Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(2): 2072-2078

Received: 15-01-2018
Accepted: 16-02-2018

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Exploitation of *Jatropha curcas*, *Senegalia polyacantha* and *Terminalia schimperiana* flowers by *Apis mellifera* (Hymenoptera: Apidae) at Dang (Ngaoundéré, Cameroon)

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Abstract
To assess the apicultural value of *Senegalia polyacantha*, *Jatropha curcas* and *Terminalia schimperiana*, *Apis mellifera* workers foraging activity was studied on the flowers of these plant species, from March to July 2015 and 2016. At Dang, the flowers of each plant species were observed two days per week, between 07.00 and 18.00h, for recording the pollen and/or nectar foraging behaviour of *A. mellifera* workers. Results showed that, *A. mellifera* harvested intensely and regularly the nectar of each plant species. In addition, *T. schimperiana* was visited intensely for pollen; *S. polyacantha* and *J. curcas* were also visited for pollen but slightly. The greatest mean number of workers foraging simultaneously in activity per 1000 flowers varied from 165 (*J. curcas*) to 608 (*T. schimperiana*). During foraging, *A. mellifera* workers improved pollination possibilities of each plant species and can thus be considered as pollinator.

Keywords: *Jatropha curcas*, *Senegalia polyacantha*, *Terminalia schimperiana*, *Apis mellifera*, bee plant, pollination

1. Introduction

Apis mellifera Linnaeus is a social insect that builds its nest in a cavity, by connecting cones to the upper wall [23]. In nests also called hives, the bees live in colonies containing about 50000 to 60000 individuals [23]. *Jatropha curcas* (Euphorbiaceae) Linnaeus, *Senegalia polyacantha* (Mimosaceae) (Willd.) Seigler and Ebinger and *Terminalia schimperiana* (Combretaceae) Hochst. are the plant species who provide the alimentary resources (nectar et pollen) for honeybees. The plant species flowers are visited by these bees for the nectar and the pollen collection. The basic foods of each *A. mellifera* colony are nectar and pollen [38, 20] collected from many plant species [26]. The nectar is transformed into honey which is stored together with pollen in the hive for future use [5]. These substances have been exploited by humans for thousands of years [5].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 [2]. 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 Apiaries [15].

Before this study, there was no literature on the relationship between the honeybees and many plant species (including *Senegalia polyacantha*, *Jatropha curcas* and *Terminalia schimperiana*) in Cameroon. Yet, in this country, because of the increasing demand for hive products such as honey and pollen, beekeeping needs to be developed [19].

The main objective of this work was to study of the relationships between *A. mellifera* Linnaeus, *S. polyacantha* (Willd.) Seigler and Ebinger, *J. curcas* Linnaeus and *T. schimperiana* Hochst. for their optimal exploitation. For each plant species, we recorded the activity of *A. mellifera* on flowers, evaluated the apicultural value and registered the pollination behaviour of *A. mellifera*.

2. Materials and Methods

2.1 Study site and biological material

The present study was carried out from March to July 2015 and 2016, at Dang a village located north of the city of Ngaoundéré in the Adamawa Region of Cameroon.

This Region is situated between the 6th and 8th degrees of latitude North and between the 11th and 15th degrees of longitude East; it belongs to the high-altitude Guinean Savannah agro-ecological zone [9]. The climate is tropical and 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%.

Plants chosen for observations were located in an area of three kilometer in diameter, centered on a kenyan top-hive inhabited by an *A. mellifera* colony. The hive was located at latitude of 07°42.266' N, a longitude of 13°53.944' E and an altitude of 1114 m a.s.l.

The animal material included many insect species naturally present in the environment. The number of honeybee colonies located in the area varied from 46 in March 2015 to 69 in July 2015 and from 48 in March 2016 to 72 in July 2016. The vegetation was represented by crops, ornamental plants, hedge plants and native plants of savannah and gallery forests. Table 1 describes plant species studied. Table 2 gives the relative abundance of opened flowers per month for each of these plants during the two observation periods.

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

From March to July 2015 and 2016, the foraging behaviour of *A. mellifera* worker was recorded on flowers of different plant species. Data were taken during two days per week, between 07.00 and 18.00 h, with three time periods per day: 07.00-11.00h, 11.00-15h and 15.00-18h. Table 3 shows the number of observation days for each plant species. For any plant species visited by the honeybees and for each investigation date, the following parameters were registered for each time period and, whenever possible: floral products (nectar or pollen) harvested during each floral visit, abundance of foragers (highest number of individual bees foraging simultaneously on a flower, an individual plant or on 1000 flowers [31], duration of individual flower visit, influence of fauna (disruption of the forager in activity by competitors and/or predators [36] and impact of the surrounding flora (attractiveness of other plant species to *A. 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 *A. mellifera* workers 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 [36].

2.3 Evaluation of the concentration in total sugars of the nectar of different plant species

The concentration in total sugars of the nectar is an important parameter for the attractiveness of the honeybee with respect to many flowers [28].

This parameter was determined with a handheld refractometer (0-90% Brix) and a thermometer that gave the ambient temperature, from March to July 2015 and from March to July 2016. *Apis mellifera* workers in full activity of nectar harvest were captured on flowers and anesthetized by introduction in a small bottle containing cotton moistened with chloroform. Nectar was then removed from honeybee crop by exerting a 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 measured (in g/100 dry matter). The registered values obtained were corrected according to the ambient temperature, using a table provided by the device leaflet [7].

2.4 Evaluation of the apicultural value of different plant species

As for other plant species, the apicultural value of each plant species studied was assessed using data on the flowering intensity, the degree of attractiveness of *A. mellifera* workers with respect of nectar and/or pollen [38, 31, 27].

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

To measure the ability of *A. mellifera* to act as pollinator of each plant species, during the nectar or pollen harvest, the number of times a forager comes into contact with stigma of the visited flower was noted [14, 12, 10]. This approach allows highlighting the involvement of *A. mellifera* in self-pollination and cross-pollination [43, 29].

2.6 Statistical analysis

Data were subjected to descriptive statistics (means, standard deviations and percentages), Student's *t*-test for the comparison of the mean of two samples, Pearson correlation coefficient (r) for the study of association between two variables and chi-square (χ^2) for the comparison of percentages, using Microsoft Excel 2010.

3. Results and Discussion

3.1 *Apis mellifera* foraging activity on flowers

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

The identity of the food harvested by *A. mellifera* workers from the flowers of each investigated plant species and the intensity and frequency of the collection of different foods are presented in Table 3 and 4. The main results are as follows: (a) *A. mellifera* workers harvested intensely and regularly the nectar of each plant species; (b) *T. schimperiana* was also visited intensely for pollen; (c) *S. polyacantha* and *J. curcas* were also visited for pollen 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 were 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 were honeybees harvested the pollen, the harvesting frequency varied from 66.66% in *T. schimperiana* to 100% in *J. curcas*. The type of substance harvested from flowers (nectar or pollen) by *A. mellifera* in a given plant species varied with hourly brackets.

The present study results are in line with that of [22] who found that honeybees harvested nectar and pollen on *J. curcas* in Mexico. In Ethiopia [11] and in India [4] *A. mellifera* also collected nectar and pollen from *S. polyacantha* flowers. In Benin, [42, 41] also observed that *A. mellifera* harvested the pollen on *S. polyacantha*. The collection of the nectar and pollen of *T. schimperiana* have also being observed by Abebe *et al*. [1] in Ethiopia and by Yédomonhan *et al*. [42] in Benin. In Burkina Faso, the nectar of *T. schimperiana* is also harvested by *A. mellifera* [30]. Thus the type of substance harvested by *A. mellifera* from flowers (nectar or pollen) of a given plant species can vary with regions.

The high nectar and pollen harvest could mainly be explained by the carbohydrate and protein needs of colonies from which originated honeybee workers.

3.1.2 Density of foragers

The highest number of *A. mellifera* workers foraging simultaneously per flower was one for each plant species. The abundance of *A. mellifera* workers per 1000 flowers varied from 1 to 248 on *S. polyacantha*, 12 to 608 on *T. schimperiana* and from 4 to 185 on *J. curcas* (Table 5). The abundance per individual plant varied from 3 to 249 on *S. polyacantha*, 15 to 721 on *T. schimperiana* and from 7 to 193 on *J. curcas* (Table 6). The observed high densities of foragers per 1000 flowers recorded in this study could be attributed to the ability of honeybees to recruit a great number of workers for the exploitation of high-yield food sources [13, 21].

3.1.3 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 year to year [36] (Table 7).

The difference between the mean duration of a flower visit for nectar collection and that for pollen collection was very highly significant in *S. polyacantha* (2015: $t = 33.00$, $df = 244$, $P < 0.0001$; 2016: $t = 19.65$, $df = 244$, $P < 0.0001$), *J. curcas* (2015: $t = 66.49$, $df = 294$, $P < 0.0001$; 2016: $t = 111.18$, $df = 337$, $P < 0.0001$) and *T. schimperiana* (2015: $t = 12.13$, $df = 213$, $P < 0.0001$; 2016: $t = 31.83$, $df = 267$, $P < 0.0001$). Therefore, on each of the three plant species, *A. mellifera* spent more time on a flower for nectar collection than for pollen harvest. The fact that *A. mellifera* 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 duration of visits was partially influenced by disruptions due to other anthophilous insects. Thus for 296 honeybees visits registered on *J. curcas* flowers in 2015, 68 were disrupted by other *A. mellifera* Linnaeus workers (Hymenoptera: Apidae; 34 visits), *Belonogaster juncea* Fabricius (Hymenoptera: Vespidae; 16 visits), *Camponotus flavomarginatus* Mayr (Hymenoptera: Formicidae; 8 visits), *Ceratina* sp. (Hymenoptera: Apidae; 5 visits) and *Lasioglossum* sp. (Hymenoptera: Halictidae; 5 visits). Among 215 visits registered on *T. schimperiana* flowers in 2015, 62 were disrupted by other *A. mellifera* Linnaeus workers (42 visits), *Belonogaster juncea* Fabricius (Hymenoptera: Vespidae; 6 visits) and *Calliphora* sp. (Diptera: Calliphoridae; 14 visits). For 226 visits registered on *S. polyacantha* flowers in 2015, 23 were disrupted by other *A. mellifera* workers (18 visits) and *B. juncea* (5 visits). The disruptions of visits by other insects reduced the duration of certain *A. mellifera* visits. This obliged some workers to visit more flowers during a foraging trip, in order to maximize their nectar or pollen loads.

3.1.4 Influence of neighboring flora

In 2015 and 2016, throughout the observation periods of each of the plant under investigation, *A. mellifera* workers visited flowers of many other plant species growing in the study area for nectar (ne) and/or pollen (po). Among these plants were *Tithonia diversifolia* (Hamsley) Gray (Asteraceae; ne and po), *Capsicum annuum* Linnaeus (Solanaceae; po), *Hyptis suaveolens* (L.) Poit. (Lamiaceae; po), *Mimosa pudica* Linnaeus (Fabaceae; po), *Commiphora kerstingii* Engl. (Burseraceae; ne and po) and *Sida rhombifolia* Linnaeus (Malvaceae; ne and po). 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 period). The analysis of the pollen loads collected from pollen baskets of worker honeybees showed that the percentages of foreign pollen were 0.19% in *J. curcas*, 0.34% in *T. schimperiana* and 0.90% in *S. polyacantha* in 2015 and 0.13% in *J. curcas*, 0.15% in *T. schimperiana* and 0.70% in *S. polyacantha* in 2016 (Table 8). This result indicates that *A. mellifera* shows flower constancy [17, 25] for the flowers of each of the three plant species studied. This floral constancy in honeybees is due to the fact that an individual forager is generally capable of memorizing and recognizing the shape, colour and odour of the flowers visited during previous foraging trips [18, 40]. The fidelity of *A. mellifera* has been demonstrated on flowers of several other plant species among which are *Persea americana* Mill. (Lauraceae) [37], *Helianthus annuus* L. (Asteraceae) [3, 34], *Vigna unguiculata* (L.) Walp. (Fabaceae) [35], *Combretum nigricans* Lepr. ex Guill. & Perr. (Combretaceae), *Erythrina sigmoidea* Hua (Fabaceae), *Lannea kerstingii* Engl. & K. Krause (Anacardiaceae) and *Vernonia amygdalina* Delile (Asteraceae) [36], *Ximenia americana* L. (Olacaceae) [7], *Syzygium guineense* (Willd.) DC var. *guineense* (Myrtaceae) [33, 8] and *Callistemon rigidus* R. Br. (Myrtaceae) [10].

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

The mean concentration in total sugar of *S. polyacantha* nectar was 29.82% ($n = 61$; $s = 4.39$; $mini = 23.46$; $maxi = 35.87$) in 2015 and 30.28% ($n = 69$; $s = 4.56$; $mini = 23.46$; $maxi = 36.56$) in 2016. The difference between these means is highly significant ($t = 3.29$, $df = 128$, $P < 0.01$). The mean concentration in total sugar of the *J. curcas* nectar was 33.73% ($n = 61$; $s = 5.65$; $mini = 22.72$; $maxi = 46.06$) in 2015 and 33.33% ($n = 69$; $s = 5.29$; $mini = 22.72$; $maxi = 45.4$) in 2016. The difference between these two latter means is highly significant ($t = 2.35$, $df = 128$, $P < 0.01$). The mean concentration in total sugars of *T. schimperiana* nectar was 8.21% ($n = 61$; $s = 1.08$; $mini = 6.21$; $maxi = 10.29$) in 2015 and 8.31% ($n = 69$; $s = 1.05$; $mini = 6.21$; $maxi = 10.29$) in 2016. The difference between these two latter means is highly significant ($t = 3.01$, $df = 128$, $P < 0.01$). For *J. curcas* and *S. polyacantha*, the above mentioned flower constancy could be partially due to the high sugar content of their nectar. The mean concentration in total sugar of *Callistemon rigidus*, *Zyzygium guinense* var. *macrocarpum* and *Voacanga africana* has evalued by Tchuenguem [31].

3.1.6 Apicultural value of the plant species

During the flowering period of each studied plant species, we recorded distinct levels of activity of *A. mellifera* workers on the flowers. There were a high density of workers per tree, good nectar collection on all plant species, low pollen collection on *S. polyacantha* and *J. curcas*, high pollen harvest on *T. schimperiana*. Moreover, in the dry season, which is the main period of honey flow, individual tree of each of three investigated plant species could produce more than 45.000 flowers. Considering these data, the plant species studied can be classified based on their apicultural value as follows: (a) highly nectariferous: *S. polyacantha*, *J. curcas* and *T. schimperiana*; (b) highly polliniferous: *T. schimperiana*; (c) slighly polliniferous: *S. polyacantha* and *J. curcas*. Table 9 summarizes the appropriate period for honey or pollen harvest 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 2015-2016. Thus in the Adamawa Region of Cameroon, honey can be harvested in June, May and June, if the environment of the apiary is dominated by strong populations of *S. polyacantha*, *J. curcas* and *T. schimperiana* respectively. Pollen can be harvested in the hives in June, if the surrounding environment of the apiary is characterized by many *T. schimperiana*. Besides, *S. polyacantha* pollen has been identified in: a) nine of the eleven honey samples collected in the study area in 2001-2002 [31]; b) five of the fourteen honey samples collected at Dang and Tchabal-Bambi in 2006-2008 [6]. In North Island, *S. polyacantha* pollen has been identified in three of the fourteen honey samples studied [24].

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

Scientific name	Family	Biotope	FP	DCOF	Strengh*	
					2015	2016
Senegalia polyacantha (Willd.) Seigler and Ebinger (++; tr)	Mimosaceae	savannah	April-July	White greenish	389	325
Jatropha curcas Linnaeus (+; sh)	Euphorbiaceae	hedge	March-June	White greenish	37	28
Terminalia schimperiana Hochst. (++; tr)	Combretaceae	savannah	May-July	White greenish	473	342

+: cultivated plant; ++: spontaneous plant; tr: tree; sh: shrub; FP: flowering period; 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 investigation periods.

Plant species	March 2015 to July 2015						March 2016 to July 2016			
	M	A	Ma	J	Ju	M	A	Ma	J	Ju
Senegalia polyacantha		*	***	****	**		**	***	****	**
Jatropha curcas	**	****	**	*		**	***	****	*	
Terminalia schimperiana			**	****	*			**	****	*

M: March; A: April; Ma: May; J: June; Ju: July; *: ≤ 100 flowers = rare; **: > 100 and ≤ 500 flowers = little abundant; ***: > 500 and ≤ 1000 flowers = abundant; ****: > 1000 flowers = very abundant

Table 3: Floral products harvested by *Apis mellifera* from the flowers of various plant species according to time, harvesting intensity and frequency of each food.

Plant species	Food harvested														
	March 2015 to July 2015					March 2016 to July 2016									
	M	A	Ma	J	Ju	M	A	Ma	J	Ju	TD	nDN	pDN	nDP	pDP
S. polyacantha		N^1	N^2P^1	P^1N^2	P^1N^1		N^1	N^3P^1	P^1N^4	P^1N^1	32	32	100.00	24	75.00
J. curcas	N^1P^1	N^2P^1	N^2P^1	N^1P^1		N^1P^1	N^2P^2	N^3P^1	N^3P^1		32	32	100.00	32	100.00
T. schimperiana			N^1P^1	N^4P^3	N^1			N^4P^3	N^4P^3	N^1	24	24	100.00	16	66.66

M: March; A: April; Ma: May; J: June: Ju: July; TD: Total number of observation days; nDN: number of days where collection of nectar was observed; pDN: percentage of days were 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; N: Nectar; P: Pollen; 1, 2, 3 and 4 given as superscripts indicate very low, low, high and very high collections, respectively

Table 4: Products harvested by *Apis mellifera* from the flowers of the three plant species according to daily time brackets.

Plant species	Hourly brackets		
	07.00-11.00 h	11.00-15.00 h	15.00-18.00 h
Senegalia polyacantha	Nectar	Nectar and pollen	Nectar
Jatropha curcas	Nectar and pollen	Nectar	Nectar and pollen
Terminalia schimperiana	Nectar and pollen	Nectar and pollen	Nectar

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	March 2015 to July 2015						March 2016 to July 2016			
	M	A	Ma	J	Ju	M	A	Ma	J	Ju
Senegalia polyacantha		1	48	56	3		16	188	248	8
Jatropha curcas	4	92	87	5		15	47	185	165	
Terminalia schimperiana			17	152	21			373	608	12

M: March; A: April; Ma: May; J: June; Ju: July

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

Plant species	March 2015 to July 2015						March 2016 to July 2016			
	M	A	Ma	J	Ju	M	A	Ma	J	Ju
Senegalia polyacantha		3	53	64	5		23	203	249	14
Jatropha curcas	7	102	97	4		18	54	193	154	
Terminalia schimperiana			15	165	31			451	721	43

M: March; A: April; Ma: May; J: June; Ju: July

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

Plant species	March 2015 to July 2015				March 2016 to July 2016				Comparison of means		
	Visiting time per flower (sec)				Visiting time per flower (sec)				of the two study periods (*t*- test)		
	n	*m* ± *sd*	*mini*	*maxi*	*n*	*m* ± *sd*	*mini*	*maxi*	*t*- value	*df*	*p*- value
S. polyacantha (N)	146	1.8 ± 0.75	1	4	186	1.57 ± 0.81	0.4	6	23.91	330	$< 0.0001^{VHS}$
S. polyacantha (P)	80	1.36 ± 0.55	1	3	60	1.25 ± 0.43	1	2	7.45	138	$< 0.0001^{VHS}$
J. curcas (N)	148	1.68 ± 0.74	1	4	204	2.33 ± 0.96	1	5	53.8	350	$< 0.0001^{VHS}$
J. curcas (P)	148	2.52 ± 1.09	1	6	135	3.86 ± 1.15	2	7	84.24	281	$< 0.0001^{VHS}$
T. schimperiana (N)	150	1.71 ± 0.73	1	4	206	1.7 ± 0.89	1	8	1.04	354	$> 0.05^{NS}$
T. schimperiana (P)	65	1.90 ± 0.65	1	3	63	1.17 ± 0.38	1	2	43.35	126	$< 0.0001^{VHS}$

n: number of visits studied; *m*: mean; *sd*: standard deviation; *mini*: minimum; *maxi*: maximum; *df*: degree of freedom; N: Nectar collection visits; P: Pollen collection visits; VHS: Very highly significant difference; NS: Non significant difference

Table 8: Pollen profile of pollen loads collected in the corbiculae of sampled *Apis mellifera* workers (09) foraging on flowers of three plants species according to the study periods.

Plant species					Pollen profile of pollen loads					
	March 2015 to July 2015				March 2016 to July 2016					
	Number of pollen grains				Number of pollen grains					
	Total	Host plant	Other plants	% foreign pollen	Identity of other plants	Total	Host plant	Other plants	% foreign pollen	Identity of other plants
S. polyacantha	4123	4086	37	0.90	Td	3039	3018	21	0.70	Td, Pg
J. curcas	6542	6530	12	0.19	Ck, Sr	6376	6368	8	0.13	Sr
T. schimperiana	2356	2348	8	0.34	Aa, Bo	4234	4228	6	0.15	Bo, Mp

Td: *Tithonia diversifolia* (Hamsley) Gray (Asteraceae); Ck: *Commiphora kerstingii* Engl. (Burseraceae); Sr: *Sida rhombifolia* Linnaeus (Malvaceae); Aa: *Allophilus africanus* P. Beauv. (Sapindaceae); Bo: *Bixa orellana* Linnaeus (Bixaceae); Mp: *Mimosa pudica* Linnaeus (Fabaceae); Pg: *Psidium guajava* Linnaeus (Myrtaceae)

Table 9: 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
Senegalia polyacantha	****	*	June	-
Jatropha curcas	****	**	May	-
Terminalia schimperiana	****	***	June	June

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

Table 10: Number and frequency of contacts between *Apis mellifera* and the stigma during the floral visits to three plant species.

Plant species	March 2015 to July 2015				March 2016 to July 2016		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	%
Senegalia polyacantha	226	226	100	246	246	100	472	472	100
Jatropha curcas	296	287	96.95	339	311	91.74	635	598	94.17
Terminalia schimperiana	215	215	100	269	269	100	484	484	100

Number and frequency of contacts comparison: (*Senegalia polyacantha*): $\chi^2_{2015/2016} = 0.00$; $df = 1$; $P > 0.05^{NS}$; (*Jatropha curcas*): $\chi^2_{2015/2016} = 7.84$; $df = 1$; $P < 0.01^{HS}$; (*Terminalia schimperiana*): $\chi^2_{2015/2016} = 0.00$; $df = 1$; $P > 0.05^{NS}$;
(*S. polyacantha*; *J. curcas*; *T. schimperiana*): $\chi^2_{2015} = 13.57$; $df = 2$; $P < 0.01^{HS}$;
(*S. polyacantha*; *J. curcas*; *T. schimperiana*): $\chi^2_{2016} = 43.98$; $df = 2$; $P < 0.001^{VHS}$

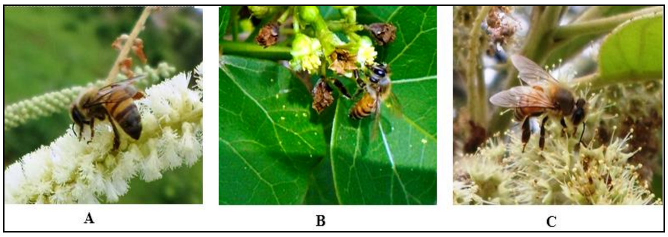

Fig 1: *Apis mellifera* collecting nectar on a flower of *Senegalia polyacantha* (A), *Jatropha curcas* (B) and *Terminalia schimperiana* (C)

3.1.7 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, *A. mellifera* was frequently in contact with the anthers and stigma [31]. 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 [16], 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 *S. polyacantha* and *T. schimperiana* during the 2015 as well as the 2016 study periods; for *Jatropha curcas*, it was 96.95% in 2015 and 94.17% in 2016 (Table 10). Consequently, *A. mellifera* workers strongly increase the pollination possibilities of *S. polyacantha*, *J. curcas* and *T. schimperiana*. The impact of *A. mellifera* of fruit or grain yields of each of these plant species via its pollination efficiency will be studied in future work.

4. Conclusion

At Dang, *A. mellifera* workers harvested intensely and regularly the nectar in the flowers of *Jatropha curcas*, *Senegalia polyacantha* and *Terminalia schimperiana*. This bee slightly collected the pollen of *J. curcas* and *S. polyacantha*; it strongly harvested pollen on *T. schimperiana* flowers. All these plant species contributed more or less to the feeding and therefore to the strengthening of the honeybee colonies. *Apis mellifera* workers increased the pollination possibilities of each plant species. Based on our results, we recommend: (a) the installation of *A. mellifera* colonies in environments where one or more of the studied plant species occur abundantly and (b) the plantation and/or protection of each plant species in the surrounding of *A. mellifera* apiaries.

5. Acknowledgements
This study was partly funded by the Minister of the Scientific Research and Innovation, via C2D-PAR (AMOAPI project). We thank P. M. Mapongmetsem for the identification of plant species.

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