Available online at http://ajol.info/index.php/ijbcs

Int. J. Biol. Chem. Sci. 4(4): 1180-1190, August 2010

ISSN 1991-8631

International Journal of Biological and Chemical Sciences

Original Paper

http://indexmedicus.afro.who.int

Foraging behaviour of *Apis mellifera adansonii* Latreille (Hymenoptera : Apidae) on *Daniellia oliveri, Delonix regia, Hymenocardia acida* and *Terminalia mantaly* flowers in Ngaoundéré (Cameroon)

Fernand-Nestor TCHUENGUEM FOHOUO[1*], Sidoni FAMENI TOPE [1], Auguste PHARAON MBIANDA [1], Jean MESSI [2] and Dorothea BRÜCKNER [3]

[1] *Faculty of Science, University of Ngaoundéré, P.O. Box 454 Ngaoundéré, Cameroon.*
[2] *Laboratory of Zoology University of Yaoundé I, P.O. Box 812 Yaoundé, Cameroon.*
[3] *Forschungsstelle für Bienenkunde, Universität Bremen, FB2, Postfach 33 04 40, 28334 Bremen, Germany.*
[*] *Corresponding author, E-mail: nt.foho@gmail.com; Tel. (237) 99 86 93 50*

ABSTRACT

To determine the apicultural value of *Daniellia oliveri*, *Delonix regia*, *Hymenocardia acida* and *Terminalia mantaly*, the foraging activity of the honey bee, *Apis mellifera adansonii* was studied on flowers in the area of Ngaoundéré, from December 2001 to May 2002 and from December 2002 to May 2003. At Dang, flowers of each plant species were prospected at least four days per month, between 07.00 and 18.00 h, for recording of the nectar and/or pollen foraging behaviour of *A. m. adansonii* workers. Results showed that *A. m. adansonii* harvested nectar and pollen of each plant species. The greatest number of workers foraging simultaneously on a plant varied from 230 (*H. acida*) to 3500 (*De. Regia*). *A. m. adansonii* workers that visited flowers of a given plant species once generally remained with this nectar and/or pollen sources throughout the observation period. Thus *Da. oliveri*, *De. regia*, *H. acida* and *T. mantaly* could be cultivated and protected to increase honey production. Each of the four plant species could enable beekeepers to increase their pollen production as a hive product. On each plant species, *A. m. adansonii* workers carried pollen from one flower to another and can thus be considered as pollinators.

Keywords: Nectar, pollen, bee plant, apicultural value, honey, pollination, Dang.

INTRODUCTION

The basic foods of each honey bee colony are nectar and pollen (Crane, 1999; Weidenmüller and Tautz, 2002, Jha and Vandermeer, 2009). Nectar is transformed into honey. Pollen and honey are store in the hive for future use. These substances have been exploited by humans for thousands of years (Crane, 1999). Honey and pollen production mainly depends on the abundance of some plant species and their attractiveness to honey bees (Williams and Carreck, 1994; Afik et al., 2006). Thus sustainable beekeeping in a given region requires a detailed knowledge of the apicultural value of the plant species that grow in the environment of the hives (Morton, 1964; Bakenga et al., 2000; Leven et al., 2005; Paterson, 2006).

Before this study, there was a dearth of literature on the relationship between the

honey bee and many plant species in Cameroon. Nevertheless, in the country, owing to increasing demand for hive products such as honey and pollen, beekeeping needs to be developed. The highest quantities of honey consumed or marketed in Cameroon came from the Adamawa Region which has a climate particularly favourable to the proliferation of bees (INADES, 2000), though production in this region is generally considered to be very low as in the whole Africa in general (Dietemann et al., 2009).

The main objective of this work was to contribute to the knowledge of the relationships between the honeybee *Apis mellifera adansonii* Latreille and *Daniellia oliveri* (Rolfe) Hutch. et Dalz (Caesalpiniaceae), *Delonix regia* (Boj.) Raf. (Caesalpiniaceae), *Hymenocardia acida* Tul. (Hymenocardiaceae) and *Terminalia mantaly* H. Perrier (Combretaceae). These plant species are among the most common woody species of the Adamawa Region. For each plant species, we recorded the activity of *A. m. adansonii* on flowers, estimated the apicultural value and evaluated the potential efficiency of *A. m. adansonii* as pollinator.

MATERIALS AND METHODS

Study site and biological materials

The studies were carried out from December 2001 to May 2002 and from December 2002 to May 2003 at Dang, a village located in the north of the city of Ngaoundéré in the Adamawa Region of Cameroon. This Region belongs to the high-altitude Guinea savannah ecological zone. The climate is tropical and 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 and the mean annual relative humidity is 70%.

Plants chosen for observations were located in an area of 3 km in diameter, centred on a kenyan top–bar hive inhabited by an *A. m. adansonii* colony. The hive is located at latitude 7°24.949' N and longitude 13°32.870' E (altitude 1093 masl). The number of honey bee colonies located in this area varied from 32 in December 2001 to 67 in January 2002. The vegetation was represented by crops, ornamental plants, hedge plants and native plants of the savannah and gallery forests. Table 1 describes plant species studied. For each of these plant species, Table 2 shows the relative abundance of open flowers per month, during the two studied periods.

Study of the foraging activity of *Apis mellifera adansonii* on flowers

From 1st December 2001 to 31st May 2002, and later from 1st December 2002 to 31st May 2003, flowers of different plant species were observed and the foraging behaviour of *A. m. adansonii* workers recorded. Data were taken for at least 4 days per month between 07.00 and 18.00 h, with three time period per day (07.00-11.00, 11.00-15.00 and 15.00-18.00 h). Table 3 provides information on the number of observation days for each plant. For each plant species visited by the bees and for each observation date, the following parameters were registered for each time period and, whenever possible, on at least 10 individual plants: floral product (nectar or pollen) harvested during each floral visit, abundance of foragers (highest number of individual bees foraging simultaneously on a flower or an individual plant), duration of individual flower visit (by using stopwatch), influence of the fauna (disruption of the forager's activity by competitors and/or predators) and impact of the other surrounding flora (i.e. attractiveness of other plant species to *A. m. adansonii* workers). The influence of this 'competitive' flora was assessed by two methods: (a) direct observation of the nectar and/or pollen collection behaviour of the bees on a given plant species and other flowering plant species near the plants under observation, and (b) study of the pollen loads

carried by *A. m. adansonii* workers caught on flowers. During each of the 3 days of full flowering, two pollen foragers were caught on the flowers of each plant species. Pollen loads of each worker were then removed from pollen baskets and submitted to the microscopic analysis for the determination of the pollen profile.

Evaluation of the apicultural value of different plant species

The apicultural value of each plant studied was evaluated using data on the flowering intensity and the degree of attraction of *A. m. adansonii* worker to their nectar and pollen (Guerriat, 1996; Tchuenguem Fohouo et al., 2004, 2007, 2008a, 2008b, 2009a, 2009b).

Evaluation of the influence of *Apis mellifera adansonii* on pollination

To measure the ability of *A. m. adansonii* to act as pollinator of each plant species, visits during which the honey bee came into contact with the stigma were counted together with the registration of the duration of the flower visits (Jacob-Remacle, 1989; Freitas, 1997).

Data analysis

Data were subjected to descriptive statistics, correlation coefficient (r) for the evaluation of the association between two variables, Student's t–test for the comparison of means of two samples using Microsoft Excel software. Values are given as means ± standard deviation (SD).

RESULTS

***Apis mellifera adansonii* foraging activity on flowers**

Floral products harvested, intensity and frequency of collection of different products

The identity of the foods harvested by *A. m. adansonii* workers on flowers of each investigated plant species as well as the intensity and frequency of the collection of different foods are shown in Tables 3 and 4. The main results are as follows: (a) on flowers of each plant species, *A. m. adansonii* workers collect nectar and pollen; (b) in general, the intensity (very low, low, high, very high) of nectar or pollen collection varies with plant species and time; (c) the harvesting frequency of nectar (percentage of the number of days where collection of nectar was observed, compared with the number of investigation days) varied from 32.29% in *De. regia* to 100% in *Da. oliveri*, and (d) the harvesting frequency of pollen varied from 25% in *H. acida* to 100% in each of the other three plant species (Table 3). The type of substance harvested from flowers (i.e. nectar or pollen) by *A. m. adansonii* on a given plant species varied with hourly brackets (Table 4).

Density of foragers

The highest number of *A. m. adansonii* workers foraging simultaneously per flower was 1 for *H. acida* and *T. mantaly*, 3 for *De. regia* and 4 for *Da. oliveri*. The abundance of *A. m. adansonii* workers per individual plant varied from 230 in *H. acida* (January 2003) to 3500 in *De. regia* (February 2002; Table 5).

Duration of visits per flower

In general, (a) the mean duration of a flower visit varied with plant species and for a given plant species with the type of floral product collected, and (b) the mean duration of a visit per flower did not vary significantly from year to year (Table 6).

The difference between the mean duration of a flower visit for nectar collection and that for pollen collection was highly significant in *Da. oliveri* (2001/2002 : t = 5.39, $P < 10^{-7}$; 2002/2003 : t = 4.78, $P < 10^{-5}$), *T. mantaly* (2001/2002 : t = 7.57, $P < 10^{-9}$; 2002/2003 : t = 7.10, $P< 10^{-9}$), *H. acida* (2001/2002 : t = 4.79, $P < 10^{-9}$; 2002/2003 : t = 5.85, $P< 10^{-9}$) and *De. regia* (2002/2003 : t = 2.32, $P < 10^{-2}$). Thus, on each of the four

plant species, *A. m. adansonii* spent more time on a flower for nectar collection than for pollen.

The duration of visits was partially influenced by disruptions due to other anthophilous insects. Thus for 108 honey bee visits registered on *De. regia* flowers in 2001/2002, 45 were disrupted by other *A. m. adansonii* (31 visits), *Xylocopa calens* Lepeletier (9 visits), *Megachile* sp. (3 visits) and *Camponotus flavomarginatus* Mayr (2 visits). Among the 108 visits registered on *H. acida* flowers in 2002/2003, 51 were disrupted by other *A. m. adansonii* (22 visits), *Meliponula ferruginea* Lepeletier (15), *Lasioglossum* spp. (9 visits) and *Xylocopa calens* (5 visits).

Influence of neighbouring flora

During the observation periods of each of the plant species under investigation, flowers of many other plant species growing in the study area were visited by *A. m. adansonii* workers, for nectar or pollen.

During one foraging trip, an individual bee foraging on a given plant species scarcely visited another plant species, and for each plant species studied, not more than three observations of such behaviour was recorded during the entire study period. In addition, the analysis of the pollen loads collected from the pollen baskets of worker bees showed that, the percentage of foreign pollen varied from 0.13% in *De. regia* and *H. acida* to 0.87% in *Da. oliveri* (Table 7).

Apicultural value of the plant species

During the observation period, we recorded distinct levels of activity of *A. m. adansonii* workers on the flowers of four plant species. In particular, there was a high density of workers per tree, good nectar collection on all plant species, high pollen collection on *L. kerstingii* and *V. amygdalina*, and continuous flowering in all the four studied plant species. Moreover, in the dry season, which is the main period of honey flow, individual tree of each of the four investigated plant species could produce more than 20,000 flowers. Based on these data, the plant species studied can be classified based on their apicultural value as follows: (a) very highly nectariferous: *Da. oliveri*, *De. regia* and *H. acida* ; (b) slightly nectariferous: *T. mantaly*; (c) very highly polliniferous: *De. regia* and *T. mantaly*, (d) highly polliniferous: *Da. oliveri* and *H. acida.*

Table 8 summarizes the appropriate period to harvest honey or pollen from hives installed in an area of at least 3 km in diameter where flora in bloom was mainly made up of a strong population of each of the plant species with high apicultural value according to the investigations of the period 2001–2003. Thus in the Adamawa Region of Cameroon: (a) honey can be harvested in February, March and June, if the environment of the apiary is dominated by strong populations of *T. mantaly*, *Da. oliveri* and *H. acida* respectively; (b) pollen can be harvested in the hives in December, January, February and May, if the surrounding environment of the apiary is characterized by many *T. mantaly*, *Da. oliveri*, *H. acida* and *De. regia* plants respectively.

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

During the collection of pollen or nectar on the flowers of the four studied plant species, foragers regularly contacted anthers and carried pollen. With this pollen, they flew frequently from flower to flower. The percentage of the total number of visits during which worker bees came into contact with the stigma of the visited flower was 100% in *L. kerstingii*, 100% in *E. sigmoidea*, 84.58% in *C. nigricans* and 88.65% in *V. amygdalina* during the 2001-2003 investigation period (Table 9).

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

Plant species	Family	Biotope	PF	DCOF	Strength*	
					December 2001	December 2002
Daniellia oliveri (Rolfe) Hutch. et Dalz (++ ; tr)	Fabaceae	savannah	Dec-Jan	white greenish	1181	1179
Delonix regia (Boj.) Raf. (+ ; tr)	Fabaceae	garden	Dec-May	red	27	27
Hymenocardia acida Tul. (++ ; sh)	Hymenocardiaceae	Savannah	Dec-Feb	red	28197	19054
Terminalia mantaly H. Perrier (+ ; sh)	Combretaceae	garden	Nov-Fév	yellowish	49	44

+, Cultivated plant; ++, spontaneous plant; tr, tree; sh, shrub; FP, flowering period; DCOF, dominant colour of open flower.
* Number of individual in bloom.

Table 2: Relative abundance of open flowers according to plant species and time.

Plant species	December 2001 to May 2002						December 2002 to May 2003					
	D	J	F	M	A	Ma	D	J	F	M	A	Ma
Daniellia oliveri	4	4					4	4				
Delonix regia	4	4	4	4	4	4	3	4	4	4	4	4
Hymenocardia acida	1	4	4				1	4	4			
Terminalia mantaly	4	2					4	1				

D, December; J, January; F, February; M, March; A, April; Ma, May ; 1: ≤100 flowers = rare; 2: >100 and ≤500 flowers = little abundant ; 3: >500 and ≤1000 flowers = abundant; 4: >1000 flowers = very abundant

DISCUSSION

The collection of nectar of *E. sigmoidea* and the harvesting of nectar and pollen of *L. kerstingii* by *A. m. adansonii* have also been observed during previous investigations in the same area of the Adamawa Region (Tchuenguem Fohouo et al., 1997). The collection of pollen and nectar of *V. amygdalina* by *A. m. adansonii* has also been recorded in Ethiopia (Fichtl and Adi, 1994). On this Asteraceae, only the collection of nectar has been observed in West Cameroon (Dongock Nguemo et al., 2004).

The collection of *Da. oliveri* nectar has also been observed in West Africa (Villières, 1987). The collection of pollen of *Da. oliveri* (Tchuenguem Fohouo et al., 1997) by *A. m. adansonii* have also been observed during previous investigations in the same area of the Adamawa Region of Cameroon. In addition, in the later study, the authors also recorded collection of pollen of *T. mantaly* in the same locality. On *H. acida*, only the collection of nectar has been observed in Gabon (Villières, 1987).

Table 3: Food harvested by *Apis mellifera adansonii* on flowers of various plant species according to time, harvesting intensity and frequency of each food.

Plant species	Food harvested																
	December 2001 to May 2002						December 2002 to May 2003										
	D	J	F	M	A	M	D	J	F	M	A	M	TD	nDN	pDN (%)	nDP	pDP (%)
Daniellia oliveri	N^4P^3	N^4P^3					N^4P^3	N^4P^3					28	28	100.00	28	100.00
Delonix regia	P^3	P^4N^1	P^4N^2	P^4N^2	P^4N^1	P^4	P^3N^1	P^4N^3	P^4N^3	P^4N^4	P^4N^4	P^2N^3	96	31	32.29	96	100.00
Hymenocardia acida	N^1	N^4P^2	N^4P^3					N^4P^3	N^4P^2				48	45	93.75	12	25.00
Terminalia mantaly	P^4N^2	P^4					P^4N^2	P^4N^1					28	13	46.43	28	100.00

D, December; J, January; F, February; M, March; A, April, Ma, May; N, nectar; P, pollen; 1, 2, 3, 4 in superscript, respectively: very low, low, high, very high collections; TD, total number of observation days; nDN, number of days where collection of nectar was observed; pDN, percentage of days where collection of nectar was observed; nDP, number of days where collection of pollen was observed; pDP, percentage of days where collection of pollen was observed.

Table 4: Products harvested by *Apis mellifera adansonii* on flowers of four plant species according to daily time brackets.

	Hourly brackets		
Plant species	**08.00–11.00 h**	**11.00–15.00 h**	**15.00–18.00 h**
Daniellia oliveri	nectar	nectar and pollen	nectar and pollen
Delonix regia	nectar and pollen	pollen	pollen
Hymenocardia acida	nectar and pollen	nectar and pollen	nectar
Terminalia mantaly	pollen	nectar and pollen	nectar

Table 5: Abundance of *Apis mellifera adansonii* workers per plant (maximum of individuals simultaneously in activity on open flowers for three observations) according to plant species and months.

Plant species	December 2001 to May 2002						December 2002 to May 2003					
	D	J	F	M	A	Ma	D	J	F	M	A	Ma
Daniellia oliveri	3400	2100					3300	1200				
Delonix regia	310	1100	3500	2800	410	140	140	360	2600	3400	800	85
Hymenocardia acida	12	110	160				23	230	130			
Terminalia mantaly	2800	610					1700	120				

D, December; J, January; F, February; M, March; A, April, Ma, May.

Table 6: Visiting time of *Apis mellifera adansonii* on flowers of four plant species according to the study periods and harvested products.

	December 2001 to May 2002				December 2002 to May 2003				Comparison of means of the two study periods (*t*-test)	
	n	**Visiting time per flower (sec)**			***n***	**Visiting time per flower (sec)**				
		m ± SD	*mini*	*maxi*		*m* ± SD	*mini*	*maxi*	*t*- value	*P*-value
Daniellia oliveri (N)	54	10.35 ± 9.27	1	61	54	10.22 ± 7.5	1	48	0.08	$> 0.05^{NS}$
Daniellia oliveri (P)	54	2.78 ± 1.62	1	9	54	2.96 ± 1.92	1	11	-0.53	$> 0.05^{NS}$
Delonix regia (N)	54	4.09 ± 2.46	1	13	54	4.15 ± 1.98	1	11	-0.14	$> 0.05^{NS}$
Delonix regia (P)	54	5.26 ± 4.41	1	24	54	5.85 ± 5.01	1	26	-0.65	$> 0.05^{NS}$
Hymenocardia acida (N)	54	1 ± 0	1	1	54	1 ± 0	1	1		
Hymenocardia acida (P)	54	1.30 ± 0.46	1	2	54	1.39 ± 0.49	1	2	-0.98	$> 0.05^{NS}$
Terminalia mantaly (N)	54	1.26 ± 0.52	1	3	54	1.39 ± 0.68	1	3	-1.12	$> 0.05^{NS}$
Terminalia mantaly (P)	54	3.80 ± 2.41	1	10	54	4.37 ± 3.01	1	16	-1.09	$> 0.05^{NS}$

N, number of visits studied; m, mean; SD, standard deviation; mini, minimum; maxi, maximum; N, nectar collection visits; P, pollen collection visits; NS, non significant difference.

Table 7: Pollen profile of pollen loads collected in the corbiculae of sampled *Apis mellifera adansonii* workers foraging on flowers of four plant species according to the investigation periods.

Plant species	**Pollen profil of pollen loads**									
	December 2001 to May 2002					**December 2002 to May 2003**				
	Number of pollen grains			**% foreign pollen**	**Identity of other plants**	**Number of pollen grains**			**% foreign pollen**	**Identity of other plants**
	Total	**Host plant**	**Other plants**			**Total**	**Host plant**	**Other plants**		
Daniellia oliveri	3014	2988	26	0.87	Sg	2570	2564	6	0.23	Sg
Delonix regia	6438	6429	9	0.14	Bo	5330	5323	7	0.13	Cr
Hymenocardia acida	3125	3110	15	0.48	Va	3840	3835	5	0.13	Sg
Terminalia mantaly	2630	2618	12	0.46	Ec, Asteraceae	3637	3628	9	0.25	Cr, Bp

Sg, *Syzygium guineense* (Willd.) DC. (Myrtaceae); Bo, *Bixa orellana* L. (Bixaceae); Va, *Vernonia amygdalina* Del. (Asteraceae); Ec, *Eucalyptus camaldulensis* Dehnh (Myrtaceae); Cr, *Callistemom rigidus* R. Br. (Myrtaceae); Bp, *Bombax pentandrum* (L.) Gaertn (Bombacaceae)

Table 8: Apicultural value of various plant species and the most favourable period to harvest honey and/or pollen from *Apis mellifera adansonii* hives installed in environments where the flowering vegetation is predominantly characterized by a large population of corresponding plant species in a delimited area of at least 3 km in diameter, following the 2001–2003 investigation period.

Plant species	Apicultural value		Period of honey and/or pollen collection	
	Nectar	Pollen	Honey	Pollen
Daniellia oliveri	4	3	February	December- January
Delonix regia	4	4	June	December -May
Hymenocardia acida	4	3	March	January - February
Terminalia mantaly	2	4	-	December

2nd column: 2 = low nectariferous value; 4 = very high nectariferous value; 3rd column: 3 = high polliniferous value; 4 = very high polliniferous value

Table 9: Number and frequency of contacts between *Apis mellifera adansonii* and the stigma during the floral visits to two plant species.

Plant species	December 2001 – May 2002			December 2002 – May 2003			Total		
	Number of studied visits	Visits with stigmatic contacts		Number of studied visits	Visits with stigmatic contacts		Number of studied visits	Visits with stigmatic contacts	
		Number	%		Number	%		Number	%
Daniellia oliveri	215	191	88.84	112	86	76.79	327	277	84.71
Delonix regia	441	153	34.69	210	93	44.29	651	246	37.79
Hymenocardia acida	96	96	100	96	96	100	192	192	100
Terminalia mantaly	427	396	92.24	317	304	95.90	744	700	94.09

Thus, the type of floral products harvested by *A. m. adansonii* on a given plant species can vary with the region and year. The observed variations in this study could be mainly explained by the availability of pollen or nectar at the level of flowers, and by the needs of the colonies of the foraging bees.

The high density of *A. m. adansonii* workers per flower of *De. regia* and *Da. oliveri* could be partly explained by the access to nectar and/or pollen that depends on the combination of two factors concerning the open flower: (a) large landing surface, and (b) high number of stamens with long filament, oriented externally.

The observed high densities of foragers per tree recorded in this study could be attributed to the ability of honey bees to recruit a great number of workers for the exploitation of high-yield food sources (Frisch, 1969; Louveaux, 1984; Schneider and Hall, 1997; Goodman, 2003; Kajobe, 2006).

In *Da. oliveri* the fact that *A. m. adansonii* spent significantly different time on a flower for pollen harvest and for nectar collection could be explained by the abundance and/or the accessibility to each of these floral products.

The disruptions of visits by other insects reduced the duration of certain *A. m. adansonii* visits. This obliged some workers to visit more flowers during a foraging trip, in order to maximize their pollen or nectar loads. Similar observations were made in *A. m. adansonii* workers foraging on flowers of *Callistemon rigidus* R. Br. (Myrtaceae) (Tchuenguem Fohouo et al., 2004), *Entada africana* Guill. et Perr. (Fabaceae) and *Psidium guajava* L. (Myrtaceae) (Tchuenguem Fohouo et al., 2007), *Croton macrostachyus* Hochst. ex Del. (Euphorbiaceae) and *Syzygium guineense* (Will.) DC var. *guineense* (Myrtaceae) (Tchuenguem Fohouo et al., 2008a), *Persea americana* Mill. (Lauraceae) and *Vitellaria paradoxa* Gaertn. F. (Sapotaceae) (Tchuenguem Fohouo et al., 2008b), *Vigna unguiculata* (L.) Walp. (Fabaceae) (Tchuenguem Fohouo et al., 2009b), and in *Meliponula erythra* (Schletterer) (Hymenoptera: Apidae) foraging on *Dacryodes edulis* (G. Don) H. J. Lam (Burseraceae) flowers (Kengue et al., 2002).

The present study shows that during one foraging trip, an individual bee foraging on a given plant species scarcely visited another plant species. This result indicates that *A. m. adansonii* shows flower constancy (Louveaux, 1984; Basualdo et al., 2000; Montgomery, 2009) for the flowers of each of the four plant species studied. This floral constancy in honeybees exist because an individual forager is generally capable of memorizing and recognizing the shape, colour and odour of the flowers visited during previous foraging trips (Hill et al., 1997; Wright et al., 2002).

Since *Da. oliveri, De. regia* and *H. acida* are highly or very highly nectariferous bee plants, they can be planted and protected to increase honey production. Besides, *De. regia* and *H. acida* pollen has been identified in the five of seven honey samples collected in the study area in 1999 and 2000 (Mbofung et al., 2000). As highly or very highly polliniferous bee plants, *Da. oliveri, De. regia, H. acida* and *T. mantaly* can permit the increase of pollen production as a hive product. All the plant species studied contributed to the food supply and therefore to the strengthening of honey bee colonies. Consequently, these plant species should be planted and protected in the environment surrounding the apiaries. During the collection of pollen or nectar on flowers of each plant species, *A. m. adansonii* foragers regularly contacted anthers and carried pollen with which they flew frequently from flower to flower. As a result, *A. m. adansonii* workers could induce self pollination, by applying the pollen of a flower on the stigma of the same flower. Foragers carried pollen from a flower of one tree to the stigma of another flower of the same tree (geitonogamy) or to that of another tree (xenogamy). Consequently, *A. m. adansonii* workers increase the pollination possibilities of *Da. oliveri, De. regia, H. acida* and *T. mantaly.* The impact of *A. m. adansonii* on fruit or grain yields of each plant species studied via its pollination efficiency will be looked at in future work.

ACKNOWLEDGEMENTS

This study was funded by the International Foundation for Science (IFS; Stockholm, Sweden) and the United Nation University (UNU; Tokyo, Japan) via a research grant to TFFN (3181-1). We thank A. Pauly for his contribution to the identification of flowering insects and P. M. Mapongmetsem for the identification of plant species. The DAAD (German Academic Exchange Programme) has awarded a research grant to TFFN (A/08/15704).

REFERENCES

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

Bakenga M, Bahati M, Balagizi K. 2000. Inventaire des plantes mellifères de Bukavu et ses environs (Sud-Kivu, Est de la République Démocratique du congo). *Tropicultura*, **18**: 89-93.

Basualdo M, Bedascarrasbure E, De Jong D. 2000. Africanized honey bees (Hymenoptera:Apidae) have a greater fidelity to sunflowers than European bees. *Journal of Economic Entomology*, **93**: 304-307.

Crane E. 1999. *The World History of Beekeeping and Honey Hunting*. Duckworth: London.

Dietemann V, Pirk CWW, Crewe R. 2009. Is there a need for conservation of honeybees in Africa? *Apidologie*, **40**: 285-295.

Dongock Nguemo D, Foko J, Pinta JY, Tchoumboué J, Zango P. 2004. Inventaire et identification des plantes mellifères de la zone soudano-guinéenne d'altitude de l'Ouest Cameroun. *Tropicultura*, **22**: 139-145.

Fichtl R, Adi A. 1994. *Honeybee Flora of Ethiopia*. Margraf Verlag: Weikerskein.

Freitas BM. 1997. Number and distribution of Cashew (*Anacardium occidentale*) pollen Grains on the bodies of its pollinators, *Apis mellifera* and *Centris tarsata*. *Journal of Apicultural Research*, **36**: 15-22.

Frisch K von. 1969. *Vie et Moeurs des Abeilles*. Michel A : Paris.

Goodman L. 2003. *Form and Function in the Honey Bee*. IBRA: Cardiff.

Guerriat H. 1996. *Etre Performant en Apiculture*. Guerriat H (ed): Daussois.

Hill PSM, Wells PH, Wells H. 1997. Spontaneous flower constancy and learning in honey bees as a function of colour. *Animal Behaviour*, **54**: 615-627.

INADES, 2000. Rapport des ateliers avec les apiculteurs de l'Adamaoua. INADES-Formation Cameroun, Antenne de Maroua (ed): Maroua.

Jacob-Remacle A. 1989. Comportement de butinage de l´abeille domestique et des abeilles sauvages dans des vergers de pommiers en Belgique. *Apidologie*, **20**: 271-285.

Jha S, Vandermeer JH. 2009. Contrasting bee foraging in response to resource scale and local habitat management. *Oikos*, **118**: 1174-1180.

Kajobe R. 2006. Pollen foraging by *Apis mellifera* and stingless bees *Meliponula bocandei* and *Meliponula nebulata* in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology*, **45**: 265-274.

Kengue J, Tchuenguem Fohouo FN, Adewusi HG. 2002. Towards the improvement of safou (*Dacryodes edulis*): population variation and reproductive biology. *Forests, Trees and Livelihoods*, **12**: 73-84.

Leven L, Boot VWJ, Mutsaers M, Segeren P, Velthuis H. 2005. *Beekeeping in the Tropics* [Agrodok 32] (6th edn). CTA: Wageningen.

Louveaux J. 1984. L'abeille domestique dans ses relations avec les plantes cultivées. In *Pollinisation et Productions Végétales*, Pesson P, Louveaux J (eds), INRA : Paris; 527-555.

Mbofung G, Tchuenguem Fohouo FN, Boukar O, Hentchoya Hemo J, Brückner D. 2000.Characterization of some honeys from the Adamawa, Cameroon usingmelissopalynological methods. *Biosciences Proceedings*, **7**: 108-120.

Montgomery BR. 2009. Do pollen carryover and pollinator constancy mitigate effects of competition for pollination? *Oikos*, **118**: 1084-1092.

Morton JM. 1964 Honeybee plants of South Florida. *Florida State Horticultural Society Proceedings*, **77**: 415-436.

Paterson PD. 2006. *Beekeeping*. CTA/ IBRA / MACMILLAN: London.

Schneider SS, Hall HG. 1997. Diet selection and foraging distances of African and European-African hybrid honeybee colonies in Costa Rica. *Insectes Sociaux*, **44**: 171-187.

Tchuenguem Fohouo FN, Djonwangwe D, Messi J, Brückner D. 2007. 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*, **3**(2): 50-60.

Tchuenguem Fohouo FN, Djonwangwe D, Brückner D. 2008a. Foraging behaviour of the African honey bee (*Apis mellifera adansonii*) on *Annona senegalensis*, *Croton macrostachyus*, *Psorospermum febrifugum* and *Syzygium guineense* var *guineense* flowers at Ngaoundéré (Cameroon). *Pakistan Journal of Biological Sciences*, **11**: 719-725.

Tchuenguem Fohouo FN, Djonwangwe D, Messi J, Brückner D. 2008b. Exploitation of *Dichrostachys cinerea*, *Vitellaria paradoxa*, *Persea americana* and *Securidaca longepedunculata* flowers by *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) at Dang (Ngaoundéré, Cameroon). *International Journal of Tropical Insect Science*, **28**(4): 225-233.

Tchuenguem Fohouo FN, Djonwangwe D, Messi J, Brückner D. 2009a. Activité de butinage et de pollinisation de *Apis mellifera adansonii* sur les fleurs de *Helianthus annus* (Asteraceae) flowers à Ngaoundéré (Cameroun). *Cameroon Journal of Experimental Biology*, **5**: 1-9.

Tchuenguem Fohouo FN, Messi J, Brückner D, Bouba B, Mbofung G, Hentchoya Hemo J. 2004. Foraging and pollination behaviour of the African honey bee (*Apis mellifera adansonii*) on *Callistemon rigidus* flowers at Ngaoundéré (Cameroon). *Journal of the Cameroon Academy of Sciences*, **4**: 133-140.

Tchuenguem Fohouo FN, Ngakou A, and Kegni BS. 2009b. 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*, **8**: 1988-1996.

Tchuenguem Fohouo FN, Nyomo, Mapongmetsem PM, Messi J. 1997. Activité d'*Apis mellifica* L. (Hymenoptera, Apidae) sur les fleurs de quelques plantes ligneuses à Dang (Adamaoua, Cameroun). *Cam. J. Biol. Biochem. Sci*., **7**(1) : 86-91.

Villières B., 1987, L'apiculture en Afrique Tropicale. Dossier "Le point sur" n° 11, GRET : Paris.

Weidenmüller A, Tautz J. 2002. In-hive behavior of pollen foragers (*Apis mellifera*) in honey bee colonies under conditions of high and low pollen need. *Ethology*, **108**: 205-221.

Williams IH, Carreck NL. 1994. Land use changes and honey bee forage plants. In *Forage for Bees in an Agricultural Landscape*, Matheson A (ed). IBRA: Cardiff; 7-20.

Wright GA, Skinner BD, Smith BH. 2002. Ability of honeybee, *Apis mellifera*, to detect and discriminate odors of varieties of canola (*Brassica rapa* and *Brassica napus*) and snapgragon flowers (*Antirrhinum majus*). *Journal of Chemical Ecology*, **28**: 721-740.