

## Foraging behaviour of *Apis mellifera* (Hymenoptera: Apidae) on *Acacia senegalensis*, *Adansonia digitata*, *Albizia coriaria* and *Steganotaenia araliacea* flowers at Ngaoundéré (Cameroon)

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### Abstract

The present investigation was conducted to assess the apicultural potential of *Acacia senegalensis*, *Adansonia digitata*, *Albizia coriaria* and *Steganotaenia araliacea*. To date in this country (Cameroon), the demand for honey and other hive products is very high, partly because of the insufficiency of the awareness of the apicultural potential of several plant species. *Apis mellifera* workers foraging activity was studied on the flowers of these plant species from November 2015 to April 2016 and 2016 to 2017. At Dang (Ngaoundéré, Cameroon), the flowers of each plant species were observed two days per week, between 07:00 am and 06:00 pm, for recording the pollen and/or nectar foraging behaviour of *Ap. mellifera* workers. Results indicated that, the foragers of *Ap. mellifera* assemble intensely and regularly the nectar of each plant species except on *S. araliacea* (low collection nectar). In addition, *Ad. Digitata* and *S. araliacea* were visited intensely for pollen; *Ac. senegalensis* and *Al. coriaria* were also visited for pollen but slightly. The abundances of foragers (greatest numbers of individuals of *Ap. mellifera* simultaneously in activity) per individual plant and on 1000 flowers varied 11 (*S. araliacea*) to 987 (*Ad. digitata*) and 15 (*S. araliacea*) to 532 (*Ad. digitata*) respectively. The average value of the sugar content of nectar varied from 18.67% (*Ad. digitata*) to 37.62% (*S. araliacea*). During its foraging activity, the foragers of *Ap. mellifera* improved pollination possibilities of each plant species.

**Keywords:** acacia senegalensis, adansonia digitata, albizia coriaria, steganotaenia araliacea, APIs mellifera, bee plant

### Introduction

Beekeeping plays a significant role in conserving the natural resources and contributes to the globe through environmental protection<sup>[1]</sup>. Honey and pollen yield, Its by product depend on availability of floral nectar and pollen resources<sup>[2]</sup>. Bees utilize particular species of plants for a limited period of time due to seasonal blooming. There are also both quantitative and qualitative differences among flowering plant species with regards to nectar and pollen production<sup>[3]</sup>. It has been observed that the quantity and quality of beehive products are reflected by the nature of plants foraged<sup>[4]</sup>. The most common way plants attract animals to visit their flowers is by providing food such as nectar and pollen<sup>[5]</sup>. *Acacia senegalensis*, *Adansonia digitata*, *Albizia coriaria* and *Steganotaenia araliacea* are the plant species who provide the alimentary resources (nectar and pollen) for honeybees. *Apis mellifera* is a social insect that builds its nest in a cavity, by connecting cones to the upper wall<sup>[6]</sup>. The honey bee plants provide pollen and nectar as main food sources for honeybees, while, flowering plants depend on bees as pollen vectors for their sexual reproduction and this interaction is particularly important in tropical ecosystems<sup>[1]</sup>. The nectar is transformed into honey which is stored together with pollen in the hive for future use<sup>[7]</sup>. These substances have been exploited by humans for thousands of years<sup>[7]</sup>. The production of these two

substances depends on the abundance of some plant species in the environment of the apiary and their attractiveness to honeybees<sup>[8]</sup>. Thus sustainable beekeeping in a given Region requires a detailed knowledge of the apicultural potential of the plant species that grow in the environment of the Apiaries<sup>[9]</sup>. Before our survey, there was no literature on the relationship between the honeybees and several plant species in Cameroon among that *Acacia senegalensis*, *Adansonia digitata*, *Albizia coriaria* and *Steganotaenia araliacea*. Nevertheless, in this country, because of the increasing demand for hive products such as honey and pollen, beekeeping needs to be developed<sup>[10]</sup>.

The present study is a contribution to the understanding of the relationships between *Apis Mellifera* Linnaeus, *Acacia senegalensis* (Houtt.) Roberty, *Adansonia digitata* Linnaeus, *Albizia coriaria* Welwitsch ex Oliver and *Steganotaenia araliacea* Hochst for their optimal exploitation. For each plant species, we recorded the activity of *Ap. mellifera* on flowers, evaluated the apicultural value and registered the pollination behaviour of *Ap. mellifera*.

### Materials and Methods

#### Material

#### Study site

The investigations were carried out from November 2015 to April 2016 and November 2016 to April 2017 in Dang, a

village in the Ngaoundéré III<sup>e</sup>, Vina Department, in the Adamaoua Region of Cameroon. This Region is situated between the 6<sup>th</sup> and 8<sup>th</sup> degrees of latitude north and between the 11<sup>st</sup> and 15<sup>th</sup> degrees of longitude East; she spread approximately 63701 km<sup>2</sup>; it belongs to the high-altitude Guinean Savannah agro-ecological zone [11]. The study station was a circular area of 1500 m in diameter centered on a Kenyan hive sheltering a colony of *Ap. mellifera* and located at a point whose geographical coordinates are as follows: latitude: 7°42.266' N, at longitude of 13°53.944' E and at altitude of 1114 m above sea level. Vegetation was represented by natural savannah species, plants from forest galleries, food crops and ornamental species. The climate is Sudano-Guinean, characterized by two seasons: a rainy season (April to October) and a dry season (November to March). The annual rainfall is about 1500 mm.

The mean annual temperature is 22 °C. The mean annual relative humidity is 70%.

**Biological material**

With the exception of *Ap. mellifera* bees, the animal material included many insect species naturally occurring in the environment of the study site. The number of honeybee colonies located in the area varied from 52 in November 2015 to 47 in April 2016 and from 54 in November 2016 to 48 in April 2017.

The plant material consisted of the flowering plants of *Ac. senegalensis*, *Ad. Digitata*, *Al. coriaria* and *S. araliacea* recognized in the natural savannah plants. Table 1 describes each plant species studied. Table 2 presents the relative abundance of opened flowers per month for each of these plants during the two studies periods.

**Table 1:** Scientific name, botanic family, biotope, some characteristics and strength (in the observation station) of different plants studied in Dang in 2016 and 2017.

Scientific name	Family	Biotope	Flowering period	DCOF	Strength*	
					2016	2017
<i>Ac. senegalensis</i> (+; tr)	Fabaceae	savannah	March-April	White	13	11
<i>Ad. digitata</i> (+; tr)	Malvaceae	savannah	November-January	White	37	35
<i>Al. coriaria</i> (+; tr)	Fabaceae	savannah	February-March	Rose-white	43	41
<i>S. araliacea</i> (+; tr)	Apiaceae	savannah	November-February	White-green	145	141

+: spontaneous plant; tr: tree; DCOF: dominant colour of open flower; \*: number of individuals in bloom

**Table 2:** Relative abundance of opened flowers on each plant species per month during the two studies periods in Dang in 2016 and 2017.

Plant species	November 2015 to April 2016						November 2016 to April 2017					
	N.	D.	J.	F.	M.	A.	N.	D.	J.	F.	M.	A.
<i>Ac. senegalensis</i>					+++	++++					++++	+++
<i>Ad. digitata</i>	+	++++	+				++	++++	+			
<i>Al. coriaria</i>			++++	+++					++++	+++		
<i>S. araliacea</i>	+++	++++	++	+			+++	++++	++			

N.: November; D.: December; J.: January; F.: February; M.: March; A.: April; +: ≤ 100 flowers = rare; ++: > 100 and ≤ 500 flowers = little abundant; +++: > 500 and ≤ 1000 flowers = abundant; ++++: > 1000 flowers = very abundant

**Study of the activity of *Apis mellifera* in the flowers**

The foraging behaviour of *Ap. mellifera* worker was recorded on flowers of different plant species from November 2015 to April 2016 and November 2016 to April 2017. Data were taken during two days per week, between 07:00 am and 06:00 pm, with three time periods per day: 07:00 am-11:00 am, 11:00 am-03:00 pm and 03:00 pm-06:00 pm. It was a question of noting whether on a flower, the honeybee collects pollen, nectar or these two substances. The harvested floral products were systematically noted during the recording of the duration of the visits by flower, using a distinctive sign on the corresponding figure [12].

Table 3 shows the number of observation per days for each plant species. For a given plant species visited by the honeybees and for each investigation date, the following parameters were registered for each daily time period and, whenever possible: floral substances (nectar or pollen) collected during each floral visit, abundance of foragers (highest number of individual bees foraging simultaneously on a flower, an individual plant or on 1000 flowers [13], duration of individual flower visit, influence of fauna (disruption of the forager in activity by competitors and/or predators [14] and impact of the surrounding flora (attractiveness of other plant species to *Ap. mellifera* workers). The influence of the competitive flora was determined by two methods: (a) direct observation of the nectar and/or pollen collection behaviour of the foragers *Ap.*

*mellifera* on a given plant and other flowering plant species under observation and (b) analysis of the pollen loads carried by honeybee workers captured on flowers. During each of the three days of full flowering, two pollen foragers were captured on the flowers of each plant species; pollen loads of each worker was then removed from pollen baskets and submitted to the microscopic analysis for the evaluation of the pollen profile [14].

**Measurement of the concentration in total sugars of the nectar of different plant species**

The concentration in total sugars of the nectar was evaluated with a handheld refractometer (0-90% Brix) and a thermometer that gave the ambient temperature, from November 2015 to April 2016 and from November 2016 to April 2017, at last three times during each of the following daily time frames: 07:00 am-11:00 am, 11:00 am-03:00 pm, 03:00 am-06:00 pm. Since the nectar of each plant is less directly accessible to the investigator, *Ap. mellifera* workers in full activity of nectar harvest were captured on the flowers. Thus collected individuals were anesthetized by their introduction in a small bottle containing cotton moistened with chloroform [15]. Nectar was then removed from honeybee crop by exerting a small pressure on the bee abdomen placed between the thumb and the forefinger of the experimenter; the nectar in the mouth was then expelled and its concentration in total sugars (in g/100 dry matter)

measured. The registered values obtained were corrected according to the ambient temperature, using a table provided by the device leaflet [16].

The concentration in total sugars of the nectar is an important parameter for the attractiveness of the honeybee with respect to many flowers [17].

**Determination of the apicultural value of different plant species**

The beekeeping value of each plant species studied was evaluated using data on the flowering intensity and, the degree of attractiveness of workers of *Ap. mellifera* to its nectar and pollen [18, 19, 20].

**Assessment of the influence of *Apis mellifera* on pollination different plant species**

This parameter was recorded during the study of the duration of visits by flower. To measure the ability of *Ap. mellifera* to act as pollinator of each plant species. It was a question of noting, during the collection of nectar or pollen, the number of times the body of foragers comes into contact with the stigma of the flower visited [19, 20]. This highlights the possibilities for *Ap. mellifera* to intervene in self-pollination and cross-pollination [12].

**Data analysis**

Data analysis was done using Excel 2016 and R commander version 2.13.0 software, descriptive statistics (calculation of means, standard deviations and percentages) and three tests: Student’s *t*-test for the comparison of the mean of two samples, Pearson’s correlation coefficient (*r*) for the study for the linear relationships between two variables and chi-square ( $\chi^2$ ) for the comparison of percentages.

**Results and Discussion**

***Apis mellifera* foraging activity on flowers  
Substances collected, intensity and frequency of harvesting of the different products**

The identity of the foods taken by workers of *Ap.*

*Mellifera* from the flowers of each investigated plant species and as well as the intensity and frequency of the harvesting of the various foods are summarizing in Table 3 and 4. The main results are as follows: a) *Ap. mellifera* workers collected intensely and regularly the nectar on *Ac. senegalensis*, *Ad. Digitata* and *Al. coriaria*; b) *Ad. digitata*, *Al. coriaria* and *S. araliacea* were visited intensely for pollen; c) *S. araliacea* was also visited for nectar but slightly; d) in general, the intensity (very low, low, high and very high) of nectar or pollen collection varied with plant species and time; e) in the plant species where honeybees harvested the nectar, the harvesting frequency (percentage of the number of days were collection of nectar was observed, compared with the number of investigation days) was 100% for each plant species; f) in the plant species where honeybees harvested the pollen, the harvesting frequency was from 100% for all studied plant species excepting *Ad. Digitata* (83.33%). The type of substance harvested from flowers (nectar or pollen) by *Ap. mellifera* in a given plant species varied with hourly brackets (Fig 1).

The present results are in line with that of Dongock *et al.* 2017 [21] who found that honeybees harvested nectar and pollen on *Al. Coriaria* in Adamaoua Region, Cameroon. In Amhara region, Ethiopia, Abebe *et al.* 2014 [1] have observed that *Ap. mellifera* also collected nectar and pollen from *Ad. Digitata* flowers. The collection of the nectar and pollen of *Ad. Digitata* have also being observed by Ahouandjinou *et al.* 2016 [22] in Benin. Abdoulahi *et al.* 2011 [23] have observed that *Ap. mellifera* also collected nectar and pollen on the flowers from *Ac. senegalensis* and *S. araliacea* in Mubi Region, Nigeria. In Nigeria, Dukku, 2013 [24] found that this honeybee collect the same floral product (nectar and pollen) on *Ac. senegalensis* and *Ad. Digitata* flowers.

Therefore the type of floral product collected by *Ap. mellifera* workers from flowers (nectar or pollen) of a given plant species can vary with regions.

The great nectar and pollen collect could specially be explained by the carbohydrate and protein needs of colonies from which originated honeybee workers.

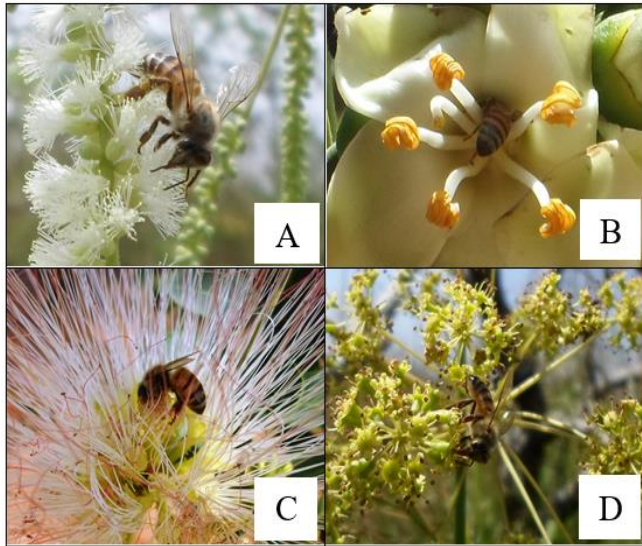
**Table 3:** Products taken by *Apis mellifera* from the flowers of each plant species according to time, intensity and frequency harvest of the various products in Dang in 2016 and 2017.

Plant species	Floral products collected																		
	November 2015 to April 2016						November 2016 to April 2017												
	N.	D.	J.	F.	M.	A.	N.	D.	J.	F.	M.	A.	TJ	nDNe	pDNe	nDPo	pDPo		
<i>Ac. senegalensis</i>					Ne <sup>1</sup> Po <sup>2</sup>	Ne <sup>4</sup> Po <sup>2</sup>							Ne <sup>3</sup> Po <sup>2</sup>	Ne <sup>4</sup> Po <sup>2</sup>	32	32	100.00	32	100.00
<i>Ad. digitata</i>	Ne <sup>1</sup> Po <sup>1</sup>	Ne <sup>4</sup> Po <sup>4</sup>	Ne <sup>1</sup> Po <sup>1</sup>				Ne <sup>2</sup> Po <sup>2</sup>	Ne <sup>4</sup> Po <sup>4</sup>	Ne <sup>1</sup>						48	48	100.00	40	83.33
<i>Al. coriaria</i>				Ne <sup>4</sup> Po <sup>3</sup>	Ne <sup>3</sup> Po <sup>2</sup>						Ne <sup>4</sup> Po <sup>3</sup>	Ne <sup>3</sup> Po <sup>2</sup>			32	32	100.00	32	100.00
<i>S. araliacea</i>	Ne <sup>2</sup> Po <sup>2</sup>	Ne <sup>2</sup> Po <sup>4</sup>	Ne <sup>2</sup> Po <sup>2</sup>	Ne <sup>1</sup> Po <sup>1</sup>			Ne <sup>2</sup> Po <sup>2</sup>	Ne <sup>2</sup> Po <sup>3</sup>	Ne <sup>2</sup> Po <sup>2</sup>						56	56	100.00	56	100.00

N.: November; D.: December; J.: January; F.: February; M.: March; A.: April; Ne: nectar harvest; Po: pollen collection; 1, 2, 3, 4: very weak, weak, strong and very strong harvests; TJ: total number of days of observation; nJNe: number of days of nectar collection; pJNe: percentage of days nectar harvested; nJPo: number of pollen harvest days; pJPo: percentage of days pollen harvested.

**Table 4:** Substances sampled by *Apis mellifera* workers from the flowers of the four plant species according to daily time bands in Dang in 2016 and 2017.

Plant species	Hourly brackets		
	07:00 am-11:00 am	11:00 am-03:00 pm	03:00 pm-06:00 pm
<i>Ac. senegalensis</i>	Nectar and pollen	Nectar and pollen	Nectar
<i>Ad. digitata</i>	Nectar and pollen	Nectar and pollen	Nectar
<i>Al. coriaria</i>	Nectar and pollen	Nectar and pollen	Nectar
<i>S. araliacea</i>	Nectar and pollen	Nectar and pollen	Pollen



**Fig 1:** Foragers of *Apis mellifera* harvesting nectar from an *Acacia senegalensis* (A), *Adansonia digitata* (B) *Albizia coriaria* (C) and *Steganotaenia araliacea* (D) flowers in Dang in 2016 and 2017.

**Abundance of foragers**

The highest number of *Ap. mellifera* workers foraging simultaneously per flower was one in *Ac. senegalensis* and *S. araliacea*, three and two for *Ad. digitata* and *Al. coriaria* respectively. The abundance of *Ap. mellifera* workers per 1000 flowers varied from 322 to 431 on *Ac. senegalensis*, 19 to 532 on *Ad. digitata*, 208 to 292 on *Al. coriaria* and from 15 to 274 on *S. araliacea* (Table 5). The abundance per individual plant varied from 487 to 854 on *Ac. senegalensis*, 63 to 987 on *Ad. digitata*, 342 to 567 on *Al. coriaria* and from 11 to 376 on *S. araliacea* (Table 6). The high abundances per 1000 flowers show the good attractiveness of the nectar and the pollen of each plant species towards *Ap. mellifera*. The observed high abundances of foragers per 1000 flowers registered in this study could be attributed to the ability of honeybees to recruit a large number of foragers to exploit an interesting food source [25, 20]. The difference observed between the abundances per 1000 flowers and per individual plant in the two years could be explained by the variation in the number of colonies present in the study site.

**Table 5:** Abundance of *Apis mellifera* workers per 1000 flowers (maximum of individuals simultaneously in activity on opened 1000 flowers for two observation periods) according to plant species and month.

Plant species	November 2015 to April 2016						November 2016 to April 2017					
	N.	D.	J.	F.	M.	A.	N.	D.	J.	F.	M.	A.
<i>Ac. senegalensis</i>					431	373					322	389
<i>Ad. digitata</i>	273	368	24				532	514	19			
<i>Al. coriaria</i>				292	288					208	291	
<i>S. araliacea</i>	56	274	86	15			67	198	205	21		

N.: November; D.: December; J.: January; F.: February; M.: March; A.: April;

**Table 6:** Abundance of *Apis mellifera* workers per individual plant (maximum of individuals simultaneously in activity on opened flowers for two observation periods) according to each plant species and month.

Plant species	November 2015 to April 2016						November 2016 to April 2017					
	N.	D.	J.	F.	M.	A.	N.	D.	J.	F.	M.	A.
<i>Ac. senegalensis</i>					854	562					860	487
<i>Ad. digitata</i>	867	952	88				987	845	63			
<i>Al. coriaria</i>				567	451					342	407	
<i>S. araliacea</i>	11	346	195	37			23	243	376	42		

N.: November; D.: December; J.: January; F.: February; M.: March; A.: April;

**Duration of visits per flower**

The mean duration of a flower visit varied with plant species and for a given plant species with the type of floral

product collected; the mean duration of a visit per flower varied significantly from one year to another year (Table 7).

**Table 7:** Duration of *Apis mellifera* visits on flowers of the four plant species according to the study periods and harvested products.

Plant species	November 2015 to April 2016				November 2016 to April 2017				Comparison of means		
	Visiting time per flower (sec)				Visiting time per flower (sec)				of the two study periods ( <i>t</i> -test)		
	<i>n</i>	<i>m</i> ± <i>sd</i>	<i>mini</i>	<i>maxi</i>	<i>n</i>	<i>m</i> ± <i>sd</i>	<i>mini</i>	<i>maxi</i>	<i>t</i> -value	<i>df</i>	<i>p</i> -value
<i>Ac. senegalensis</i> <sup>(Ne)</sup>	124	2.22 ± 0.82	1	4	119	2.47 ± 0.81	1	5	18.54	241	< 0.001 <sup>VHS</sup>
<i>Ac. senegalensis</i> <sup>(Po)</sup>	93	1.89 ± 0.64	1	3	88	2.19 ± 0.65	1	4	20.91	179	< 0.001 <sup>VHS</sup>
<i>Ad. digitata</i> <sup>(Ne)</sup>	69	16.40 ± 9.57	2	85	49	15.38 ± 8.27	3	5	3.20	116	< 0.01 <sup>HS</sup>
<i>Ad. digitata</i> <sup>(Po)</sup>	54	10.01 ± 2.65	5	20	54	7.01 ± 2.35	2	48	32.00	106	< 0.001 <sup>VHS</sup>
<i>Al. coriaria</i> <sup>(Ne)</sup>	103	9.56 ± 6.36	1	27	98	10.01 ± 6.75	2	17	3.43	199	< 0.001 <sup>VHS</sup>
<i>Al. coriaria</i> <sup>(Po)</sup>	75	2.81 ± 1.27	1	6	70	4.31 ± 2.43	1	12	28.09	143	< 0.001 <sup>VHS</sup>
<i>S. araliacea</i> <sup>(Ne)</sup>	88	1.37 ± 0.68	1	3	83	1.96 ± 0.92	1	5	31.10	169	< 0.001 <sup>VHS</sup>
<i>S. araliacea</i> <sup>(Po)</sup>	108	4.58 ± 2.43	1	14	103	4.62 ± 2.40	1	14	0.86	209	> 0.05 <sup>NS</sup>

*n*: number of durations of visits recorded; *m*: average; *sd*: standard deviation; *mini*: minimum; *maxi*: maximum; *df*: degree of freedom; Ne: Nectar collection visits; Po: Pollen collection visits; VHS: Very highly significant difference; HS: highly significant difference; NS: Non-significant difference

The difference between the mean duration of a flower visit for nectar collection and that for pollen collection was very

highly significant in *Ac. senegalensis* (2016: *t* = 23.33, *df* = 215, *P* < 0.001; 2017: *t* = 18.89, *df* = 205, *P* < 0.001), *Ad.*

*Digitata* (2016:  $t = 26.01$ ,  $df = 121$ ,  $P < 0.001$ ; 2017:  $t = 35.77$ ,  $df = 101$ ,  $P < 0.001$ ), *Al. coriaria* (2016:  $t = 59.35$ ,  $df = 176$ ,  $P < 0.001$ ; 2017:  $t = 42.93$ ,  $df = 166$ ,  $P < 0.001$ ) and *S. araliacea* (2016:  $t = 83.24$ ,  $df = 194$ ,  $P < 0.001$ ; 2017:  $t = 64.38$ ,  $df = 184$ ,  $P < 0.001$ ). Therefore, on each of the four plant species, *Ap. mellifera* spent more time on a flower for nectar collection than for pollen harvest. This fact could be explained by the abundance and/or the accessibility of each of these floral substances.

### Influence of wildlife

The visits of *Ap. mellifera* were interrupted by other individuals of the same species or other species who were competitors for the harvest of floral substances. Therefore, for 424 honeybees visits registered on *Ac. senegalensis* flowers in 2016/2017, 73 were disrupted by other *Ap. mellifera* workers (51 visits), *Belonogaster juncea* (Hymenoptera: Vespidae; 6 visits), *Ceratina* sp. (Hymenoptera: Apidae; 3 visits) and *Lasioglossum* sp. (Hymenoptera: Halictidae; 13 visits). Among 226 visits registered on *Ad. Digitata* flowers in 2016/2017, 123 were disrupted by other *Ap. mellifera* workers (117 visits) and *Ceratina* sp. (Hymenoptera: Apidae; 6 visits). For 346 visits registered on *Al. coriaria* flowers in 2016/2017, 97 were disrupted by other *Ap. mellifera* workers (86 visits), *Camponotus acvapimensis* (Hymenoptera: Formicidae; 6 visits) and *Camponotus flavomarginatus* (Hymenoptera: Formicidae; 5 visits). Among 382 visits registered on *S. araliacea* flowers in 2016/2017, 127 were disrupted by other *Ap. mellifera* workers (69 visits), *Be. Juncea* (Hymenoptera: Vespidae; 23 visits), *Calliphora* sp. (Diptera: Calliphoridae; 7 visits), *Ca. acvapimensis* (11 visits) and *Ca. flavomarginatus* (17 visits). They resulted in the reduction of the duration of certain visits, the loss of part of the pollen transported and the increase in certain foraging speeds. In order to obtain their optimal load of nectar and/or pollen, the foragers of *Ap. mellifera* victims of such disturbances were certainly obliged to visit a greater number of flowers during the corresponding foraging trips, as reported by Tchuenguem *et al.* 2020 [20] for the same bee at the level of *Agave sisalana* flowers in Dang (Ngaoundere, Cameroon).

### Influence of the surrounding flora

In 2016 and 2017, throughout the observation periods of each of the plant species under investigation, *Ap. mellifera* foragers were observed visiting flowers of several other plant species of the experimental site were also visited, for floral substances (their nectar and/or their pollen), by the workers of *Ap. mellifera*. Among these plants were *Caesalpinia pulcherrima* (Fabaceae; nectar and pollen), *Delonix regia* (Fabaceae; nectar and pollen), *Manihot esculenta* (Euphorbiaceae; nectar and pollen), *Psorospermum febrifugum* (Hypericaceae; nectar); *Wedelia paludosa* (Asteraceae; nectar and pollen), *Vernonia amygdalina* (Asteraceae; nectar and pollen). During one foraging trip, an individual bee foraging on these plant species scarcely visited another plant species (for each plant species studied, not more than three observations of such behavior, for the study periods). The foragers *Ap. mellifera* bees were not change of from each plant species investigation flowers of other plant species and vice versa was noted. Therefore, on a foraging trip, the foragers of *Ap. mellifera* were loyal for four plants species. This result

indicates that *Ap. mellifera* shows flower constancy [26, 27] for the flowers of each of the four plant species studied. This fidelity can be explained by the fact that in the honeybee, the forager is generally able to memorize and recognize the shape, smell and color of flowers visited during previous foraging trips [28]. In Cameroon, the honeybees fidelity has also been reported on the flowers of several other plants including *Callistemon rigidus* [29], *Croton macrostachyus* and *Sesum indicum* [30], *Sesum indicum* [31], *Persea americana* [32], *Helianthus annuus* [33, 34], *Vigna unguiculata* [35], *Combretum nigricans*, *Erythrina sigmoidea* and *Vernonia amygdalin* [14], *Ximenia americana* [16], *Syzygium guineense* [36, 37], *Croton macrostachyus* [38], *Agave sisalana* [20], *Bidens stephia*, *Cordia africana*, *Pittosporum viridiflorum* and *Psychotria mahonii* [39], *Brillantaisia ulugurica*, *Caesalpinia pulcherrima*, *Calliandra tweedii* and *Tecona stans* [40].

### Concentration in total sugar of the nectar of studied plants species

The average concentration in total sugar of *Ac senegalensis* nectar was 29.82% ( $n = 59$ ;  $s = 4.39$ ;  $mini = 23.46$ ;  $maxi = 35.87$ ) in 2016 and 30.31% ( $n = 67$ ;  $s = 4.28$ ;  $mini = 23.46$ ;  $maxi = 36.55$ ) in 2017. The difference between these means is very highly significant ( $t = 3.52$ ,  $Df = 124$ ,  $P < 0.001$ ). The average concentration in total sugar of the *Ad. Digitata* nectar was 19.17% ( $n = 38$ ;  $s = 1.29$ ;  $mini = 17.54$ ;  $maxi = 23.70$ ) in 2016 and 18.67% ( $n = 43$ ;  $s = 1.22$ ;  $mini = 16.45$ ;  $maxi = 24$ ) in 2017. The difference between these two latter means is not significant ( $t = 7.94$ ,  $Df = 79$ ,  $P > 0.05$ ). The average concentration in total sugars of *Al. coriaria* nectar was 24.23% ( $n = 34$ ;  $s = 1.91$ ;  $mini = 21.12$ ;  $maxi = 31.63$ ) in 2016 and 24.11% ( $n = 33$ ;  $s = 1.99$ ;  $mini = 17.62$ ;  $maxi = 31.47$ ) in 2017. The difference between these two latter means is not significant ( $t = 1.01$ ,  $Df = 65$ ,  $P > 0.05$ ). The average concentration in total sugars of *S. araliacea* nectar was 36.84% ( $n = 31$ ;  $s = 3.95$ ;  $mini = 29.81$ ;  $maxi = 47.14$ ) in 2016 and 37.62% ( $n = 37$ ;  $s = 4.55$ ;  $mini = 30.73$ ;  $maxi = 48.23$ ) in 2017. The difference between these two latter means is highly significant ( $t = 3.02$ ,  $df = 66$ ,  $P < 0.01$ ). Pacini and Nepi, 2007 [41] have indicated that nectar secretion rate, sugar concentration and energy content are determinants of the plant/pollinator (e.g. honeybees) relationship.

### Apicultural value of the plant species

During the two flowering period of each studied plant species, we registered remarkable activity of the workers of *Ap. mellifera* at the flower level. There were a high abundantly of workers per tree, a large collection of nectar on all plant species excepting for *S. araliacea* (nectar harvest is low), high pollen collect in *Ad. Digitata*, *Al. coriaria* and *S. araliacea*. In addition, we observed fidelity of foragers to flowers during foraging trips Furthermore, in the dry season, which is the main period of honey flow, individual tree of each investigated plant species can produce more than 156000 flowers. At grounding these results, the plant species studied can be classified based on their apicultural value as follows: a) very strongly nectariferous and polliniferous: *Ad. Digitata* and *Al. coriaria*; b) very strongly nectariferous: *Acacia senegalensis*; c) very strongly polliniferous: *S. araliacea*. Table 8 indicates the appropriate period for honey or pollen take from hives installed in area of at last 3 km in diameter

where flora in bloom is mainly made up of a strong population of each of the plant species with a high Apicultural value according to the investigations done in the period 2016-2017.

**Table 8:** Apicultural value of various plant species and the most favorable period to harvest honey and/or pollen from *Apis mellifera* hives.

Plant species	Apicultural value		Period of honey and/or pollen collection	
	Nectar	Pollen	Honey	Pollen
<i>Ac. senegalensis</i>	++++	++	April	-
<i>Ad. digitata</i>	++++	++++	December	December
<i>Al. coriaria</i>	++++	+++	February	February
<i>S. araliacea</i>	++	++++	-	December

Therefore, in the Adamaoua savannah in Cameroon, honey can be harvested in December, February and April if the environment of the apiary is dominated by strong populations of *Ad. Digitata*, *Al. coriaria* and *Ac. senegalensis* respectively. Pollen can be harvested in the hives in December and February, if the surrounding environment of the apiary is characterized by many individuals of *Ad.*

**Table 9:** Number and frequency of contacts between of the foragers of *Apis mellifera* and the stigma during the floral visits to four plant species in Dang in 2016 and 2017.

Plant species	November 2015 to April 2016			Number of studied visits	November 2016 to April 2017		Total <sup>2016/2017</sup>		
	Number of studied visits	Visits with stigmatic contacts			Visits with stigmatic contacts	Number of studied visits	Visits with stigmatic contacts		
		Number	%				Number	%	
<i>Ac. senegalensis</i>	217	217	100.00	207	207	100.00	424	424	100.00
<i>Ad. digitata</i>	123	27	13.70	103	38	18.90	226	65	16.33
<i>Al. coriaria</i>	178	178	100.00	168	168	100.00	346	346	100.00
<i>S. araliacea</i>	196	196	100.00	186	186	100.00	382	382	100.00

**Conclusion**

For our survey, the honeybees taken the nectar and pollen in the flowers of *Acacia senegalensis*, *Adansonia digitata*, *Albizia coriaria* and *Steganotaenia araliacea*. These honeybees very strongly collected nectar of *Ac. senegalensis*, *Ad. Digitata*, *Al. coriaria*; it strongly harvested pollen on *Ad. Digitata*, *Al. coriaria* and *S. araliacea* flowers; in addition, the foragers of *Apis mellifera* slowly harvested nectar of *S. araliacea*. All these plant species contributed more or less to the feeding and therefore to the strengthening of the honey bee colonies. The honeybee *Ap. mellifera* workers enhanced the pollination possibilities of each plant species. The equipment of *Ap. mellifera* colonies near of each plant species is advised to enhance fruit/pod or seed production.

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**References**

1. Abebe JW, Amssalu B, Kefelegn K. Floral phenology

*Digitata*, *Al. coriaria* and *S. araliacea*.

**Impact of *Apis mellifera* activity on pollination of the plant species**

When collecting pollen and/or nectar on the flowers of the three studied plant species, *Ap. mellifera* was frequently in contact with the anthers and stigma [42]. They could therefore be directly involved in self-pollination, by putting pollen grains of one flower on the stigma of the same flower. The individual bee passing from flower to flower on different plants were seen carrying pollen from one plant to another.

They could therefore allowed xenogamy [43] by putting the pollen of a giving plant species on the stigma of another plant species. The percentage of the total number of visits during which worker honeybees came into contact with the stigma of the visited flower was 100% for each studied plant species Excepted for *Ad. Digitata* (16.33%) (Table 9). Therefore, the honeybees strongly enhance the pollination possibilities of *Ac.*

*Senegalensis*, *Ad. Digitata*, *Al. coriaria* and *S. araliacea*. The impact of the foragers of *Ap. mellifera* bees of pod or grain yields of each of these plant species via its pollination efficiency will be investigated in next work.

and pollen potential of honey bee plants in North-East dry land areas of Amhara region, Ethiopia. Journal of Agriculture and Veterinary Science. 2014; 7(5):36-49.

2. Yédomonhan H, Houenon GJ, Akoégninou A, Adomou AC, Tossou GM, Van der Maesen LJG, *et al.* The woody flora and its importance for honey production in the Sudano - Guinean zone in Benin. International Journal of Science and Advanced Technology. 2012; 2:1-11.

3. Kebede H, Gebrechirstos S. Floral establishment of major honey plants in Tahtay Qoraro, north western zone of Tigray, Ethiopia. Bulletin of Environment Pharmacology and Life Sciences, 2016; 5(12):49-56.

4. Lafèche B. Les abeilles. Guide pratique de l'apiculture amateur. Solar Nature. 1981, 76.

5. Abrol DP. *Pollination biology: biodiversity conservation and agricultural production*. Springer Dordrecht Heidelberg, London, 2012, 792.

6. Michel N, Bierna M, Greuse MJ, Decot B, Cloes G, Rafamatamantsoa LE, *et al.* L'apiculture. Echos du cota n° 65, 1994, 15.

7. Crane E. The world history of beekeeping and honey hunting. Duckworth, London, 1999, 682.

8. Afik O, Dag A, Shafir S. The effect of avocado (*Persea Americana*) nectar composition on its attractiveness to honeybees (*Apis mellifera*). Apidologie. 2006; 37:317-325.

9. Leven L, Boot VWJ, Mutsaers M, Segeren P, Velthuis

- H. Beekeeping in the Tropics [Agrodock 32] (6th edn). Agromisa Foundation and CTA, Wageningen, 2005, 87.
10. INADES. Rapport des ateliers avec les Apiculteurs de l'Adamaoua. INADES-Formation Cameroun, Antenne de Maroua (ed), Maroua, 2000, 29.
  11. Amougou JA, Abossolo SA, Tchindjang M. Variability of precipitations at Koundja and Ngaoundere based on temperature changes of Atlantic Ocean and El NINO. Ivoiriy Coast Review of Science and Technology. 2015; 25:110-124.
  12. Tchuenguem FFN. Activité de butinage et de pollinisation de *Apis mellifera adansonii* (Hymenoptera: Apidae, Apinae) sur les fleurs de trois plantes à Ngaoundéré (Cameroun): *Callistemon rigidus* (Myrtaceae), *Syzygium guineense* var. *macrocarpum* (Myrtaceae) et *Voacanga africana* (Apocynaceae). Thèse de Doctorat d'État, Université de Yaoundé I, 2005, 103.
  13. Tchuenguem FFN, Népide NC. Efficacité pollinisatrice de *Apis mellifera* L. (Hymenoptera : Apidae) sur *Sesamum indicum* (Pedaliaceae) var. Graine Blanche et Lisse à Dang (Ngaoundéré, Cameroun). International Journal of Biological and Chemical Sciences. 2018; 12(1):446-461.
  14. Tchuenguem FFN, Fameni T, Pharaon MA, Messi J, Brückner D. Foraging behaviour of *Apis mellifera adansonii* (Hymenoptera: Apidae) on *Combretum nigricans*, *Erythrina sigmoidea*, *Lannea kerstingii* and *Vernonia amygdalina* flowers at Dang (Ngaoundéré, Cameroon). International Journal of Tropical Insect Science. 2010; 30(1):40-47.
  15. Tchuenguem FF-N, Djonwangwé D, Messi J, Brückner D. Exploitation des fleurs de *Entada africana*, *Eucalyptus camaldulensis*, *Psidium guajava* et *Trichillia emetica* par *Apis mellifera adansonii* à Dang (Ngaoundéré, Cameroun). Cameroon Journal of Experimental Biology. 2007; 3:50-60.
  16. Djonwangwé D, Tchuenguem FFN, Messi J. Foraging and pollination activities of *Apis mellifera adansonii* (Hymenoptera: Apidae) on *Ximenia Americana* (Olacaceae) flowers at Ngaoundéré (Cameroon). International Research Journal of Plant Science. 2011a; 2(6):170-178.
  17. Philippe JM. La pollinisation par les abeilles: pose des colonies dans les cultures en floraison en vue d'accroître les rendements des productions végétales. EDISUD, Aix-en-Provence, 1991, 178.
  18. Villières B. L'apiculture en Afrique Tropicale. Dossier "Le point sur" n°11, GRET, Paris, 1987, 220.
  19. Wékéré C, Kingha TBM, Dongock ND, Djakbé JD, Faïbawa E, Tchuenguem FF-N, et al. Exploitation of *Jatropha curcas*, *Senegalia polyacantha* and *Terminalia schimperiana* flowers by *Apis mellifera* (Hymenoptera: Apidae) at Dang (Ngaoundéré, Cameroon). Journal of Entomology and Zoology Studies. 2018; 6(2):2072-2078.
  20. Tchuenguem FF-N, Faïbawa E, Fameni TS. Exploitation of the flowers of *Agave sisalana* (Asparagaceae) by *Apis mellifera* (Hymenoptera: Apidae) in Dang (Ngaoundéré, Cameroon). Journal of Chemical, Biological and Physical Sciences. 2020; 10(4):481-498.
  21. Dongock ND, Tientcheu MLA, Mbaiti D, Saradoum G, Pinta JY. Importance écologique et potentialité apicole à la périphérie du Parc national de Manda en zone soudanienne du Moyen - Chari (Tchad), International Journal of Environmental Studies. 2017; 74(3):443-457.
  22. Ahouandjinou STB, Yedomonhan H, Adomou AC, Tossou MG, Akoegninou A. Caractéristiques techniques et importance socio - économique de l'apiculture au Nord - Ouest du Bénin : cas de la commune de Cobly. International Journal of Biological and Chemical Sciences. 2016; 10(3):1350-1369.
  23. Abdullahi G, Sule H, Chimoya IA, Isah MD. Diversity and relative distribution of honey bees foraging plants in some selected reserves in Mubi region, Sudan savannah ecological zone of Nigeria. Advances in Applied Science Research. 2011; 2(5):388-395.
  24. Duku UH. Identification of plants visited by the honeybee, *Apis mellifera* L. in the Sudan Savanna zone of northeastern Nigeria. African Journal of Plant Science. 2013; 7(7):273-284.
  25. Egono NCC, Kingha TBM, Fameni TS, Dounia, Tchuenguem FF-N. Pollination efficiency of *Apis mellifera* (Hymenoptera: Apidae) on *Helianthus annuus* (Asteraceae) flowers at Dang (Ngaoundéré, Cameroon). International Journal of Biosciences. 2018; 13(3):314-328.
  26. Louveaux J. L'abeille domestique dans ses relations avec les plantes cultivées. In: "Pollinisation et productions végétales", Pesson P. & Louveaux J. (eds), INRA, Paris, 1984, 527-555.
  27. Montgomery BR. Do pollen carryover and pollinator constancy mitigate effects of competition for pollination? Oikos. 2009; 118:1084-1092.
  28. Wright GA, Skinner BD, Smith BH. Ability of honeybee, *Apis mellifera*, to detect and discriminate odors of varieties of canola (*Brassica Rapa* and *Brassica napus*) and snapdragon flowers (*Antirrhinum majus*). Journal of Chemical Ecology. 2002; 28(4):721-740.
  29. Fameni ST, Tchuenguem FFN, Brückner D. Pollination efficiency of *Apis mellifera* (Hymenoptera: Apidae) on *Callistemon rigidus* (Myrtaceae) flowers at Dang (Ngaoundéré, Cameroon). International Journal of Tropical Insect Science 2012; 32(1):2-11.
  30. Népide NC. Efficacité pollinisatrice de *Apis mellifera* L. (Hymenoptera : Apidae) sur *Croton macrostachyus* (Euphorbiaceae) et *Sesamum indicum* (Pedaliaceae) à Dang (Ngaoundéré, Cameroun). Université de Ngaoundéré, 2017, 104.
  31. Pharaon MA, Dounia, Douka C, Otiobo AEN, Tchuenguem FFN. Pollination efficiency of *Apis mellifera* L. (Hymenoptera: Apidae) on flowers of *Sesamum indicum* L. (Pedaliaceae) at Bilone (Obala, Cameroon). International Journal of Research Studies in Agricultural Sciences. 2018; 4(3):12-20.
  32. Valdeyron G. Production des semences pour quelques plantes de grandes cultures: céréales, graminées fourragères, betterave à sucre. In: "Pollinisation et productions végétales", Pesson P. & Louveaux J. (eds), INRA, Paris, 1984, 143-330.
  33. Basualdo M, Bedascarrasbure E, De Jong D. Africanized honeybees (Hymenoptera: Apidae) have a greater fidelity to sunflowers than European bees. Journal of Economic Entomology. 2000; 93:304-307.
  34. Tchuenguem FFN, Ngakou A, Kengni BS. Pollination and yield responses of cowpea (*Vigna unguiculata* L.

- Walp.) to the foraging activity of *Apis mellifera adansonii* (Hymenoptera: Apidae) at Ngaoundéré (Cameroon). African Journal of Biotechnology. 2009a; 9:1988-1996.
35. Tchuenguem FFN, Djonwangwé D, Messi J, Brückner D. Activité de butinage et de pollinisation de *Apis mellifera adansonii* (Hymenoptera, Apidae) sur les fleurs de *Helianthus annuus* (Asteraceae) à Ngaoundéré (Cameroun). Cameroon Journal of Experimental Biology. 2009b; 5(1):1-9.
36. Tchuenguem FFN, Djonwangwé D, Brückner D. Foraging behaviour of the african honeybee (*Apis mellifera adansonii*) on *Annona senegalensis*, *Croton macrostachyus*, *Psorospermum febrifugum* and *Syzygium guineense* var. *guineense* at Ngaoundéré (Cameroon). Pakistan Journal of Biological Sciences. 2008; 11:719-725.
37. Djonwangwé D, Tchuenguem FFN, Messi J, Brückner D. Foraging and pollination activities of *Apis mellifera adansonii* (Apidae) on *Syzygium guineense* var. *guineense* (Myrtaceae) flowers at Ngaoundéré (Cameroon). Journal of Animal and Plant Sciences. 2011b; 3(10):1325-1333.
38. Népidé NC, Tchuenguem FFN. Pollination efficiency of *Apis mellifera adansonii* (Hymenoptera: Apidae) on *Croton macrostachyus* (Euphorbiaceae) flowers at Dang, Ngaoundéré, Cameroon. International Journal of Biosciences. 2016; 9(3):75-88.
39. Mbéré N, Azo'o EM, Tchobsala, Tchuenguem FF-N. Floral activity of *Apis mellifera* (Hymenoptera: Apidae) on *Bidens steppia* (Asteraceae), *Cordia Africana* (Boraginaceae), *Pittosporum viridiflorum* (Pittosporaceae) and *Psychotria mahonii* (Rubiaceae) in Nyambaka (Adamawa, Cameroon). African Journal of Agricultural Research. 2020; 16(9):1278-1288.
40. Oumarou B, Mazi S, Pando JB, Fameni TS, Tchuenguem FF-N. Foraging activity of *Apis mellifera* Linnaeus (Hymenoptera: Apidae) visiting the flowers of four plant species in the urban area of Ngaoundéré (Cameroon). Journal of Entomology and Zoology Studies. 2020; 8(5):2055-2063.
41. Pacini E, Nepi M. Nectar Production and Presentation. In: Nicolson, S.W., M. Nepi and E. Pacini (Eds.). Nectaries and Nectar. Dordrecht: Springer, 2007, 167-214.
42. Jacob-Remacle A. Comportement de butinage de l'abeille domestique et des abeilles sauvages dans des vergers de pommiers en Belgique. Apidologie. 1989; 20:271-285.
43. Lobreau-Callen D, Coutin R. Ressources florales exploitées par quelques Apoïdes des zones cultivées en savane arborée sénégalaise durant la saison des pluies. Agronomie. 1987; 7:231-246.