

Full Length Research Paper

Pollination and yield responses of cowpea (*Vigna unguiculata* L. Walp.) to the foraging activity of *Apis mellifera adansonii* (Hymenoptera: Apidae) at Ngaoundéré (Cameroon)

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To determine the apicultural value of *Vigna unguiculata* (L.) Walp. (Fabaceae) and evaluate the *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) activity on its pod and seed yields, the bee foraging and pollinating activities were studied in Ngaoundéré. The experiment was carried out within the University of Ngaoundéré Campus on 210 flowers differentiated in two lots, based on the protection/or not of plant inflorescences against insect visits. The bee's seasonal rhythm of activity, its foraging behaviour on flowers, the fructification rate, the number and dry weight of seeds/pod, the percentage of normal seeds/pod, and the pod length were evaluated. Results show that *A. m. adansonii* foraged on plants throughout the whole blooming period. Worker bees intensively and preferably harvested nectar. The greatest mean number of workers foraging simultaneously was 500 per 1000 flowers. The mean foraging speed was 8.67 flowers/min. These findings allow the classification of *V. unguiculata* as a highly nectariferous bee plant. The number and dry weight of seed/pod, the pod length and the percentage of normal seeds/pod from unprotected flowers were significantly higher than those of flowers protected from insects. The fructification rates were 62 and 48%, while the percentages of healthy seeds were 97.61 and 76.17%, respectively in unprotected and protected inflorescences. The installation of *A. m. adansonii* colonies close to *V. unguiculata* field could be recommended to improve its pods and seeds production in the region.

Key words: *Apis mellifera adansonii*, *Vigna unguiculata*, bee plant, foraging, pollination, increased yield.

INTRODUCTION

There are more than 20000 species of bees disseminated all over the world among which *Apis mellifera* is the most important for the highest quantity of honey production they account for (Crane, 1999; Michener, 2000). This insect visits flowers of various plant species where it mostly collects nectar or pollen (Louveaux, 1984). Nectar is used to make honey. Pollen and honey are stored in cells built by bee workers (Louveaux, 1984; Roubik, 1989). These stored products are sampled by human for nutritional and therapeutic needs (Sabot, 1980; Loiriche, 1984). Since bees depend on flowering

plants for their subsistence, the sustainable development of apiculture in a given region involves a detailed knowledge of bee plants growth in the environment of the hives (Bakenga and Mapatamo, 1994; Tchuenguem Fohouo et al., 1999; Bakenga et al., 2000). In fact, honey and pollen production of honey bee colonies is proportional to the abundance of some plant species and their attractiveness to worker bees (Guerriat, 1996).

Many insects visiting flowers play a crucial role in the pollination of corresponding flowers. In developing countries and particularly in Cameroon where the economy is essentially based on agriculture, results obtained from insect-plant interactions present a great advantage to human (Tchuenguem Fohouo, 1993, 2005; Tchuenguem Fohouo et al., 2001, 2004). However, many farmers still

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ignore the role of harmless flower visiting insects in general, and bees in particular on pollination of growing plants. According to them, higher yield are achieved by several techniques such as fire-prone, crop rotations, organic manures, and control of pests. Nevertheless, yield of various plants can be decreased by half or more in the absence or the presence of insufficient number of pollinating insects during flowering (Philippe, 1991).

Vigna unguiculata is one of the most important grain legume in the tropical savannah zone of Africa (Cisse and Hall, 2003). It provides more than half the food protein through its biological nitrogen fixation ability (Peoples, 1995). Mature cowpea seeds averagely content 23 to 25% of protein, 50 to 67% of starch and vitamin B (Ntougam et al., 1993). In Cameroon, demand for *V. unguiculata* seeds is high and its seed yields are low.

Before this work, no available information was published on the relationships between cowpea and its flower visiting insects in Cameroon. Therefore, investigations were conducted on the foraging and pollination of cowpea by *Apis mellifera adansonii* at Ngaoundéré during the cropping season extending from April to July 2007. The present study is thus a contribution to the knowledge of the interactions between *V. unguiculata* and flower visiting insects, for their optimal management. Specific objectives were the registration of the activity of *A. m. adansonii* on *V. unguiculata* flowers, the estimation of the apicultural value of this fabaceae, and the evaluation of the impact of *A. m. adansonii* on pollination, pod and seed yields of *V. unguiculata*.

MATERIALS AND METHODS

Study site, experimental plots and biological material

The studies took place during the first cropping season extending from April to July at Dang, a village of Ngaoundéré in the Adamawa region. This region belongs to the high altitude Guinean savannah ecological zone. The climate is characterized by two seasons: a rainy season (April - October) and a dry season (November - March). The annual rain fall is about 1500 mm. The mean annual temperature is 22°C, while the mean annual relative humidity is 70%.

The experimental plot (19 x 12) m² was located within the University of Ngaoundéré Campus, at 600 m from a kenyan top-bar hive inhabited by *A. m. adansonii* Latreille 1804. The hive was located at the latitude 7°24,635'N, the longitude 113°32,827'E and the altitude 1091 masl. The number of honey bee colonies located in an area of 3 km in diameter centred on the experimental plots was 37 in August 2007.

The experimental plot was subdivided into 4 (8 x 4.5) m² replicated subplots separated 1 m apart. During the survey, flowers of other plant species growing near *V. unguiculata* were observed to attract *A. m. adansonii*. Among these plant species were: *Tithonia diversifolia* and *Bidens pilosa* (Astraceae); *Solanum tuberosum* (Solanaceae); *Commelina* sp. (Commelinaceae); *Spermacoce* sp. (Rubiaceae).

V. unguiculata seeds of the local Bafia cultivar were selected for their long flowering period that can be important for honey bee forage. Its growth cycle extends from 85 to 95 days after planting. Seeds are white-brown in colour, with violet flowers that open early

in the morning and close between 11 am and 12 pm. Each inflorescence bears 4 to 5 flowers (m = 4.19; s = 0.54; n = 32). Shading of flowers occurs two days after emergence (m = 1.23; s = 0.43; n = 31). Plants are averagely 40 to 60 cm height (m = 43.71; s = 10.22; n = 24). Each flower produces nectar and pollen.

Sowing and weeding

Four cowpea seeds were sown on the flat in seven lines (25 cm within and 75 cm apart) of each subplot on the 12 May 2007. Two weeks after sowing, plantlets were thinned to two per hole. Weeding was manually performed as necessary to maintain plots weeds free.

Determination of the reproduction system of *V. unguiculata*

On the 29 July 2007, 100 flower buds were labelled per plots among which 50 were free (Lot 1) and 50 protected from bees and other insects with gauze bags (Lot 2). Ten days after shading of the last flower, the number of pods was assessed in Lots 1 and 2. The podding index of each Lot (P_i) was calculated as described by Tchuenguem Fohouo et al. (2001):

$$P_i = F_2 / F_1$$

Where F_2 is the number of pods formed and F_1 the number of viable flowers initially set.

The allogamy rate (Alr) from which derives the autogamy rate (Atr) was expressed as the difference in podding indexes between lot 1 and lot 2.

$$Alr = [(P_1X - P_2Y) / P_1X] \times 100$$

Where P_1X and P_2Y are respectively the podding average indexes of lot 1 and lot 2.

$$Atr = 100 - Alr$$

Determination of the position of *A. m. adansonii* in the floral entomofauna of *V. unguiculata*

The position of *A. m. adansonii* in the entomofauna of cowpea was determined based on observations on flowers of Lot 1, from the 1st to the 28th of August 2007 and for each of the following daily time frames: 7 - 8 h; 9 - 10 h and 11 - 12 h. Different insects encountered on flowers were registered and the cumulated results expressed in number of visits. The frequency of insect visits enabled the determination of the position of *A. m. adansonii* in the anthophilous entomofauna of *V. unguiculata* (Tchuenguem Fohouo, 2005).

Study of the activity of *A. m. adansonii* on flowers

During the flowering period which extended from the 1st to the 28th of August 2007, and between 7 and 12 am, divided into three time frames (7 - 8 h, 9 - 10 h, 11 - 12 h), flowers of *V. unguiculata* plant were observed for the registration of the foraging activity of *A. m. adansonii* workers. For each of the labelled plant visited by foragers, nectar and pollen harvested, the abundance of foragers (highest number of individuals foraging simultaneously on a flowers or 1000 flowers), the duration of the individual floral visit (using a stopwatch), the disruption of the activity of foragers by competitors, and the attractiveness exerted by other plants on *A. m. adansonii* were assessed.



Figure 1. Part of a cowpea plant showing pods (a), leaves (b), and *A. m. adansonii* (c) collecting nectar in a flower (d).

The foraging speed (V_b) defined as the number of visits per min (Jacob-Remacle, 1989) was given by the following formula:

$$V_b = (Fi / di) \times 60$$

Where di expressed in second, is read on a chronometer, and Fi the number of flowers visited during di . If during the process it happens that the bee comes back on a visited flower, this was considered as a new flower. A mobile thermo-hygrometer was used to register the temperature and the relative hygrometry. The physical effects of wind and sunlight during experimentation were also registered.

The duration of visits, foraging speed as well as abundance of foragers, were sampled on the 2, 7, 9, 10, 11 and 13 August 2007.

Assessment of the total concentration of sugar in nectar of *V. unguiculata*

The concentration of sugar in nectar of cowpea was determined with a mobile refractometer (0 – 90 Brix) equipped with a thermometer, on the 2, 7, 9, 10, 11 and 13 August 2007. *A. m. adansonii* were captured on cowpea flowers and inactivated with chloroform. Nectar was removed from the mouth of the honey bee by exerting a pressure on the stomach of inactivated bees.

Evaluation of the apicultural value of *V. unguiculata*

The apicultural value of cowpea plants were assessed as in other plants species, using the data on the flowering intensity and the attractiveness of *A. m. adansonii* workers with respect to nectar and pollen (Guerriat, 1996; Tchuenguem Fohouo et al., 2004; Tchuenguem Fohouo et al., 2007; Tchuenguem Fohouo et al., 2008).

Assessment of the effect of *A. m. adansonii* on *V. unguiculata* pollination

During harvesting of the floral products, the number of time a foraging bee comes into contact with the stigma of the host plant was used to assess the contribution of *A. m. adansonii* to pollination of *V. unguiculata*. Figure 1 illustrates a part of a cowpea plant in the field. This figure shows cowpea pods (a), leaves (b), and *A. m. adansonii* (c) collecting nectar in a flower (d).

Assessment of the effect of *A. m. adansonii* on *V. unguiculata* yields

This evaluation was based on the impact of *A. m. adansonii* and other anthophilous insects on pollination; the impact of pollination on podding of *V. unguiculata*, and the comparison of yields (fructification rate, number of seeds per pod, percentage of normal seeds per pod, mean weight of a seed per pod and pod length) of lots 1 and 2.

The flowers and pods counts on each labelled inflorescence were used to evaluate the ability of cowpea to bear pods using the fraction: (number of pods/number of flowers carried by inflorescences). This fraction which corresponds to the podding index was calculated for each inflorescence and used to compare lots 1 and 2 (Tchuenguem et al., 2001). The podding index (%) due to the influence of foraging insects was calculated by the formula:

$$\% P_I = [(m_1 - m_2) / m_1] \times 100$$

Where m_1 and m_2 are mean of podding indexes in lots 1 and 2 respectively. The contribution of *A. m. adansonii* to podding was then quantified by the formula:

Table 1. Diversity and density of floral insects on cowpea flowers.

Order	Family	Genus, species, sub-species	Number visits	Percent visit
Hymenoptera	Apidae	<i>Apis mellifera adansonii</i>	234	53.42
	Vespidae	<i>Belonogaster juncea</i>	1	0.22
		<i>Polistes</i> sp.	61	13.92
		(other Vespoidea)	(sp. 1)	12
	Sphecidae	(sp. 1)	6	1.36
	Formicidae	<i>Camponotus acvapimensis</i>	18	4.11
		<i>Myrmecaria opaciventris</i>	5	1.14
	Megachilidae	<i>Chalicodoma</i> sp.	29	6.62
		<i>Amegilla</i> sp.	19	4.43
		<i>Megachille</i> sp.	1	0.22
Hemiptera	Pentatomidae	(sp. 1)	28	6.39
Coleoptera	Curculionidae	(sp. 1)	3	0.68
	Lagriidae	<i>Lagria villosa</i>	8	1.82
	Coccinellidae	<i>Cheilomenes lunata</i>	2	0.45
	(other Coleoptera)	(2 sp.)	1	0.22
	Lepidoptera	Hesperiidae	(sp. 1)	10
Total		17 species	438	100

$$(\% P) \times [V_a/100]$$

Where V_a is the percentage of *A. m. adansonii* visits on flower clusters of lot 1. At maturity, pods were harvested from each Lot and the number of seeds per pod counted. The mean number of seeds per pod was then calculated for each lot. The impact of *A. m. adansonii* on seed yield was evaluated using the same method as mentioned above for podding index.

Data analysis

Data were statistically analyzed by ANOVA using a Statgraphic Plus, version 5.0 (SIGMA PLUS) computer program. Means were compared between treatments using the student's t-test or the least significant difference (LSD) procedure at 5% level. Correlations between parameters were assessed using the SPSS computer program.

RESULTS

Reproduction system of cowpea

The podding index of cowpea was 0.62 and 0.49, respectively for unprotected inflorescences and inflorescences protected from insects. Thus allogamy rate was 20.90% and autogamy rate was 79.03%. It appears that cowpea has a mixed reproduction regime with the predominance of autogamy over allogamy.

Position of *A. m. adansonii* in the floral entomofauna of cowpea

In Table 1 showing the 438 visits of 17 insect species recorded on cowpea flowers, *A. m. adansonii* was the

most represented insect with 234 visits (53.2%). The less represented of these insects belong to the Coccinellidae and Vespidae families with respectively 0.22 and 0.45% of all visits.

Activity of *A. m. adansonii* on *V. unguiculata* flowers

From our field observations, *A. m. adansonii* workers were found to intensively and preferably harvest nectar. On an average of 234 bee visits recorded, 225 (96.15%) accounted for nectar collection and only 9 (3.85%) for pollen. All the 234 *A. m. adansonii* visits were registered on 100 *V. unguiculata* flowers between 7 and 12 am. The bee activity period coincided with the opening flowers of this fabaceae, while the peak activity was located between 7 and 8 am. The number of visits followed the same pattern as the number of opened flowers, fluctuating with time. A positive and significant correlation ($r = 0.64$; $p < 0.05$) was registered between the number of visits of *A. m. adansonii* and the number of open flowers per plant (Figure 2A).

From Figure 2B, it can be drawn out that the lowest visit frequency (13.67%) was recorded between 11 - 12 am. *A. m. adansonii* was faithful to cowpea during the foraging activity. The greatest number of foragers of *A. m. adansonii* found simultaneously in activity on flowers was 2, with an average of 1.27 ($n = 22$; $s = 0.46$), whereas the highest number of workers was 500 on 1000 flowers. The mean visiting time of *A. m. adansonii* on *V. unguiculata* flowers was 8.42 sec ($n = 109$; $s = 5.89$). In a *V. unguiculata* field, the foraging speed of *A. m. adansonii* workers was 8.67 flower/min ($n = 99$; $s = 5.95$). During their foraging activity, *A. m. adansonii* workers

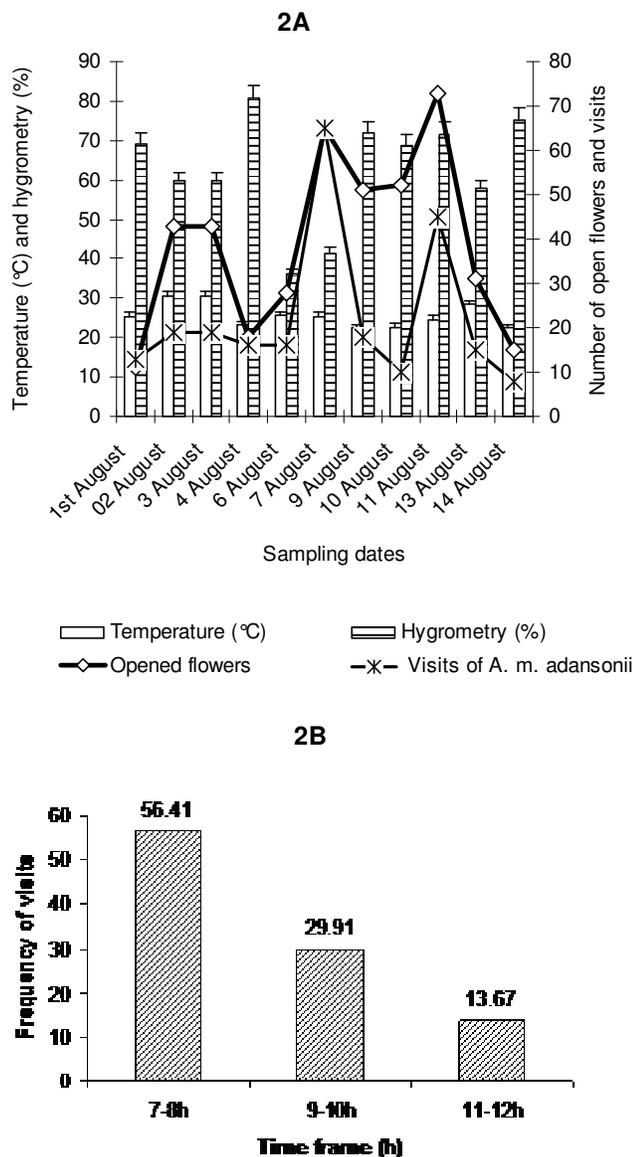


Figure 2. Daily distribution of *A. m. adansonii* visits relative to temperature and hygrometry (A) and their visit frequencies (B) on cowpea opened flowers.

were disturbed by other competing insects for nectar collection. These disturbances were evidenced by the disruption of visits that occur during the collision or the occupation of flowers. Eleven disruptions representing 4.70% of a total of 234 visits registered were caused by *A. m. adansonii* workers, with the reduction of the visiting time as the direct consequence. During their activity, no *A. m. adansonii* forager was found to move from *V. unguiculata* flowers to the neighbouring plant flowers. Thus this bee species was faithful to *V. unguiculata*.

There was no significant difference ($p = 0.944$) between the time frames (7 - 8 am; 9 - 10 am; 11 - 12 am) as far as the open flowers is concerned. However, *A. m. adansonii* spent more time foraging between 7 and 8 am,

but at a relatively lower speed than at between 9 and 10 am and between 11 and 12 am (Table 2). Similarly, the number of visits on *V. unguiculata* flower was significantly double between 7 and 8 am than 9 - 10 am, and 4 fold than between 11 - 12 am (Table 3). Whereas the hygrometry was relatively constant throughout the bee activity, the temperature gradually and significantly ($p = 0.0005$) increased from one time frame to another. Between 11 and 12 am, there was a negative and significant correlation ($r = -0.43$; $p = 0.017$) between the temperature and the number of *A. m. adansonii* visits.

Sugar content in cowpea nectar

The mean concentration of sugar in nectar was 43.03 g/100 g dry matter ($s = 0.83$; $n = 90$; minimum = 34.13; maximum = 54.27). The highest concentration value was displayed between 7 and 8 am, while the lowest was registered between 11 and 12 am.

The concentrations of total sugar in nectar of cowpea flowers did not significantly vary from one time frame to another (Figure 3), and were influenced by temperature and relative hygrometry. Between 11 and 12 am, there was a positive and significant correlation ($r = 0.42$; $p = 0.020$) between the concentration in sugar of *V. unguiculata* nectar and the temperature. Between 9 and 10 am, there was a positive and significant correlation ($r = 0.37$; $p = 0.046$) between the concentration in sugar of *V. unguiculata* nectar and the number of *A. m. adansonii* visits.

Apicultural value of *V. unguiculata*

During the observation period, we noted a well elaborated activity of *A. m. adansonii* workers on the flowers of *V. unguiculata*. In particular, there were high density of workers per 1000 flowers, good nectar collection, low pollen collection and constancy on flowers. Furthermore, our field observations revealed that in the rainy season (period of the food shortage within the honey bee colony), individual *V. unguiculata* plant could averagely produce up to 35 flowers. These findings allow the classification of *V. unguiculata* as a highly nectariferous and slightly polliniferous bee plant.

Effect of *A. m. adansonii* on *V. unguiculata* pollination

During the collection of pollen or nectar on *V. unguiculata*, foragers always check flowers and sometimes contacted anthers and carried pollen. With this pollen, they flew frequently from flower to flower. The percentage of the total visits number during which worker bees came into contact with the stigma of the visited flower was 4.70% (11 of 234 visits).

Table 2. Daily variation of cowpea flowers as well as foraging time and speeds of *A. m. adansonii*.

Daily period (h)	No. of opened flowers	Duration of a flower visit(s)	Foraging speed (flower/min)
7 - 8	3.76a	47.06b	5.85a
8 - 10	3.65a	33.26ab	10.12b
10 - 12	3.63a	30.63a	9.49b
p-value	0.944	0.018	0.007
LSD (5%)	ns	16.42	3.63

Values in the same column followed by the same letter are not significantly different at 5% level.

Table 3. Daily variation of temperature, hygrometry and visits of *A. m. adansonii*.

Daily period (h)	Hygrometry (%)	Temperature (°C)	Number visits
7 - 8	63.9a	22.27a	12c
8 - 10	66.18a	25.54ab	6.36b
10 - 12	58.54a	29.45b	2.90a
p-value	0.549	0.0005	0.014
LSD (5%)	ns	7.18	0.09

Values in the same column followed by the same letter are not significantly different at 5% level.

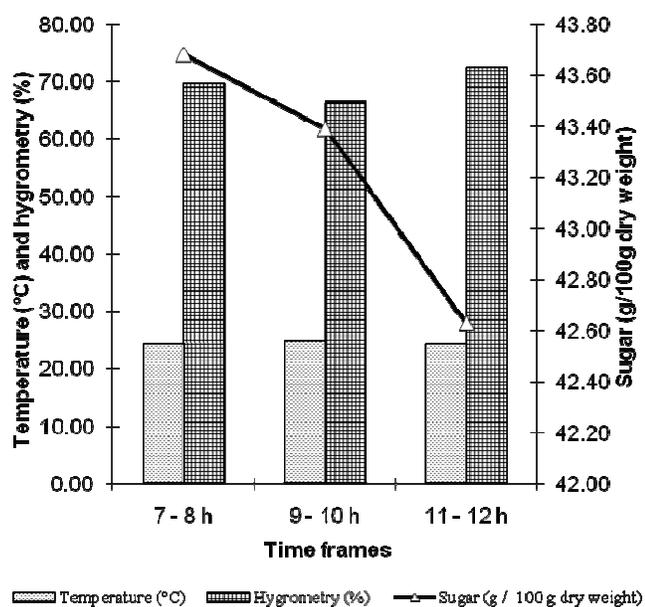


Figure 3. Daily variation of the concentration in total sugar (g/100 g dry matter) in cowpea nectar.

Yield responses of cowpea to *A. m. adansonii* activity

When cowpea yield was compared between the two groups of plants with protected and unprotected inflorescences (Table 4) it was noticed that the length, dry weight and percentage of healthy seeds per pod, the pod length, weight per plant were all significantly greater ($p < 0.0001$) in unprotected (lot 1) than protected (lot 2) flowers. Conversely, protecting flowers with gauze bags

rather significantly ($p = 0.0005$) increased the number of aborted seeds per pod as compared to that of unprotected flowers.

The fructification rates were 62 and 48%, while the percentages of healthy seeds were 97.61 and 76.17%, respectively in unprotected and protected inflorescences. Similarly, the average length of pods was 19.15 cm for lot 1 compared to 11.7 cm for lot 2. *A. m. adansonii* contributed respectively to 18.8, 9.31 and 11.73% increment of pod length, total number and healthy seeds per cowpea pod.

Within both unprotected and protected flowers, there was a positive and highly significant correlation ($r = 0.49$; $p < 0.0001$) between the dry weight and pod length, the number of healthy pods per plant and healthy seeds per pod. The correlations between the healthy pods per plant and healthy seed per pod ($r = 0.63$; $p < 0.0001$) was also positive and highly significant (Table 5). In contrast, no significant correlation was observed between each of the yield parameter and the number of abortive seeds per pod ($r = 0.11$; $p > 0.05$).

DISCUSSION

Results obtained from this study indicate that *A. m. adansonii* was the main floral insect frequent on *V. unguiculata*. In a related study conducted in Algeria, *A. m. adansonii* was only ranked second in terms of abundance of the insects floral on *Vicia faba* L. var *major* (Fabaceae) in Algeria, after the solitary bee *Eucera numida* (Benachour et al., 2007). The significant difference between the visit frequencies of *A. m. mellifera* and those of other insects can be explained by the strategies

Table 4. Cowpea yields in lot 1 (unprotected flowers) and lot 2 (protected flowers).

Yield parameters	Treatment		p-value	LSD (5%)
	Unprotected inflorescences	Protected inflorescences		
Number of seed/pod	15b	10a	< 0.0001	5.78
Seed Length (mm)	37.07b	35.06a	< 0.0001	2.00
Dry weight seed/pod (g)	0.166b	0.124a	< 0.0001	0.041
Healthy seeds/pod	15.46b	9.68a	< 0.0001	5.79
Abortive seeds/pod	0.31a	3.03b	0.0005	2.71
Healthy seeds weight/pod (g)	2.18b	0.78a	< 0.0001	1.39
Pod weight (g)	3.14b	1.16a	< 0.0001	1.97
Pod Length (cm)	19.75b	11.71a	< 0.0001	8.04

Values in the same row followed by the same letter are not significantly different at 5% level.

Table 5. Correlations between the yield parameters in protected and unprotected inflorescences.

Inflorescence	Pod dry weight	Healthy pod dry weight	Healthy seeds/pod	Abortive seed/pod
Unprotected inflorescences				
Pod length	r = 0.84 P < 0.0001	r = 0.80 P < 0.0001	r = 0.49 P = 0.004	r = 0.11 P = 0.548
Pod dry weight		r = 0.98 P < 0.0001	r = 0.60 P < 0.0001	r = 0.11 P = 0.527
Healthy pod weight			r = 0.63 P < 0.0001	r = 0.09 P = 0.599
Inflorescences protected with gauze bags				
Pod length	r = 0.71 P < 0.0001	r = 0.66 P < 0.0001	r = 0.63 P < 0.0001	r = 0.11 P = 0.419
Healthy seeds/pod				r = 0.09 P = 0.616
Pod dry weight		r = 0.98 P < 0.0001	r = 0.75 P < 0.0001	r = -0.37 P = 0.036
Healthy pod weight			r = 0.77 P < 0.0001	r = -0.44 P = 0.011
Healthy seeds/pod				r = -0.19 P = 0.286

adopted by this bee that consists of engaging several bee workers for the exploitation of an interesting nutritional resource close to the colony (Louveaux, 1984; Schneider and Hall, 1997). Consequently, there may be a limitation of the number of visits of other insect species due to the occupation of the majority of open flowers by *A. m. adansonii*. The difference between the visits frequencies accounting for nectar and/or pollen collection was attributed to the specific organization of work within the colony. As reported by Philippe (1991), averagely 4% of forager visits were preserved for pollen collection. The peak activity of *A. mellifera* on *V. unguiculata* mostly concerned nectar than pollen collection and was found to occur in the morning between 7 am and 12 am. This could be linked to the period of high availability of these products in flowers. Conversely, the floral visits of *A. m.*

adansonii was reported to mostly concerned with pollen (Benachour et al., 2007), and occurred between 10 am and 14 pm. The daily activity of the domestic bee on flowering plants may depend either on the production of pollen (Stone et al., 1998), or nectar (Suzo et al., 2001; Pouvreau, 2004).

The positive and significant correlation between the number of *A. m. adansonii* visits and the number of open flowers, together with the abundance of *A. m. adansonii* workers on 1000 flowers reveal the high attraction exerted by nectar and/or pollen of *V. unguiculata* on *A. m. adansonii*. The attraction of *A. m. adansonii* by nectar could partly be attributed to its elevated concentration in total sugar (43.03%), compared to the range of 15 - 75% in which fail most of the plant species (Proctor et al., 1996). A concentration of sugar lower than 20% was sug-

gested to be unable to allow a net energy gain to the colony (Philippe, 1991). Taking this into consideration, the foraging bee *A. m. adansonii* could certainly enable their colony to gain energy when nectar was harvested from *V. unguiculata*. The bee foragers had a high affinity with respect to *V. unguiculata* compared to the neighbouring plant species, indicating their faithfulness to this Fabaceae, a phenomenon known as «floral constancy» (Louveaux, 1984; Backhaus, 1993; Basualdo et al., 2000). This finding may be linked to the high concentration of sugar encountered in cowpea nectar, *A. mellifera* workers being reported constant on a plant species when the concentration of sugar in nectar is higher than 15% in general (Philippe, 1991). The fidelity of *A. m. adansonii* to a specific plant flower has also been attributed to recognition and memorization of the colour and odour of the flowers during previous foraging trips (Hill et al., 1997; Wright et al., 2002; Tchuenguem Fohouo et al., 2008). The disruptions of *A. m. adansonii* workers visits on *V. unguiculata* by competitor insects were reported on other plant species (Tchuenguem Fohouo, 2005; Tchuenguem Fohouo et al., 2007; Tchuenguem Fohouo et al., 2008).

As a highly nectariferous and lowly polliferous bee plant, *V. unguiculata* could be grown and protected in the neighbouring environment of hives in Cameroon in order to stabilize *A. m. adansonii* colonies during the rainy seasons.

During the harvesting activity of pollen and nectar, *A. m. adansonii* workers check flowers and thus provoke auto-pollination by applying pollen of one flower on its own stigma. This autogamy was already reported in *V. unguiculata* (Magah, 1986). *A. m. adansonii* workers were also able to carry pollen with their furs, legs or mouth accessories, and transport it from one flower of a given cowpea plant to the stigma of another flower of the same plant (geitongamy), or that of another plant (xenogamy). The contribution of *A. m. adansonii* foragers to pollination of *V. unguiculata* was more important with their increased density and foraging speed. Similarly, it was suggested that pollinators have a complementary role in the yield of cowpea, by creating a mixed pollination system dominated by self-pollination (Vaz et al., 1998).

The improved pod and seed yield of *V. unguiculata* attributed to *A. m. adansonii* can be vindicated by the activity of honey bee workers either on autopollination and/or on cross-pollination of visited flowers. The most important yield (length of pods, size of seeds, biomass of healthy seeds, number of healthy pods, percentage of abortive seeds in pods) recorded in non-protected inflorescences can be attributed to the important role of the pollinating insects. The plants that were exposed to pollinators provided more pods per plant, more seeds per pod with the heavier seeds and of better shape than the protected plants, in agreement to previous results reported on soybean (Benachour et al., 2007). The soybean plants (v. IAC-114) was reported to show

increased pods number (58.58%) and seeds (82.31%) when they were visited by the honeybees (Moreti et al., 1998). The evidence of the contribution of *A. m. adansonii* to improvement of cowpea yield corroborates with other results reported on *Glycine max* (Chiari et al., 2005).

Conclusion

A. m. adansonii is ranked first among the insect species found to visit cowpea flowers. This domestic bee forages cowpea flowers from 7 to 12 am daily, with a peak activity at between 7 - 8 am. Its visits mostly concerned nectar collection which is 43.03% rich in sugar. *A. m. adansonii* is faithful to cowpea during the foraging activity, with a foraging time and speed of respectively 8.42 s and 8.67 flowers/min. These results suggest that *V. unguiculata* is a highly nectariferous floral plant able to substantially contribute to maintaining the nutritional needs of the bee colony. *A. m. adansonii* contributed respectively to 17.43% of the number of seeds per pod and 11.20% of the fructification rate through the pollinating action of workers. The installation of *A. m. adansonii* colonies close to *V. unguiculata* field could be recommended to increase the pods and seeds production.

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