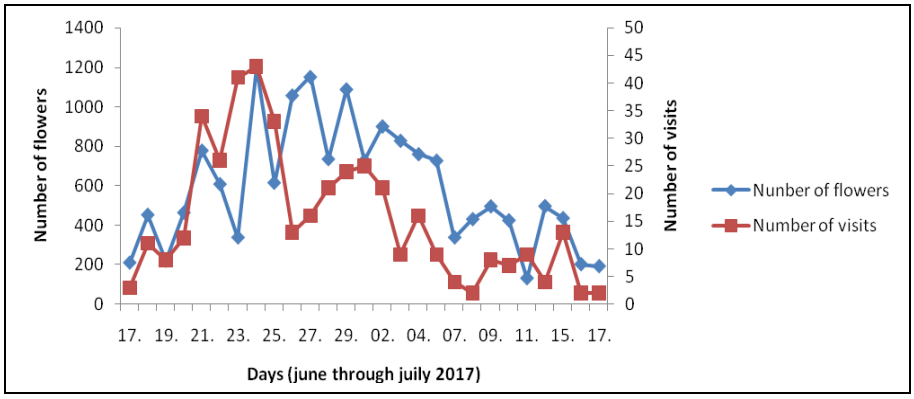

Fig 1: Variation of the number of bloomed flowers of *Arachis hypogaea* and the number insects' visits according to daily observations at Tchabbal – Mounguel in 2017

3.5 Abundance of foraging insects

The largest number of individuals simultaneously active on a flower was 1. The mean abundance per 1000 flowers (MATF) ranged from 70.28 (n = 12, s = 44.93) with *A. mellifera* to 666.67 (n = 3, s = 288.68) with *Lasioglossum* sp. 2 (Table 3).

Table 3: Abundance of four insect species per 1000 *Arachis hypogaea* flowers at Tchabbal - Mounguel in 2017

Insectes	Abundance per 1000 flowers				
	n	***m***	***s***	***mini***	***maxi***
Apis mellifera	12	70.28	44.93	20	150
Eurema sp. 1	61	457.65	254.14	88.33	1000
Lasioglossum sp. 1	515	335.5	146.91	50	1000
Lasioglossum sp. 2	3	666.67	288.68	50	1000

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

3.6 Duration of visits per flower

The mean duration of insect's visit varies from 18.67sec (n = 3; s = 8.50) for *Lasioglossum* sp. 2 to 68.37 sec (n = 482, s = 52.33) for *Lasioglossum* sp. 1 (Table 4).

Table 4: Duration of visits of three insect species on *Arachis hypogaea* flowers at Tchabbal - Mounguel in 2017

Insectes		Duration of visits per flower (seconds)			
	n	***m***	***s***	***mini***	***maxi***
Apis mellifera	9	21.11	7.72	10	36
Lasioglossum sp. 1	482	68.37	52.33	1	352
Lasioglossum sp. 2	3	18.67	8.50	11	24

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

3.7 Foraging speed

The foraging speed's mean of insects on *A. hypogaea* flowers is 1.99 flowers / min for *Lasioglossum* sp. 1 and 5.15 flowers / min with *A. mellifera* (Table 5).

Table 5: Foraging speed of some insect species on *Arachis hypogaea* flower at Tchabbal–Mounguel in 2017

Insectes	Vitesse de butinage (fleur / min)				
	n	***m***	***s***	***mini***	***maxi***
Apis mellifera	7	5.15	2.13	3.21	9.47
Lasioglossum sp. 1	300	1.99	1.40	0.18	10.59

n: number recorded foraging speed; ***m***: mean; ***s***: standard deviation; ***mini***: minimum; ***maxi***: maximum

3.8 Influence of neighboring flora

Throughout our investigations, flowers of several other flowering plant species near the experimental site were visited by some insects foraging on *A. hypogaea* flowers for pollen and / or nectar. Table 6 shows some of these plants, the flowering insects as well as the floral products harvested.

Table 6: Floral products harvested by four insect species on seven bloomed plant species neighboring *Arachis hypogaea* flowers at Tchabbal – Mounguel in 2017.

Plant species	*Apis mellifera*		*Eurema* sp.1		*Polyrachis* sp.	*Lasioglossum* sp.1	
	Ne	Po	Ne		Po	Ne	Po
Allophyllus africanus Bidens pilosa	+++	+++	++				
Psidium guajava		++					
Tithonia diversifolia	+++	+++	+				
Mytracarpus sp. *Vernonia* sp	+++	+++	+++		+++	++	++

Ne: nectar; Po: pollen; + : very low harvest; ++: low harvest; +++: high harvest

3.9 Apiculture value of *Arachis hypogaea*

During the flowering period of *A. hypogaea*, there was very low pollen harvesting activity of *A. mellifera* workers on the flowers of this Fabaceae. This result highlights the low attractiveness of *A. mellifera* workers towards *A. hypogaea* pollen and consequently allows to classifying this plant species among the low bee plant species.

3.10 Impact of insects on pollination, pod and seed yields of *Arachis hypogaea*

When collecting pollen on *A. hypogaea* flowers, most insects carried pollen from flower to flower on the same plant and on different plants. They were always in contact with the anthers and the stigma and could therefore directly intervene in the self-pollination and cross-pollination.

3.10.1 Fruiting rate

The fruiting rate was 53% in treatment 1 and 45% in treatment 2; the difference between these two percentages is very highly significant ($\chi 2 = 173.62$, $df = 1$, $P < 0.001$). The percentage (*Pi*) of fruiting rate due to the influence of the flowering insects was 15.09%.

3.10.2 Mean number of seeds per pod

The mean number of seeds per pod was 1.72 in treatment 1 and 1.81 in treatment 2; the difference between these two means is very highly significant ($t = 530.01$, $df = 10642$, $P < 0.001$). The percentage (*Pg*) of the number of seeds per pod due to the influence of flowering insects was 3.94%.

3.10.3 Percentage of normal seeds

The percentage of normal seeds was 79.98% in treatment 1 and 60.14% in treatment 2; the difference between these two percentages is very highly significant ($\chi 2 = 886.41$, $df = 1$, $P < 0.001$). The percentage of normal seeds (*Pn*) due to the influence of flowering insects was 24.81 % (Table 7).

Table 7: Fruiting rate, mean number of seeds per pod and percentage of normal seeds according to different treatments on *Arachis hypogaea* at Tchabbal - Mounguel in 2017

Treatments	NSE	NFP	FT (%)	Seeds / pods			TNS	NNS	%NS	W (g)
				N	*M*	*S*				
1(PF)	15994	8409	53	6191	1.72	0.46	10651	8519	79.98	0.66
2 (UF)	14661	6604	45	4453	1.81	0.41	8075	4856	60.14	0.60

PF: protected flowers from insects; **UF**: unprotected flowers; **NSE**: number of studied flowers; **NFP**: number of formed pods; **FT**: fruiting rate; **TNS**: Total number of seeds; **NNS**: number of normal seeds; **%NS**: percentage of normal seeds; **WSR**: weight of seeds at ripeness (gramme).

3.10.4 Mean weight of seeds

The mean seed weight was 0.66 g in treatment 1 and 0.60 g in treatment 2; the difference between these two means is very highly significant: ($t = 31.04$, $df = 98$, $P < 0.001$).

A. B.

Fig 2: Abnormal (a) and normal (b) seeds of *Arachis hypogaea* var 28 - 206

4. Discussion

4.1 Foraging activity of insects on *Arachis hypogaea's* flowers

At Chabbal-Monguel, Hymenoptera were the most important order with 83.18% of 416 visits. They were mainly represented by Halictidae family; the most important among them was *Lasioglossum* sp. 1 (76.44%). Coleoptera and Lepidoptera were poorly represented with 8.41% of visits each.

These results are similar to those obtained by [9] indicating that at Dang, among *A. hypogaea* entomofauna, Hymenoptera are the most important Order (with 98.48% of visits in 2009 and 91.25% in 2010), among Hymenoptera, Halictidae ranked first (79.06% in 2009 and 25.95% in 2010).

The high frequency of Halictidae on *A. hypogaea* flowers could be explained by the good attractiveness of its pollen vis - à - vis of these insects, by its accessibility, its availability and also by the presence of their nests in the experimental field. By contrast in Israel, Carmin (cited by [23]) noted that *Ceratina bispinosa* is the main visitor insect of the same Fabaceae. On the other hand, in Malawi, *Apis mellifera*, *Nomia* spp. and *Megachile* spp. were the most frequent and common flower visitors [22]. These data prove that the diversity of peanut insects may vary in time and space.

The abundance of insect visits on flowers was recorded in the morning time, with the peak situated between 10 am and 11 am. This time frame may correspond to the daily time when pollen grains are released in large quantities and are accessible to foragers. Between 6:00 am and 7:00 am time slot, no insect visits were recorded. This period could correspond to the time when flowers of this Fabaceae are not yet well bloomed. [34] found that flowering was observed to begin from 06:45 am on a fine morning with maximum blooming around 7:30 am; on dull and wet mornings, the flowering was delayed by half an hour. These results are in line with those obtained by [9] who indicate that at Dang the visits are more abundant on peanut flowers in mornings.

The high abundance per 1000 flowers of insects highlights the good attractiveness of pollen grains of this plant vis-à-vis of insects. This leads us to think that the floral product of this essence possesses stimuli responsible for the attractiveness exerted on the insects. It would mainly be olfactory and taste stimuli. Indeed, for a given plant, the pollen has its own smell [35] which can be detected by insects using antennas and palps [36].

The duration of a visit per flower vary with the insect species. This variation is due to the importance each forager has to the pollen of this Fabaceae as well as to its accessibility. Anthers are hidden by the corolla. So to collect pollen, insects spread the petals in order to come into contact with the anthers. The duration of visits also varies with the availability of pollen. According to [37], insects take longer time to obtain their maximum load of nectar and / or pollen on flowers where these resources are easily accessible and available in large quantities. During the flowering periods of *A. hypogaea*, there was a very low pollen harvesting activity of *A. mellifera* workers on this plant flowers. This result highlights the low attractiveness of *A. mellifera* workers towards *A. hypogaea* pollen and consequently allows us to classify this plant species among the weak polliniferous bee plant species.

4.2 Impact of insect activity on pollination and yields of *Arachis hypogaea*

When collecting pollen on *A. hypogaea* flowers, most insects carried pollen from flower to flower on the same plant and on different plants. They were always in contact with the anthers and the stigma and could therefore directly intervene in the self-pollination and cross-pollination of this Fabaceae. From our observations, some insects, particularly *A. mellifera* and the Halictidae, usually carried pollen from flower to flower of one or more plants.

The fruiting rate, the percentage of seeds per pod, the percentage of normal seeds and the percentage of seed weight due to the influence of flowering insects were 15.09%, 3.94%, 24.81%. % and 9.09% respectively. These data proof that flowering insects are not only important in the improvement of pod and seed yields of this plant, but they play also an important role in the production of seeds of good quality. According to [38], the more a flower receives pollen grains, the more it has the potential to turn into a bulky fruit containing many seeds. According to the results obtained by [9], the contribution of insects in the first three aforementioned parameters on *A. hypogaea* variety 55 - 437 RMP - 91 were 39.65%, 14.97% and 26.77% respectively.

These results are higher than those obtained during our work. This difference could be explained by the variation between the diversity and the abundance of insects that visited the flowers of this Fabaceae in the two study sites. Thus, the density and diversity of flowering insects play an important role in increasing the yield of pollinated plants [39]. These authors have shown that yields are increased by 31% (mean) between a plot visited by 2.5 insects per 100 flowers and another where 5.5 insects have foraged on 33 plant species including a Fabaceae, *Phaseolus vulgaris*.

The role of insects in increasing yields was also found by: [9] in Ngaoundere on *Phaseolus coccineus* where *Xylocopa olivacea* contributed in the increase in the fruiting rate by 27.49%, the number of seeds per pod by 45.43% and the percentage of normal seeds by 89.38%; [16] in Maroua on *Glycine max* where the corresponding percentages are respectively 13.06%, 21.22% and 25.89% with *Lipotriches collaris*.

During their foraging activity on groundnut flowers, insects increase possibility of pollination. In fact, by laying on the flowers, they shake them and thus facilitate the release of pollen of the anthers, for the optimal occupation of the stigma. The optimal charge of pollen on the stigma would itself be favorable for the production of pods and seeds. [40] noted that fruiting is mainly dependent on pollination intensity. Thus, the increase in fruiting rate, the percentage of the mean number of seeds per pod and the percentage of normal seeds due to insects is the consequence of the activity of these insects on flowers of the Fabaceae.

5. Conclusion

Of nine insect species recorded on the flowers of this Fabaceae, *Lasioglossum* sp. 1 rank first with 76.44% of visits, followed by Chrysomelidae (7.69%) and *Eurema* sp.1 (6.97%). On the flowers of the plant, the activity of insects begins around 8am and ends around 3pm, with a peak situated between 10am and 11am. Among these flowering insects *Lasioglossum* sp.1, *Lasioglossum* sp. 2 and *A. mellifera* harvest intensely and exclusively pollen. The highest number of individuals simultaneously active on 1000 flowers ranged from 70.28 with *A. mellifera* to 666.67 with *Lasioglossum* sp. 2. The mean foraging speed varies from 1.99 flowers / min for *Lasioglossum* sp.1 to 5.15 flowers / min for *A. mellifera*. Comparing the yields of unprotected flowers to those

protected from insect visits, there is a significant increase in the fruiting rate of 15.09%, the percentage of mean seeds per pod of 3.94%, the percentage of normal seeds of 24.81% and the percentage of seed weight of 9.09% due to the flowering insects. Insects were active during the first 30 days of flowering. The foraging behavior varies with insect species, which are otherwise faithful to the flowers of this plant species during foraging trips. In order to improve pod and seed yields of *A. hypogaea* variety 28-206, it is advisable to develop nesting sites for Halictidae in or near the fields of this Fabaceae.

6. References

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