INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 14, No. 1, p. 1-11, 2019

RESEARCH PAPER OPEN ACCESS

Pollination efficiency of *Apis mellifera* L. (Hymenoptera: Apidae) on flowers of *Vigna unguiculata* (L.) Walp. (Fabaceae) at Bilone (Obala, Cameroon)

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Key words: *Apis mellifera, Vigna unguiculata*, Flower, Pollination efficiency.

http://dx.doi.org/10.12692/ijb/14.1.1-11 Article published on January 11, 20199

Abstract

To evaluate *Apis mellifera* impact on pod and seed yields of *Vigna unguiculata,* its foraging and pollinating activities were studied in Bilone during the rainy season of 2016 and 2017. Treatments included unlimited flowers access by all visitors, bagged flowers to avoid all insects' pollinators and limited of single visit of *A. mellifera* worker. For each year of study, observations were made on 40±7 flowers per treatments. *Apis mellifera* foraging behavior and its pollination efficiency were evaluated. Results show that this bee foraged nectar and pollen on *V. unguiculata* flowers during the whole blooming period. The number of seeds per pod of unprotected flowers were significantly higher than those of flowers protected from insects ($P<0.001$). Through its pollination efficiency, *A. mellifera* provoked a significant increment the number of seeds per pod by 2.34% in 2016 and 18.89% in 2017 and the percentage of normal seeds by 0.28% in 2016 and 0.17% in 2017. The installation of *A. mellifera* colonies close to *V. unguiculata* fields is recommended to increase pod and seed yield in the region.

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Introduction

Several plant species depend on insect pollinators for their reproduction (McGregor, 1976; Philippe, 1991). In agro ecosystems, these pollinators have a great ecological and economic importance because they influence positively plant productions (Philippe, 1991; Tchuenguem, 2005). *Vigna unguiculata* is annual plant originated from Africa (Dabire, 2001). *Vigna unguiculata* grow vertically (upright to 5 m); climbing stems can reach two to three meters high. The leaves are generally trifoliate, the flower is pink, but can vary from white to red (Philippe, 1991) and produces nectar and pollen which attract insects (Dabire, 2001; Rodolphe-Edouard *et al.,* 2002; Mone, 2008; Pando *et al.,* 2014; Djonwangwé *et al.*, 2017). Cross-pollination by insects is generally observed (Dabire, 2001; Mone, 2008; Rodolphe-Edouard *et al.,* 2002; Bricas *et al.,* 2009; Pando *et al.,* 2014; Djonwangwé *et al.*, 2017). Niger and Nigeria are the largest producers of *V. unguiculata* and Cameroon is the best producer in Central Africa (Bricas *et al.,* 2009).

The fruit is a pod containing average fifteen seeds (Tchuenguem *et al.*, 2009). Per 100 g of dry matter, ripe seeds contain proteins (23.65 to 29.98%), glucose (44.1 to 49.6%), and lipids (1.35 to 1.66%) (Iqbal *et al.*, 2006; Piergivanni *et al.*, 1989) those are important for human's diets.

These researches conducted in Benin by Pauly *et al.* (2009), in Cameroon by Tchuenguem *et al.* (2009), Pando *et al.* (2014) and Djonwangwé *et al.* (2017) have revealed that *Apis mellifera* visits *V. unguiculata* flowers and collect nectar and pollen. No previous research has been reported on the relations between *V. unguiculata* flowers and *A. mellifera* in Bilone (Center Region, Cameroon), although, the activities of insects on the flowers can vary with region (Tchuenguem, 2005; Roubik, 2000). The main objective of this research was to gather more data on the relations between *V. unguiculata* and *A. mellifera*. Specific objectives were to study the activities of this bee on *V. unguiculata* flowers and to evaluate its pollination efficiency on pod and seed yields.

Materials and methods

Site and biological materials

The studies were conducted twice, April to July respectively in 2016 and 2017 in a field located at the campus of the Institute of Agronomy in Bilone (Obala) (Latitude: N 04.20514°, Longitude: E 011.51694°, Altitude: 525 m) in the Center Region of Cameroon. This Region belongs to the tropical rain forest agro-ecological zone (Letouzey, 1985). 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% (Suchel, 1988). The experimental plot was an area of 544m². The animal material was represented by insects naturally present in the environment and a colony of *A. mellifera* (Hymenoptera: Apidae) located 22m from the experimental field. Vegetation was represented by wild species and cultivated plants. The plant material was represented by the seeds of *V. unguiculata* var: LORY provided by the Institute of Agricultural Research for Development in Nkolbisson (Yaoundé).

Planting and maintenance of culture

On April 02, 2016 and April 03, 2017, the experimental plot was divided into fifteen ridges of 8m. Seeds were sown on one line per ridges; each line had fourteen holes and each hole received 5 seeds. The spacing was 50cm between rows and 2m between ridges. Each hole was 4 cm depth. Two weeks after germination, the plants were thinned and only two were left per hole. Weeding was performed manually as necessary to maintain plot weeds-free.

Determining the reproduction mode

In June 03 and June 08 respectively in 2016 and 2017, 90 flowers of *V. unguiculata* at the bud stage were labeled. Forty-five of the total number flowers were allowed for treatment 1 (open pollination) and 45 others flowers belong to treatment 2 (bagged with gauze bags to prevent visitors or external pollinating

agents) (Fig. 1) (Delaplane *et al.* 2013). For each year, fifty days after the wilting of the last flower, the number of pod formed in each treatment was counted. For each treatment, the fruiting index (*Ifr*) was then calculated using the following formula: $Ifr = (F_1/F_2)$, where F_1 is the number of pod formed and F_2 the number of flowers initially labeled (Tchuenguem, 2005). The out crossing rate (*TC*) was calculated using the formula: $TC = \{[(Ifr_1 - Ifr_2 / Ifr_1] * 100\}$, where Ifr_1 and Ifr_2 are mean fruiting indexes in treatments 1 and 2 respectively (Tchuenguem, 2005). The rate of self-pollination in the broad sense (*TA*) was calculated using the formula: $TA = (100 - TC)$.

Study of the activities of Apis mellifera on Vigna unguiculata flowers

Observations were conducted on individually opened flowers of treatment 1 each day, from June 08 to July 02 in 2016 and from June 07 to June 29 in 2017 at one hour interval from 9 to 16 h (9-10h, 11-12h, 13-14h, 15-16h). In as low walk along all labeled flowers of treatment 1, the identity of all insects that visited *V. unguiculata* flowers was recorded. All insects encountered on flowers were recorded and the cumulated results expressed in number of visits to determine the relative frequency of *A. mellifera* in the anthophilous entomofauna of *V. unguiculata*. Direct observations of the foraging activity of worker bees on flowers were made. The floral products (nectar and/or pollen) collected by the foragers were recorded for the same dates and time slots as that of the insect counts. The duration of visits (Jean-prost, 1987) and the foraging speed (number of flowers visited per minute) (Jacob-Remacle, 1989; Tchuenguem, 2005) were timed to the same dates and in four time slots (10-11h, 12-13h, 14-15h, 16-17h). Abundances (larger numbers of individuals simultaneously active) per flower and per 1000 flowers (A_{1000}) were recorded on the same dates and time slots as that of the registration of the duration of visits. The first parameter was recorded as a result of direct counts. For the abundance per 1000 flowers, honey bees were counted on a known number of open flowers; $A_{1000} = [(A_x/F_x) * 1000]$, where F_x and A_x are respectively the number of flowers and the number of individual bees actually counted on F_x (Tchuenguem, 2005). During the days of investigation, the temperature and humidity of the study site were recorded every 30min, from 9 am to 17 pm, using a thermo-hygrometer installed in the shade.

Evaluation of the impact of pollinating insects on Vigna unguiculata yield

This evaluation was based on the impact of flowering insect on pollination, the impact of pollination on fruiting and the comparison of yields (fruiting rate, mean number of seeds per pod and percentage of normal or well developed seeds) of treatment 1 (unprotected flowers) and treatment 2 (bagged flowers).

The fruiting rate due to the influence of foraging insects (Fr_i) was calculated using the formula: $Fr_i = \{[(Fr_1 - Fr_2)/Fr_1]*100\}$, where Fr_1 and Fr_2 are the fruiting rate in treatments 1 and 2 respectively. The fruiting rate of a treatment (*Fr*) is $Fr = [(F_2 / F_1)*100]$, where, F_2 is the number of pods formed and F_1 the number of viable flowers initially set (Tchuenguem, 2005). At maturity, pods were harvested from all treatments. The mean number of seeds per pod and the percentage of normal seeds were then calculated for each treatment.

Assessment of the pollination efficiency of Apis mellifera on Vigna unguiculata

In 2016, along with the development of treatment 1 and 2, 30 flowers were protected using gauze bag (treatment 3). In 2017 the same experience was repeated with the same number of flowers. Between 6 and 9 am, the gauze bag is gently removed from each newly bloomed flower which was then observed during one to 20 min. Flowers visited by *A. mellifera* were marked. After this manipulation, the flowers were protected once more.

The number of seeds per pod, the percentage of normal seeds was then calculated for treatment 3 (protected flowers and visited exclusively by *A. mellifera*). The impact of *A. mellifera* on fruiting rate (Pf_{am}) was calculated using the following formula:

Pf_{am} = {[(f_3-f_2)/f_3]* 100}, where f_3 and f_2 are the fruiting rates in treatment 3 (protected flowers and visited exclusively by *A. mellifera*) and treatment 2 (protected flowers) (Tchuenguem, 2005).

Data analysis

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

Results

Reproduction mode

In 2016, the podding index was 0.93 for treatment 1 and 0.84 for treatment 2, while in 2017; it was 0.91 and 0.86 for the two treatments respectively. Consequently, in 2016 the allogamy rate was 9.68% and the autogamy rate was 90.32 %. In 2017, the corresponding figures were 5.49% and 94.51%. It appears that the *V. unguiculata* var: LORY used in our experiments has a mixed reproduction mode, autogamous-allogamous, with the predominance of autogamy over allogamy.

Table 1. Diversity of insects on *Vigna unguiculata* flowers in 2016 and 2017, number and percentage of visits of different insects at Bilone.

Insects			2016		2017		Total	
Order	Family	Genus, Species	n_1	p_1%	n_2	p_2%	$n_{1,2}$	$p_{1,2}$%
Diptera	Calliphoridae	(1 sp.)[nt]	6	1.46	0	0	6	0.65
	Muscidae	*Musca domestica*[nt]	0	0	15	2.89	15	1.61
Hymenoptera	Apidae	*Apis mellifera*[po, nt]	109	26.52	221	42.66	330	35.52
		Xylocopa olivacea[po, nt]	96	23.36	111	21.43	207	22.28
		Amegilla sp.[po, nt]	45	10.95	95	18.34	140	15.07
	Formicidae	(1 sp.) [nt]	82	19.95	12	2.32	94	10.12
	Megachilidae	*Chalicodoma*sp.[nt]	32	7.79	44	8.49	76	8.18
		*Megachile*sp.[po, nt]	15	3.65	0	0	15	1.61
	Vespidae	*Synagris cornuta* [po, nt]	14	3.41	0	0	14	1.51
Lepidoptera	Acraeidae	*Acraea acerata*[nt, rt]	8	1.95	0	0	8	0.86
	Pieridae	*Catopsilia flerella*[nt, rt]	4	0.73	8	1.54	12	1.29
Orthoptera		(1 sp.)[df]	0	0	9	1.74	9	0.97
Nevroptera		(1 sp.)[pr]	0	0	3	0,58	4	0.43
Total		13 species	411	100	518	100	929	100

n_1: number of visits on 45 flowers in 16 days. n_2: number of visits on 45 flowers in 23 days. p_1 et p_2:percentages of visits. p_1 = (n_1/411) *100. p_2 = (n_2/518) *100. $n_{1,2}$= (n_1 + n_2). $p_{1,2}$= [(n_1 + n_2)/929] *100. nt: visitor collected nectar. po: visitor collected pollen. df: defoliator. rt: rest. pr: predator. sp. :undetermined species.

Activities of Apis mellifera on Vigna unguiculata flowers

Seasonal frequency of visits: Amongst the 411 and 518 visits of 10 and 9 insects species recorded on *V. unguiculata* flowers respectively in 2016 and 2017; *A. mellifera* was the most represented insect with 109 visits (26.52%) in 2016 and 221 visits (42.66%) in 2017 (Table 1). The difference between these two percentages is very higher significant (χ^2 = 26.08; df = 1; P< 0.001).

Floral substances harvested: From our field observations, *A. mellifera* workers were found to collect pollen and to harvest nectar on *V. unguiculata* flowers (Fig. 2). In 80 and 80 visits counted on flowers respectively in 2016 and 2017, 60 (75.00%) and 55 (68.75%) were for nectar collection, 15 (18.75%) and 21 (26.25%) for pollen collection, respectively in 2016 and 2017 (Table2). For the total of 160 visits recorded during the two seasons, the number of visits allocated to nectar harvest was 115

(71.88%) and that for pollen collection was 36 (22.50%). The difference between the percentages for collecting nectar and pollen is significant (χ^2 = 1.21; *df* =1; *P* < 0.1).

Abundance of *Apis mellifera* workers: In 2016, the highest mean number of *A. mellifera* workers simultaneously in activity on *V. unguiculata* was one per flower (*n*=30; *s*=0) and 156 per 1000 flowers (*n*=30; *s*=22). In 2017, the corresponding figures were one per flower (*n*=30; *s*=0) and 108 per 1000 flowers (*n*=30; *s*=18). The difference between the mean number of bees per 1000 flowers in 2016 and 2017 was significant (*t*=-1.89; *df*=55; *P*<0.05) (Table. 3).

Table 2. Products harvested by *Apis mellifera* on flowers of *Vigna unguiculata* in 2016 and 2017 at Bilone.

Year	Number of visits studied	Visit for pollen harvest		Visit for nectar harvest		Visit for pollen and nectar harvest	
		Number	%	Number	%	Number	%
2016	80	15	18.75	60	75.00	5	6.25
2017	80	21	26.25	55	68.75	4	5.00
Total	160	36	22.50	115	71.88	9	5.62

Duration of visits per flower**:** The mean duration of *A. mellifera* visit on flower of *V. unguiculata* depended on the substance collected (Table 4). In2016, the mean duration of a visit was 2.32 sec (*n*=15; *s*=0.12) for pollen collection against 4.97 sec (*n*=60; *s*=1.87) for nectar harvest. In 2017, the corresponding results were 1.55 sec (*n*=21; *s*=0.53) for pollen harvest and 4.43 sec (*n*=55; *s*=1.09) for nectar collection. The differences between the duration of a visit to harvest nectar (*t*=-9.93; *df*=103; *P*<0.001) and that for pollen collection (*t*=15.68; *df*=34; *P*<0.001) are very highly significant in 2016 and 2017.

Table 3. Abundance of *Apis mellifera* workers on flowers of *Vigna unguiculata* in 2016 and 2017 at Bilone.

Year	Mean abundance per 1000 flowers					
	n	*m*	*s*	*mini*	*maxi*	Comparison of means
2016	30	156	22	61	206	t= 35,21; *df*= 58;*P* <0,001
2017	30	108	18	44	196	
Total	60	132	20			

Foraging speed of *Apis mellifera* on the flowers of *Sesamum indicum***:** On the flowers of *V. unguiculata, A. mellifera* visited 5 to 14 flowers/min in 2016 and 4 to 9 flowers/min in 2017. The mean foraging peed was 7.38 flowers/min (*n*=30; *s*=3.51) in 2016 and 9.05 flowers/min (*n*=30; *s*= 1.04) in 2017 (Table 5). The difference between the means foraging speeds in 2016 and 2017are very highly significant (*t* =-10.49; *df*=58; *P*<0.001).

Table 4. Duration of *Apis mellifera* visits on flowers of *Vigna unguiculata* in 2016 and 2017 at Bilone.

Year	Foods harvest	Duration of visit per flower (sec)				
		n	*m*	*s*	*mini*	*maxi*
2016	Pollen	15	2.32	0.12	1	8
	Nectar	60	4.97	1.87	1	13
2017	Pollen	21	1.55	0.53	1	6
	Nectar	55	4.43	1.09	1	15
Total	Pollen	36	1.93	0.32	1	8
	Nectar	115	4.70	1.48	1	15

Daily rhythm of visits: *Apis mellifera* workers were active on the flowers of *V. unguiculata* from 9 am to 16 pm, with a peak of visits between 9 am and 10 am in 2016 and in 2017 (Fig.3). Climatic conditions have influenced the activity of *A. mellifera* workers on *V. unguiculata* flowers in field conditions.

Table 5. Foraging speed of *Apis mellifera* on the flowers of *Vigna unguiculata* in 2016 and 2017 at Bilone

Year	Foraging speed (flowers / min)					
	n	*m*	*s*	*mini*	*maxi*	Comparison of means foraging speed
2016	30	7,38	3,51	5	14	t = - 9,51; df= 58; P< 0,001
2017	30	9,05	1,04	4	9	
Total	60	8,21	2,27	4	14	

The correlation was positive and significant between the numbers of *A. mellifera* visits on *V. unguiculata* flowers and temperature in 2016 (r=0.60; df=3; P<0.05) and not significant between these two parameters in 2017 (r=0.10; df=3; P>0.05). The correlation between the number of visits and the relative humidity of the air was negative and significant in 2016 (r=-0.80; df=3; P<0.05) and positive and not significant in 2017 (r=0.10; df=3; P>0.05) (Fig. 4).

Apicultural value of Vigna unguiculata

During the mild rainy season in Bilone, we noted a well elaborated activity of *A. mellifera* workers on *V. unguiculata* flowers. In particular, there was a very good nectar harvest, a good pollen collection and workers faithfulness to those flowers. On Fig. 2, *A. mellifera* is shown collecting nectar on a *V. unguiculata* flower. These data allow to place *V. unguiculata* highly nectariferous and polliniferous bee plants.

Table 6. Fruiting rate, number of seed per pod and percentage of normal seeds according to different treatments of *Vigna unguiculata* in 2016 and 2017 at Bilone.

Treatment	year	Flowers	Pod	Fruiting rate	Seeds/Pod		Total seeds	Normal seeds	Normal seeds (%)
					m	*s*			
1 (UV)	2016	45	42	93.33	8.01	1.5	220	201	91.36
2 (BF)		45	38	84.44	6.12	0.90	173	154	89.01
3(BFVEAM)		30	22	73.33	5.98	0.75	89	79	88.76
1 (UV)	2017	45	41	91.11	7.98	0.88	246	223	90.65
2 (BF)		45	39	86.66	6.86	0.45	253	221	87.35
3(BFVEAM)		30	24	76.66	5.77	0.97	120	105	87.50

UV: Unlimited visits; BF: Bagged flowers; BFVEAM: Bagged flowers and visit exclusively by *Apis mellifera*.

Impact of flower-feeding insects in pollination and yields of Vigna unguiculata

During pollen and nectar harvest, flowering insects of *V. unguiculata* were in regular contact with the anthers and stigma. Thus, these insects increased the pollination possibilities of this plant species. Table 6 presents the results on the fruiting rate, the number of seeds per pod and the percentage of normal seeds in different treatments. From this table, we documented the following:

First, the comparison of the fruiting rate showed that the difference was very highly significant between treatment 1 (opened flowers) and treatment 2 (bagged flowers) in the first year (χ^2=46.84; df=1; P<0.001) and in the second year (χ^2=46.52; df=1; P<0.001).

Second, the comparison of the mean number of seeds per pod showed that the difference was very highly significant between treatments 1 and 2 (t=29.75; df=78; P<0.001) in 2016 and in 2017 (t=20.42; df=79; P<0.001). Consequently, in 2016 and 2017, a mean number of seeds per pod of the unprotected flowers were higher than that of protected flowers.

Third, the comparison of the percentage of normal seeds showed that the difference was not significant between treatments 1 and 2 in the first year (χ^2=0 .61; df=1; P>0.05) and highly significant in the second year (χ^2=9.73; df=1; P<0.01).

The numeric contribution of pollinating insects on the fruiting rate, percentage of fruits with seeds and the percentage of normal seeds were 9.52%, 23.59% and 2,57% in 2016 respectively.

The corresponding figures were 4.88%, 14.03% and 3.64% in 2017, respectively. For the two cumulate years, the numeric contributions were 7.20%, 18.81% and 3.10% for the fruiting rate, percentage of fruits with seeds and the percentage of normal seeds, respectively. The impact of pollinating insects on fruits and seeds yields was positive and significant.

Fig. 1. Plants of *Vigna unguiculata*showing flowers isolated from insects.

Pollination efficiency of Apis mellifera on Vigna unguiculata

From Table 6, it appears that:

First, the comparison of the fruiting rate showed that the difference was very highly significant between treatment 3 (flowers protected and visited exclusively by *A. mellifera*) and treatment 2 (bagged flowers) in 2016 ($\chi 2$=19.47; *df*=1; *P*<0.001) as well as in 2017 ($\chi 2$=22.36; *df*=1; *P*<0.001).

Second, the comparison of the mean number of seeds per pod showed that the difference was highly significant between treatments 3 and 2 (*t*=-2.26; *df*=58; *P*<0.001) in the first year and in the second year (*t*=-22.91; *df*=61; *P*<0.001).

Consequently, in 2016 and 2017, the pods produce by flowers bagged and visited exclusively by *A. mellifera* produced more seeds than those of protected flowers.

Third, the comparison of the percentage of normal seeds showed that the difference was significant between treatment 3 and treatment 2 in 2016 ($\chi 2$=4.26; *df*=1; *P*<0.05) and highly significant in 2017 ($\chi 2$=9.73; *df*=1; *P*<0.01) respectively. For the two years, the pods produce by flowers bagged and visited exclusively by *A. mellifera* have more normal seeds than those of protected flowers.

Fig. 2. *Apis mellifera* collecting nectar in a flower of*Vigna unguiculata*.

The numeric contribution *A. mellifera* on the fruiting rate, percentage of fruits with seeds and the percentage of normal seeds were 13.15%, 2.28% and 0.28% in 2016, respectively. The corresponding figures were 11.53%, 15.88% and 0.17%% in 2017, respectively. For the two cumulate years, the numeric contributions were 12.34%, 9.08% and 0.22% for the fruiting rate, percentage of fruits with seeds and the percentage of normal seeds, respectively. The impact of *A. mellifera* on fruits and seeds yields was positive and significant.

Discussion

Activity of Apis mellifera on Vigna unguiculata flowers

Results indicate that *Apis mellifera* was the main floral visitor of *V. unguiculata* during the observation period. This bee has been reported as the main floral visitor of this plant in Benin (Pauly *et al.*, 2009) and in Cameroon (Tchuenguem *et al.*, 2009; Pando *et al.*, 2014; Djonwangwé *et al.*, 2017). *Apis mellifera* was also shown to be the most abundant

floral visitors of other Fabaceae members such as *Glycine max* in Douala (Taimanga and Tchuenguem, 2018), *Phaseolus vulgaris* in Ngaoundéré (Kingha *et al.,* 2012) and in Maroua (Douka and Tchuenguem, 2013). The peak of the activity of *A. mellifera* on *V. unguiculata* flowers was located between 9 and 10 am, which correlated with the highest availability period of nectar on *V. unguiculata* flowers.

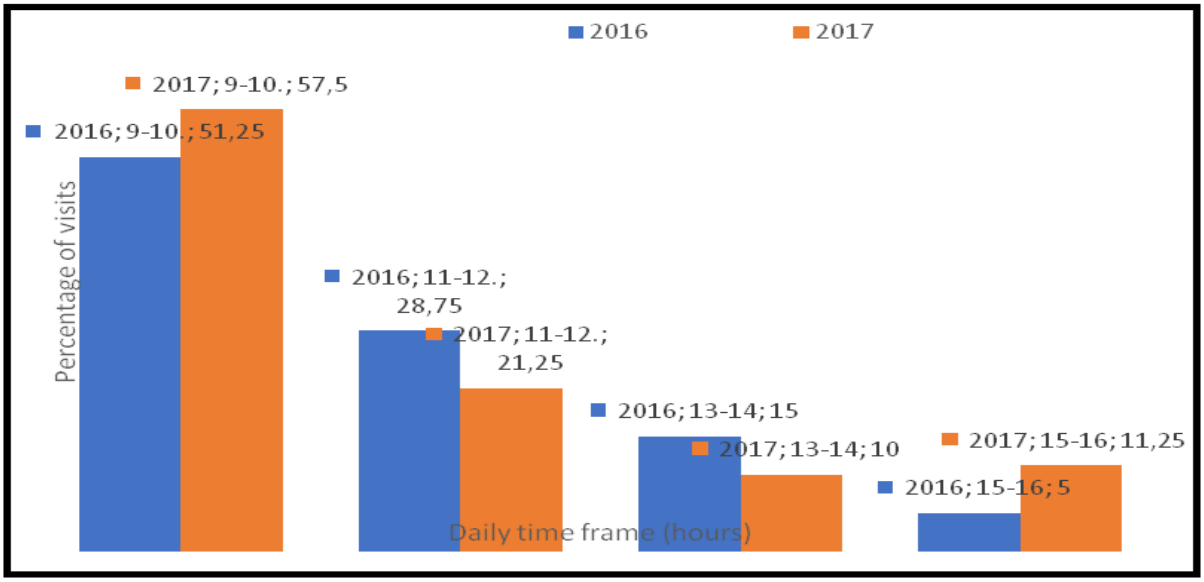

Fig. 3. Distribution of visits of *Apis mellifera* on the flowers of *Vigna unguiculata* according to daily time in 2016 and 2017.

The significant difference between the mean duration of the visit for pollen harvest and that for nectar collection could be attributed to the availability of floral products or the variation in the diversity of flowering insects from one year to another. During each flowering periods of *V. unguiculata, A. mellifera* harvested nectar and pollen; this could be attributed to the needs of colonies during the corresponding period. This research indicated that *A. mellifera* can provide benefits to pollination management of *V. unguiculata*.

Impact of Apis mellifera activity on the pollination and yield of Vigna unguiculata

During the collection of nectar and pollen on each flower, *A. mellifera* foragers regularly come in to contact with the stigma. They were also able to carry pollen with their hairs, legs and mouth accessories from a flower of one plant to stigma of another flower of the same plant (geitonogamy), to the same flower (autogamy) or to that of another plant (xenogamy) (Philippe, 1991). The significant contribution of *A. mellifera* in pods and seed yield of *V. unguiculata* is in agrees with the similar findings in Benin(Pauly *et al.*, 2009) and in Cameroon (Tchuenguem *et al.*, 2009; Pando *et al.,* 2014; Djonwangwé *et al.*, 2017) on the same Fabaceae. This plant species produces fewer seeds per pod in the absence of efficient pollinators (Pando *et al.,* 2014). The contribution of *A. mellifera* to *V. unguiculata* production through its pollination efficiency was significantly higher than that to fall insects on the exposed flowers. The weight of *A. mellifera* played a positive role during nectar and pollen collection. *Apis mellifera* shook flowers and could facilitate the liberation of pollen by anthers for the optimal occupation of the stigma. This phenomenon was also reported by Tchuenguem and Dounia (2014) on *Glycine max* in Maroua (Cameroon). The higher production of seeds per pod and that of normal seeds in the treatment with flowers visited exclusively by *A. mellifera* workers compared to that of the treatment with protected flowers showed that *A. mellifera* visit was effective increasing pollination. Our results confirmed those of Pando *et al.* (2014) who revealed that *V. unguiculata* flowers set little pods in the absence of insect pollinators.

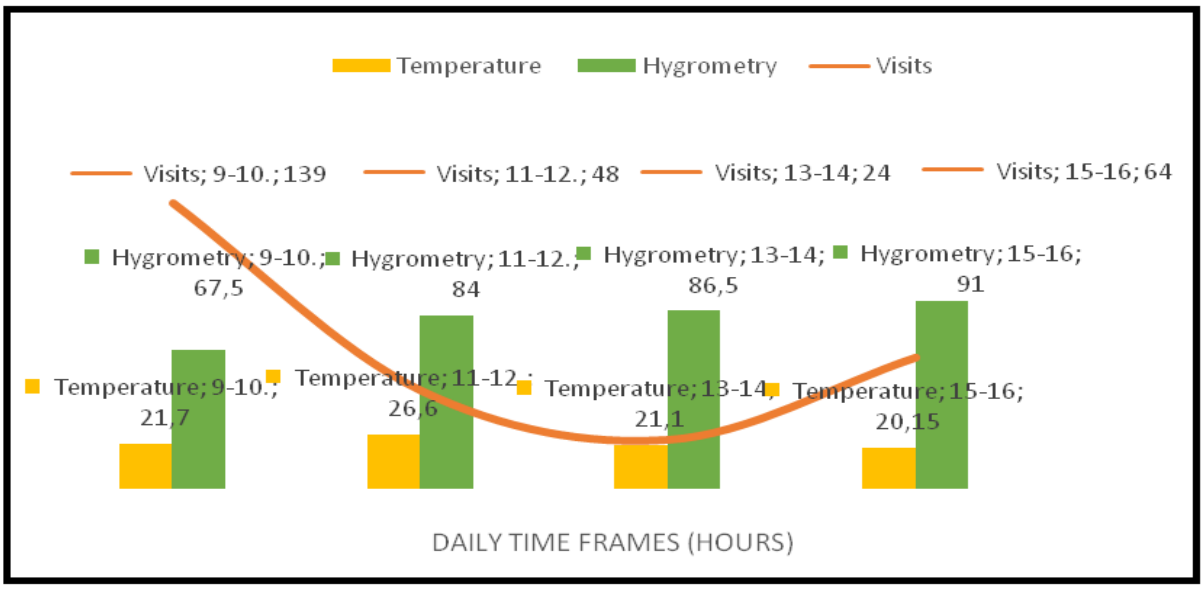

Fig. 4. Mean daily temperature and humidity and mean number of visits of *Apis mellifera* on *Vigna unguiculata* flowers in 2016 and 2017.

Conclusion

This study reveals that the variety of *V. unguiculata* studied is a highly nectariferous and polliniferous bee plant that obtained benefits from the pollination by insects among which *A. mellifera* is the most important. The comparison of pod and seed sets of protected flowers of that of flowers visited exclusively by *A. mellifera* underscores the value of this bee in increasing pod and seed productions as well as seed quality. In the Center Region of Cameroon, the installation of *A. mellifera* hive close to *V. unguiculata* fields is recommended for the increase of the seed yields of this valuable crop.

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