Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

JEZS Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(5): 2055-2063

Received: 20-07-2020
Accepted: 23-08-2020

Oumarou Bouba
University of Ngaoundéré, Faculty of Science, Laboratory of Applied Zoology, P.O. Box Ngaoundéré, Cameroon

Mazi Sanda
University of Ngaoundéré, Faculty of Science, Laboratory of Applied Zoology, P.O. Box Ngaoundéré, Cameroon

Pando Joseph Blaise
University of Maroua, Higher Teachers' Training College, Laboratory of Biological Sciences, P.O. Box Maroua, Cameroon

Fameni Tope Sidonie
University of Maroua, Faculty of Science, Department of Biological Sciences, P.O. Box Maroua, Cameroon

Tchuenguem Fohouo Fernand-Nestor
University of Ngaoundéré, Faculty of Science, Laboratory of Applied Zoology, P.O. Box Ngaoundéré, Cameroon

Corresponding Author:
Oumarou Bouba
University of Ngaoundéré, Faculty of Science, Laboratory of Applied Zoology, P.O. Box Ngaoundéré, Cameroon

Foraging activity of *Apis mellifera* Linnaeus (Hymenoptera: Apidae) visiting the flowers of four plant species in the urban area of Ngaoundéré (Cameroon)

Oumarou Bouba, Mazi Sanda, Pando Joseph Blaise, Fameni Tope Sidonie and Tchuenguem Fohouo Fernand-Nestor

Abstract
This study was conducted to identify the foraging behaviour of honey bees *Apis mellifera* in the search for food during their visit to *Brillantaisia ulugurica, Caesalpinia pulcherrima, Calliandra tweedii* and *Tecoma stans* flowers and to assess the apicultural value of these plants. *Apis mellifera* foraging activity was therefore studied from March 2016 to February 2018 at Ngaoundéré town (Adamaoua, Cameroon). The flowers of each plant species were observed two days per week, between 07.00 am and 18.00 pm, for recording the pollen and/or nectar foraging behaviour of the honey bee. Results showed that *A. mellifera* harvested nectar and pollen on each of these plant species, nectar being the most intensely harvested floral product. The greatest mean numbers of workers foraging simultaneously per 1000 flowers were 158.27, 77.70, 141.37 and 141.02 for *B. ulugurica*, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans* respectively. The mean foraging speed varied from 9.97 flowers/min (*T. stans*) to 21.44 flowers/min (*Cae. pulcherrima*). Thus, *B. ulugurica*, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans* could be cultivated and protected to increase honey production in the urban area of Ngaoundéré. Moreover, *B. ulugurica*, *Cae. pulcherrima* and *Cal. Tweedii* could be cultivated and protected to increase pollen production as a hive product in this environment.

Keywords: *Apis mellifera*, bee plant, *Brillantaisia ulugurica, Caesalpinia pulcherrima, Calliandra tweedii, Tecoma stans*

Introduction
Many plant species benefit greatly from honey bee's pollination (Reyes-Carrillo *et al*., 2007; Blazyte-Cereskiene *et al*., 2010) [1, 2], via seed production (Sushil *et al*., 2013) [3] as well as seed quality (Yucel and Duman, 2005) [4]. Honey bees provide plants with nitrogen indirectly through their faeces (Mishra *et al*., 2013) [5]. On the other side, many plant species provide the alimentary resources (nectar and pollen) for honey bees (Kebede and Gebrechirstos, 2016) [6]. The nectar is transformed into honey which is stored together with pollen in the hive for future use (Crane, 1999) [7]. By investing limited expenses, beekeeping can be practiced to obtain maximum subsidiary income through honey (PRODEL, 2016) [8], beewax (Bogdanov, 2004) [9] and other bee products. The sustainable beekeeping in a given Region requires 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) [10, 11, 12]. Moreover, the abundances of the dominant species of flower visitors are linked to the amount of energy provided by the nectar (Roubik, 1989) [13]. However, daily changes in available nectar affect the identity and abundance of flower feeders (Potts *et al*., 2001; 2004) [14, 15]. Before this study, relatively little is known about the honey bee foraging behavior in urban areas of Cameroon.
The main objective of this work was to study the relationship between *Apis mellifera*, *Brillantaisia ulugurica*, *Caesalpinia pulcherrima*, *Calliandra tweedii* and *Tecoma stans* 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 the honey bee.

Materials and Methods
Study site and biological material: The present study was carried out from March 2016 to February 2018 in the urban area of Ngaoundéré, Adamaoua 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 (Djoufack *et al*., 2012) [16]. The climate is tropical and characterized by two seasons: a rainy season (April to October) and a dry season (November to March) (Tchuenguem, 2005) [17]. The annual rainfall is about 1500 mm. The mean annual temperature is 22 °C, while the mean annual relative humidity is 70% (Amougou *et al*., 2015) [18].

Plants chosen for observations were located in an area of three kilometers in diameter, centered on the Ngaoundéré Urban Community (latitude: 07°19.064' N, longitude: 13°34.622' E, altitude: 1133 m a.s.l.). 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.

Animal material included *A. mellifera* and other insect species naturally present in the environment. The number of honey bee colonies in the area varied from 18 in March 2016 to 25 in February 2017 and from 23 in March 2017 to 44 in February 2018. The vegetation was represented by crops, ornamental plants, hedge plants and native plants of savannah and gallery forests.

Registration of the foraging activity of *Apis mellifera* on flowers

From March 2016 to February 2017 and From March 2017 to February 2018, the foraging behaviour of *A. mellifera* workers was recorded on flowers of different plant species. Data were taken during two days per week, between 7 am and 18 pm, according to three time slots: 07 am-11am, 11 am-15 pm and 15 pm-18pm (Tchuenguem *et al*., 2007) [19]. Table 3 provides information on the number of observation days for each plant species. For a given plant species visited by a honey bee and for each investigation date, the following parameters were registered for each daily time slot and, whenever possible: floral products (nectar or pollen) harvested, abundance of foragers (highest number of individual bees foraging simultaneously on a flower and on 1000 flowers) (Tchuenguem, 2005) [17], duration of individual flower visit, influence of fauna (disruptions of foragers by competitors and/or predators) and impact of the surrounding flowers (attractiveness of other plant species to *A. mellifera* workers) (Tchuenguem *et al*., 2010) [20]. The influence of the competitive flowers was determined by two methods: (a) direct observation of the nectar and/or pollen collection behaviour of workers on a given plant and other flowering plant species under observation and (b) analysis of the pollen loads carried by honey bee workers captured on flowers (Tchuenguem *et al*., 2010) [20]. During each of the three days of full flowering, two pollen foragers were caught 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 (Tchuenguem *et al*., 2010) [20].

Table 1: Scientific name, botanic family, biotope, some characteristics and strength of different plants studied at Ngaoundéré in 2016 and 2017.

Scientific name	Family	Biotope	FP	DCOF	Strength*	
					2016	2017
Brillantaisia ulugurica Lindau and Jahrbücher (++; he)	Acanthaceae	Gallery forest	January - April; August - December	purple	3542	3487
Caesalpinia pulcherrima Linnaeus (+; sh)	Caesalpiniaceae	hedge	January - December	yellow	3835	4522
Calliandra tweedii Bentham (+; sh)	Fabaceae	hedge	January - December	red	71	88
Tecoma stans Linnaeus (+; sh)	Bignoniaceae	hedge	January - December	yellow	317	463

+: cultivated plant; ++: spontaneous plant; sh: shrub; he: herbaceous; 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 investigation periods.

Plant species	Study periods (March to February)	Months											
		Ma	Ap	My	Jn	Jl	Au	Se	Oc	No	De	Ja	Fe
Brillantaisia ulugurica	2016 - 2017						*	**	***	****	****	****	****
	2017 - 2018	**	**				*	**	***	**	****	****	****
Caesalpinia pulcherrima	2016 - 2017	**	***	****	****	**	****	***	***	**	***	***	***
	2017 - 2018	***	***	**	****	***	****	**	**	***	****	*	*
Calliandra tweedii	2016 - 2017	***	***	**	***	****	***	***	****	****	****	***	****
	2017 - 2018	****	***	**	**	***	****	****	****	****	****	****	***
Tecoma stans	2016 - 2017		**	***	****	***	*	**	**	****	****	***	***
	2017 - 2018	**	***	****	****	***	***	**	**	**	*		

Ja: January; Fe: February; Ma: March; Ap: April; My: May; Jn: June; Jl: July; Au: August; Se: September; Oc: October; No: November; De: December; *: ≤ 100 flowers = rare; **: > 100 and ≤ 500 flowers = little abundant; ***: > 500 and ≤ 1000 flowers = abundant; ****: > 1000 flowers = very abundant (Tchuenguem *et al*., 2007) [19].

Evaluation of the concentration in sugar content of the nectar of different plant species

The concentration in total sugars of the nectar is an important parameter for the attractiveness of the honey bee to many flowers (Philippe, 1991) [21].

This parameter was evaluated from March 2016 to February 2017 and from March 2017 to February 2018, with a handheld refractometer (0-90% Brix) and a thermometer that gives the ambient temperature. *Apis mellifera* workers in full activity of nectar harvest were captured on flowers and anesthetized by their introduction into a small bottle containing cotton moistened with chloroform (Djonwangwé *et al*., 2011) [22].

Nectar was thereafter removed from honey bee gut by exerting pressure on the 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) (Nye and Pedersen, 1962) [23]. The registered values obtained were corrected according to the ambient temperature, using a table provided by the device leaflet.

Evaluation of the apicultural value of different plant species

The apicultural value of each plant species was assessed using data on the flowering intensity, the degree of attractiveness of *A. mellifera* workers for nectar and/or pollen (Villières, 1987; Tchuenguem *et al*., 2007; Tchuenguem *et al*., 2008a, 2008b; Djonwangwé *et al*., 2011) [24, 19, 25, 26, 22].

Evaluation of the influence of *Apis mellifera* on pollination

To measure the ability of *A. mellifera* to act as a pollinator of each plant species, during nectar or pollen harvest, the number of times a forager comes into contact with the stigma of the visited flower was noted (Jacob-Remacle, 1989) [27]. This approach allows highlighting the involvement of *A. mellifera* in self-pollination and cross-pollination (Zumba *et al*., 2013; Potts *et al*., 2015) [28, 29].

Data analysis

Data were subjected to descriptive statistics, ANOVA (*F*) for the comparison of means of more than two samples, student's *t*-test for the comparison of the mean of two samples, the Pearson correlation coefficient (*r*) for the study of the association between two variables, chi-square ($\chi 2$) for the comparison of percentages, using Microsoft Excel 2010 software and R commander, version R.13.2.0.

Results

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

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

The floral products harvested by *A. mellifera* workers on flowers of each investigated plant and its intensity and frequency of collection are presented in Tables 3 and 4. The main results are as follows: a) *A. mellifera* workers harvested nectar and pollen on each plant species (Fig. 1); b) the foragers intensely and regularly harvested nectar of each studied plant; c) *B. ulugurica*, *Cae*. *pulcherrima* and *Cal*. *tweedii* were intensely visited for pollen; d) *T. stans* was slightly visited for pollen; e) in general, the intensity (very low, low, high and very high) of nectar or pollen collection varied with plant species and time; f) on plant species where honey bees harvested nectar, the related frequency (percentage of the number of days where collection of nectar was observed, compared with the number of investigation days) was 100% for each plant species; g) on plant species where honey bee harvested pollen, the related frequency varied from 32.50% for *T. stans* to 100% for *B. ulugurica* and *Cae*. *pulcherrima* (Table 3). The type of product harvested from flowers (nectar or pollen) by *A. mellifera* in a given plant species varied with time slots.

Abundance of foragers

The highest number of workers foraging simultaneously per flower was one for each plant species. The abundance per 1000 flowers varied from 7 to 440 on *B. ulugurica*, from 3 to 200 on *Cae*. *pulcherrima*, from 19 to 592 on *Cal*. *tweedii* and from 2 to 420 on *T. stans* (Table 5). The abundance per individual plant varied from 4 to 232 on *B. ulugurica*, from 2 to 89 on *Cae*. *pulcherrima*, from 15 to 712 on *Cal*. *tweedii* and from 8 to 635 on *T. stans* (Table 6).

Duration of visits per flower

Table 7 indicates that in general, the mean duration of a flower visit varied with plant species and for a given plant species, with the type of floral product collected.

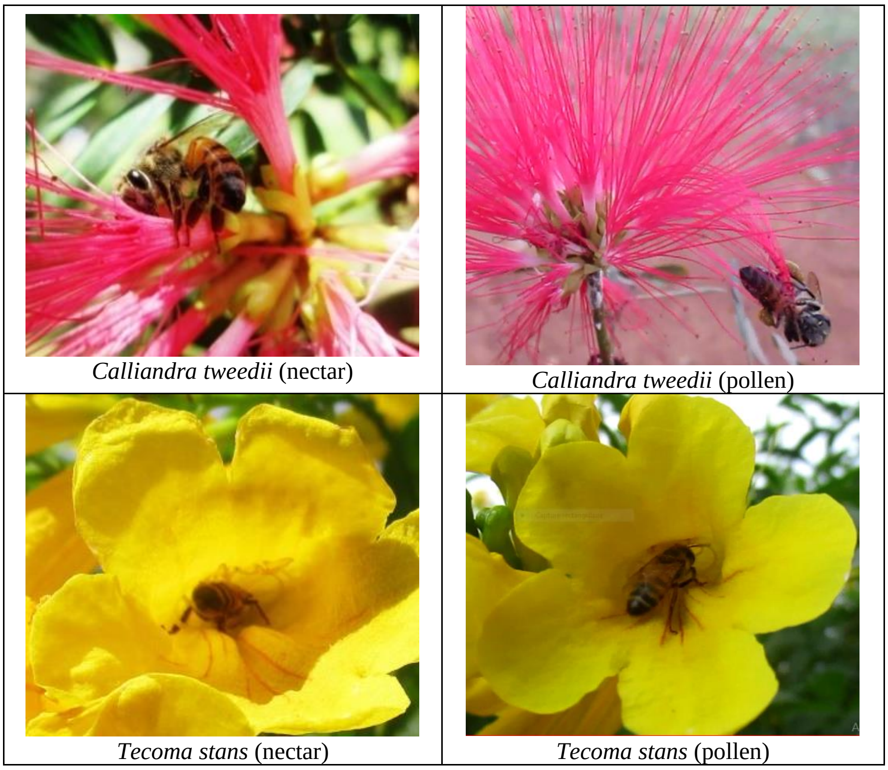
The mean duration of a visit per flower for nectar collection varied from 4.54 sec for *Cae*. *pulcherrima* in 2016/2017 to 10.50 sec for *Cal*. *tweedii* in 2017/2018. The mean duration of a visit per flower for pollen collection varied from 1.25 sec for *Cae*. *pulcherrima* in 2016/2017 to 3.38 sec for *T. stans* in 2017/2018. The mean duration of a visit per flower slightly varied from one year to another.

Brillantaisia ulugurica (nectar)

Brillantaisia ulugurica (pollen)

Caesalpinia pulcherrima (nectar)

Caesalpinia pulcherrima (pollen)



Calliandra tweedii (nectar) | *Calliandra tweedii* (pollen)

Tecoma stans (nectar) | *Tecoma stans* (pollen)

Fig 1: *Apis mellifera* collecting nectar or pollen on a flower of studied plant species

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

Plant species	Study periods (March to February)	Months												TD	nDN	pDN (%)	nDP	pDP (%)
		Ma	Ap	My	Jn	Jl	Au	Se	Oc	No	De	Ja	Fe					
Brillantaisia ulugurica	2016 - 2017						P^1	N^3P^1	N^3P^4	N^4P^3	N^4P^3	N^1P^3	P^3	128	128	100.0	128	100.0
	2017 - 2018	N^1P^1	N^1P^2				P^1	N^3P^2	N^3P^4	N^4P^3	N^3P^3	N^1P^2	P^2					
Caesalpinia pulcherrima	2016 - 2017	N^1	N^1P^2	N^3P^4	N^4P^4	N^3P^3	N^4P^1	N^3P^2	N^2P^2	N^3P^2	N^4P^2	N^2P^3	N^2P^1	192	192	100.0	192	100.0
	2017 - 2018	N^1P^2	N^2P^2	N^1P^3	N^4P^4	N^2P^4	N^3P^2	N^2P^1	N^1P^2	N^2P^1	N^2P^2	N^1P^1	N^1					
Calliandra tweedii	2016 - 2017	N^1P^1	N^1P^1	N^4P^1	N^2P^1	N^2	N^2P^4	N^2P^3	N^4P^4	N^4P^3	N^2P^1	N^2P^2	N^4P^2	197	197	100.0	164	83.25
	2017 - 2018	N^2P^3	N^2P^2	N^1	N^1P^1	N^2P^2	N^4P^4	N^4P^3	N^3P^2	N^2P^3	N^1P^1	P^2	N^1					
Tecoma stans	2016 - 2017			N^3	N^3P^1	N^4P^1	N^2	N^3	N^2P^1	N^4P^1	N^4P^1	N^4P^1	N^4P^1	160	160	100.0	52	32.50
	2017 - 2018	N^3P^1	N^4P^1	N^4P^1	N^4P^1	N^4P^1	N^3	N^3P^1	N^2	N^3	N^1							

Ja: January; Fe: February; Ma: March; Ap: April; My: May; Jn: June; Jl: July; Au: August; Se: September; Oc: October; No: November; De: December; 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 in superscripts indicate very low, low, high and very high collections respectively (Tchuenguem *et al*., 2008b) [26]

Table 4: Floral products harvested by *Apis mellifera* from the flowers of four plant species according to daily time slots.

Plant species	Daily time slots		
	7 am - 11 am	11 am - 15 pm	15 pm - 18 pm
Brillantaisia ulugurica	Nectar and pollen	Nectar and pollen	Nectar and pollen
Caesalpinia pulcherrima	Nectar and pollen	Nectar and pollen	Nectar and pollen
Calliandra tweedii	Nectar and pollen	Nectar and pollen	Nectar
Tecoma stans	Nectar	Nectar and pollen	Nectar

Table 5: Abundance of *Apis mellifera* workers per 1000 flowers according to plant species and month.

Plant species	Study periods (March to February)	Abundance per 1000 flowers											
		Ma	Ap	My	Jn	Jl	Au	Se	Oc	No	De	Ja	Fe
Brillantaisia ulugurica	2016 - 2017						7	11	96	198	297	440	171
	2017 - 2018	72	36				8	84	440	180	151	120	110
Caesalpinia pulcherrima	2016 - 2017	7	23	106	190	165	97	51	13	4	19	24	30
	2017 - 2018	27	30	44	60	42	137	120	146	200	160	20	3
Calliandra tweedii	2016 - 2017	98	56	19	49	270	164	122	376	189	251	82	193
	2017 - 2018	43	30	47	253	592	261	269	181	125	160	188	119
Tecoma stans	2016 - 2017			35	63	42	5	17	122	280	243	186	140
	2017 - 2018	22	73	174	420	198	48	23	25	12	2		

Ja: January; Fe: February; Ma: March; Ap: April; My: May; Jn: June; Jl: July; Au: August; Se: September; Oc: October; No: November; De: December

Comparaison of means abundunce per 1000 flowers: $A1000_{2016/2017}$: F = 34.84 ($df\ 1$ = 3; $df\ 2$ = 737; P< 0,001; VHS); $A1000_{2017/2018}$: F = 97.45 ($df\ 1$ = 3; $df\ 2$ = 826; P< 0,001; VHS)

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	Study periods (March to February)	Abundance per plant											
		Ma	Ap	My	Jn	Jl	Au	Se	Oc	No	De	Ja	Fe
Brillantaisia ulugurica	2016 - 2017						4	7	13	21	85	228	89
	2017 - 2018	28	16				11	73	232	76	49	91	87
Caesalpinia pulcherrima	2016 - 2017	5	20	50	89	17	38	40	10	5	17	15	30
	2017 - 2018	22	25	18	5	35	85	42	15	58	40	18	2
Calliandra tweedii	2016 - 2017	120	85	15	97	337	155	110	230	216	185	56	152
	2017 - 2018	29	35	93	244	712	358	294	125	104	167	95	76
Tecoma stans	2016 - 2017			38	74	53	18	29	25	247	635	447	89
	2017 - 2018	35	66	40	28	260	129	36	15	33	8		

Ja: January; Fe: February; Ma: March; Ap: April; My: May; Jn: June; Jl: July; Au: August; Se: September; Oc: October; No: November; De: December

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

Plant species	Visiting time per flower (sec)								Comparison of means of the two study periods (*t*- test)		
	March 2016 to February 2017				March 2017 to February 2018						
	n	*m ± sd*	*mini*	*maxi*	*n*	*m ± sd*	*mini*	*maxi*	*t- value*	*df*	*p- value*
Brillantaisia ulugurica (ne)	149	5.76 ± 3.89	2	22	162	5.87 ± 5.10	1	34	0.21	309	> 0.05^{NS}
Brillantaisia ulugurica (po)	296	2.91 ± 2.17	1	9	219	2.95 ± 2.24	1	14	0.20	513	> 0.05^{NS}
Caesalpinia pulcherrima (ne)	250	4.54 ± 2.08	1	14	281	4.58 ± 2.67	1	15	0.19	529	> 0.05^{NS}
Caesalpinia pulcherrima (po)	256	1.31 ± 0.64	1	5	260	1.30 ± 0.53	1	3	0.19	514	> 0.05^{NS}
Calliandra tweedii (ne)	255	10.4 ± 6.44	1	35	220	10.50 ± 6.51	1	36	0.17	473	> 0.05^{NS}
Calliandra tweedii (po)	185	2.65 ± 1.12	1	7	158	2.7 ± 1.47	1	6	0.35	341	> 0.05^{NS}
Tecoma stans (ne)	259	7.11 ± 5.48	1	47	336	7.05 ± 6.12	1	44	0.13	593	> 0.05^{NS}
Tecoma stans (po)	64	3.30 ± 1.59	1	6	60	3.38 ± 1.34	2	8	0.30	122	> 0.05^{NS}

n: number of visits studied; m: mean; sd: standard deviation; mini: minimum; maxi: maximum; df: degree of freedom; ne: nectar collection visits; po: pollen collection visits; NS: non significant difference

Comparaison of means duration of visits: $Nectar_{2016/2017}$: F = 79.12 ($df\ 1$ = 3; $df\ 2$ = 909; P< 0.001; VHS); $Nectar_{2017/2018}$: F = 64.17 ($df\ 1$ = 3; $df\ 2$ = 995; P< 0.001; VHS); $Pollen_{2016/2017}$: F = 197.25 ($df\ 1$ = 3; $df\ 2$ = 909; P< 0.001; VHS); $Pollen_{2016/2017}$: F = 72.34 ($df\ 1$ = 3; $df\ 2$ = 693; P< 0.001; VHS)

The statistical analyses reveal globally a highly significant differences between the mean duration of a flower visits of *A. mellifera* on the different plant species for nectar collection in 2016/2017 (F = 79.12; $df\ 1$ = 3; $df\ 2$ = 909; P< 0.001) as in 2017/2018 (F = 64.17; $df\ 1$ = 3; $df\ 2$ = 995; P< 0,00), then for pollen harvested in 2016/2017 (F = 197.25; $df\ 1$ = 3; $df\ 2$ = 909; P< 0.001) as in 2017/2018 (F = 72.34; $df\ 1$ = 3; $df\ 2$ = 693; P< 0.001).
The difference between the mean duration of a flower visit for nectar collection and that of pollen collection was highly significant for *B. ulugurica* (2016/2017: t = 8.29, df = 443, P< 0.001; 2017/2018: t = 6.80, df = 379, P< 0.001), *Cae. pulcherrima* (2016/2017: t = 23.44, df = 504, P< 0.001; 2017/2018: t = 20.13, df = 539, P< 0.001), *Cal. tweedii* (2016/2017: t = 18.79, df = 438, P< 0.001; 2017/2018: t = 17.13, df = 376, P< 0.001) and *T. stans* (2016/2017: t = 9.63, df = 321, P< 0.001; 2017/2018: t = 9.73, df = 394, P< 0.001). Therefore, on each of the four plant species, *A. mellifera* spent more time on a flower for nectar collection than for pollen harvest.

Influence of other flowering insects

Honey bees were disturbed during their foraging activity on each studied plant species by other individuals from the same species or from other insect species that were competing for nectar or pollen. For 826 visits registered on *B. ulugurica* flowers respectively in 2016/2017 and 2017/2018, 99 were disrupted by other *A. mellifera* workers (32 visits), *Xylocopa olivacea* (27 visits), *Xylocopa inconstans* Smith (24 visits) and *Amegilla* sp. (Hymenoptera: Apidae; 16 visits). Among 1047 visits registered on *Cae. pulcherrima* flowers in 2016/2017 and 2017/2018, 108 were disrupted by *A. mellifera* workers (63 visits), *Xylocopa olivacea* (19 visits), *Graphium angolanus* Goeze (Lepidoptera: Papilionidae; 13 visits) and *Amegilla* sp. (13 visits). For 818 visits registered on *Cal. tweedii* flowers in 2016/2017 and 2017/2018, 63 were disrupted by *A. mellifera* workers (40 visits) and *Belonogaster juncea* Fabricius (Hymenoptera: Vespidae; 23 visits). For 719 visits registered on *T. stans* flowers in 2016/2017 and 2017/2018, 51 were disrupted by *A. mellifera* workers (17 visits), *Xylocopa olivacea* (15 visits) and *Xylocopa inconstans* (19 visits).

Influence of neighboring flora

Throughout the observation period on each plant species, *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), *Tagetes erecta* Linnaeus (Asteraceae; ne and po), *Delonix regia* (Bojer ex Hooker) Rafinesque (Fabaceae; ne and po), *Mimosa pudica* Linnaeus (Fabaceae; po), *Sida rhombifolia* Linnaeus (Malvaceae; ne and po), *Hibiscus rosa-sinensis* Linnaeus (Malvaceae; ne and po) and *Psidium guajava* Linnaeus (Myrtaceae; po). During one foraging trip, an individual bee foraging on plant species under investigation scarcely visited another plant species (for each studied plant species, not more than three observations of such behavior were done during the entire study period). In addition, the analysis of the pollen loads collected from baskets of foragers showed that the percentages of foreign pollen grain were 1.15% for *B. ulugurica*, 0.83% for *Cae. pulcherrima*, 0.78% for *Cal. tweedii* and 0.67% for *T. stans* (Table 8). These results indicate that *A. mellifera* workers showed flower constancy (Louveaux, 1984; Basualdo *et al*., 2000) [30, 31] for the flowers of each of the four plant species studied suring foraging bouts.

Concentration in total sugar of the nectar of studied plants species

Table 9 presents the concentration in total sugar of the nectar of studied plant species. The differences between the means concentration in total sugar of the nectar for these plant species are globally significant (F = 150.71; $df\ 1$ = 3; $df\ 2$ = 404; P< 0.001) in 2016/2017 as in 2017/2018 (F = 241.54; $df\ 1$ = 3; $df\ 2$ = 526; P< 0.001). The mean concentration in total sugar of *B. ulugurica* nectar was 44.15% in 2016/2017 and 42.38% in 2017/2018. The difference between these means is significant (t = 2.43; df = 166; P< 0.05). The mean concentration in total sugar of *Cae. pulcherrima* nectar was 37.44% in 2016/2017 and 25.97% in 2017/2018. The difference between these two means is significant (t = 10.16; df = 203; P< 0.001). The mean concentration in total sugars of *Cal. tweedii* nectar was 37.81% in 2016/2017 and 36.55% in 2017/2018. The difference between these two means is significant (t = 2.42; df = 283; P< 0.05).The mean concentration in total sugars of *T. stans* nectar was 28.65% in 2016/2017 and 28.62% in 2017/2018. The difference between these means is not significant (t = 0.04; df = 278; P > 0.05).

Apicultural value of the plant species studied

During the flowering period of each studied plant species, there were a high abundance of *A. mellifera* workers on flowers. Moreover, we have observed high nectar collection on flowers of each plant, high pollen harvest on *B. ulugurica*, *Cae. pulcherrima* and *Cal. tweedi*, but low pollen collection on *T. stans*. Furthermore, our investigations revealed that in the dry season, which is the main period of honey flow in the study Region (Tchuenguem *et al*., 2007) [19], individual from each investigated plant species could produce between 250 and more than 15000 flowers. Based on these data, the studied plants can be classified into five categories of bee plants: a) very highly nectariferous: *Cae. pulcherrima*, *Cal. tweedii* and *T. stans*; b) highly nectariferous: *B. ulugurica*; c) very highly polliniferous: *B. ulugurica*; d) highly polliniferous: *Cae. pulcherrima* and *Cal. Tweedii* and e) slightly polliniferous: *T. stans*.

Table 10 summarizes the appropriate period to harvest honey or pollen in hives installed in an area of at least 3 km in diameter dominated by the studied plant species (Tchuenguem *et al*., 2018) [32].

Thus, in the urban area of Ngaoundéré, honey can be harvested in January, June, October to December, if the environment of the apiary is dominated by strong flowering populations of *B. ulugurica*, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans*.

In the same environment, pollen can be harvested from the hives in October, May to July and August, if the surrounding of the apiary is dominated by many *B. ulugurica*, *Cae. pulcherrima* and *Cal. tweedii* plants in bloom respectively.

Table 8: Pollen profile of pollen loads collected in the corbiculae of nine *Apis mellifera* workers foraging on flowers of four plant species according to the study periods.

Plant species	Pollen profile of pollen loads									
	March 2016 to February 2017					March 2017 to February 2018				
	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		
Brillantaisia ulugurica	7046	7014	32	0.45	Mp, Pm, Td	1035	1006	19	1.84	Pg, Pm, Td
Caesalpinia pulcherrima	6173	6125	48	0.78	Dr, Hr	4238	4201	37	0.87	Td, Dr
Calliandra tweedii	3961	3939	22	0.56	Hr	4296	4253	43	1.00	Te
Tecoma stans	3014	2988	26	0.86	Bt	3827	3809	18	0.47	Hr

Pm: *Persicaria maculosa* Gray (Polygonaceae); Td: *Tithonia diversifolia* (Hamsley) Gray (Asteraceae); Pg: *Psidium guajava* Linnaeus (Myrtaceae); Mp: *Mimosa pudica* Linnaeus (Fabaceae); Hr: *Hibiscus rosa-sinensis* Linnaeus (Malvaceae); Bt: *Bauhinia tomentosa* Linnaeus (Fabaceae); Te: *Tagetes erecta* Linnaeus (Asteraceae); Dr: *Delonix regia* (Bojer ex Hooker) Rafinesque (Fabaceae)

Table 9: Concentration in total sugar of the nectar of studied plants species.

Plant species	Concentration in total sugars of the nectar (%)								Comparison of means of the two study periods (t- test)		
	March 2016 to February 2017				March 2017 to February 2018						
	n	*m ± sd*	*mini*	*maxi*	*n*	*m ± sd*	*mini*	*maxi*	*t- value*	*df*	*p- value*
Brillantaisia ulugurica	97	44.15 ± 4.98	29.81	52.79	71	42.38 ± 4.36	35.56	50.81	2.43	166	$< 0.05^{S}$
Caesalpinia pulcherrima	59	37.44 ± 7.93	23.87	47.38	146	25.97 ± 5.26	13.05	50.73	10.16	203	$< 0.001^{VHS}$
Calliandra tweedii	116	37.81 ± 4.22	28.07	47.23	169	36.55 ± 4.41	26.56	49.79	2.42	283	$< 0.05^{S}$
Tecoma stans	136	28.65 ± 5.89	10.73	37.39	144	28.62 ± 5.60	10.73	45.31	0.04	278	$> 0.05^{NS}$

m: mean; sd: standard deviation; NS: non significant difference; S: significant difference; VHS: very highly significant difference; n: strength; mini: minimum; maxi: maximum; df: degree of freedom

Comparison of the means concentration in total sugar of the nectar for different plant species: 2016/2017: F = 150.71 ($ddl\ 1$ = 3; $ddl\ 2$ = 404; P< 0,001; VHS); 2017/2018: F = 241.54 ($ddl\ 1$ = 3; $ddl\ 2$ = 526; P< 0,001; VHS)

Impact of *Apis mellifera* activity on pollination

During collection of pollen and/or nectar on flowers, foragers were frequently in contact with the anthers and stigma. They could therefore, be directly involved in self-pollination. The individual bees passing from flower to flower on different plants were seen carrying pollen from one plant to another. Consequently, they could allowed cross pollination. The percentage of the total number of visits during which worker honey bees came into contact with the stigma of the visited flower was 92.36% for *B. ulugurica*, 91.11% for *Cae. pulcherrima*, 85.45% for *Cal. tweedii* and 60.37% for *T. stans* in 2016/2017 and 88.98% for *B. ulugurica*, 88.91% for *Cae. pulcherrima*, 94.44% for *Cal. tweedii* and 61.87% for *T. stans* in 2017/2018 (Table 11). Thus, *A. mellifera* foragers greatly increased the pollination possibilities of *B. ulugurica*, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans*.

Discussion

Apis mellifera workers visited the flowers of *B. ulugurica*, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans* for nectar and pollen. The collection of nectar from *B. ulugurica* and the harvesting of nectar and pollen from *T. stans* flowers by this bee have also been observed in the Democratic Republic of Congo (Bakenga *et al*., 2000) [11]. On *T stans*, Iritie *et al*. (2014) [33] have observed the harvest of the pollen only in Ivory Coast. Thus, the type of floral products harvested by honey bee could vary from one plant to another and with the region.

Table 10: 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
Brillantaisia ulugurica	***	****	January	October
Caesalpinia pulcherrima	****	***	June	May - July
Calliandra tweedii	****	***	October - December	August
Tecoma stans	****	*	June	-

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

Table 11: Number and frequency of contacts between *Apis mellifera* and the stigma during floral visits of four plant species.

Plant species	March 2016 to February 2017			March 2017 to February 2018			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	%
Brillantaisia ulugurica	445	411	92.36	381	339	88.98	552	495	89.67
Caesalpinia pulcherrima	506	461	91.11	541	481	88.91	521	464	89.06
Calliandra tweedii	440	376	85.45	378	357	94.44	604	540	89.40
Tecoma stans	323	195	60.37	396	245	61.87	601	412	68.55

Overall comparison of frequency of visits with stigmatic contacts: a) March 2016 to February 2017: χ^2_{global} = 178.69 (*df* = 3; *P*< 0.001^{VHS}); b) March 2017 to February 2018: χ^2_{global} = 190.19 (*df* = 3; *P*< 0.001^{VHS})

Comparison of frequency of visits with stigmatic contacts of the two study periods: *Brillantaisia ulugurica*: χ^2 = 2.81 (*df* = 1; *P* > 0.05^{NS}); *Caesalpinia pulcherrima*: χ^2 = 1.40 (*df* = 1; *P* > 0.05^{NS}); *Calliandra tweedii*: χ^2 = 17.65 (*df* = 1; *P*< 0.001^{HS}); *Tecoma stans*: χ^2 = 0.17 (*df* = 1; *P* > 0.05^{NS})
VHS: Very highly significant difference; NS: non significant difference; *df*: degree of freedom

Furthermore, according to Pamminger *et al*. (2019) [34], nectar serves as the main carbohydrate source for bees and consequently, the total caloric value, as well as the rate of calories uptake, are important aspects of nectar quality for bees. Moreover, one of the main factors determining the uptake rate is nectar viscosity, which in the term is largely determined by nectar sugar concentration (Pamminger *et al*., 2019) [34]. Our results with *B. ulugurina*, *Cae. pulcherrima* and *Cal. tweedii* are in line with those of Kim *et al*., (2011) [35] who found that in general the concentration in total sugar of the nectar of many plant species visited by bee ranged between 35 and 60%. According to Roubik and Buchmann (1984) [36], bees will collect nectar with sugar concentrations below 35% under natural conditions. Our observations on *T. stans* confirmed this founding. Cnaani *et al*. (2006) [37] suggest that at least social bees avoid foraging on nectar sources below 20% sugar concentration, likely because the calories intake cannot support sustained foraging activity, with potentially detrimental effects for the bee colony.
The observed high abundances of foragers per 1000 flowers could be attributed to the ability of honey bees to recruit a great number of workers for the exploitation of good food sources (Frisch, 1969; Louveaux, 1984; Schneider and Hall, 1997) [38, 30, 39].

The fact that a honey bee spent significantly different time on a flower for nectar harvest than for pollen collection could be explained by the abundance and/or accessibility of each floral product.
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 to maximize their nectar and/or pollen loads. Similar observations have been made in Ngaoundéré on the flowers of: *Entada africana* Guillaume et Perrault (Fabaceae) and *Psidium guajava* Linnaeus (Myrtaceae) (Tchuenguem *et al*., 2007) [19]; *Croton macrostachyus* Hochstetter ex Delile (Euphorbiaceae) and *Syzygium guineense* var. *guineense* (Wildeman) Pyramus de Candolle (Myrtaceae) (Tchuenguem *et al*., 2008a) [25]; *Persea americana* Miller (Lauraceae) and *Vitellaria paradoxa* Gärtner Friedrich (Sapotaceae) (Tchuenguem *et al*., 2008b) [26]; *Jatropha curcas* Linnaeus (Euphorbiaceae), *Senegalia polyacantha* (Willdenow) Seigler and Ebinger (Mimosaceae) and *Terminalia schimperiana* Hochstetter (Combretaceae) (Wékéré *et al*., 2018) [40] and *Helianthus annuus* Linnaeus (Asteraceae) (Egono *et al*., 2018) [41].
The scarcity of movement of *A. mellifera* workers from one plant species to another and the low percentages of foreign pollen in the pollen loads collected from its baskets prove the strong faithfulness of this bee to each of the studied plant species. This floral constancy in honey bees 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 (Wright *et al*., 2002) [42].
The fidelity of workers on flowers of each studied plant species could be explained by the attractiveness of each of them for *A. mellifera*. This flower constancy could be

partially due to the high sugar concentrations in nectar. Indeed, according to Philippe, (1991) [21], *A. mellifera* workers are generally constant on a plant species when sugar concentrations in nectar is more than 15%.

Brillantaisia ulugurica, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans* are highly nectariferous bee plants that could be planted to increase honey production in the urban area of Ngaoundéré. As highly polliniferous bee plants, *B. ulugurica*, *Cae. pulcherrima* and *Cal. tweedii* can be cultivated for the increase of pollen production as a hive product. All the studied plant species contribute to the food supply and therefore, to strengthening honey bee colonies. Consequently, these plants should be planted and protected in the environments surrounding the apiaries.

During the collection of pollen and/or nectar from its flowers, *A. mellifera* foragers increased the pollination possibilities of *B. ulugurica*, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans*. They could induce self-pollination (Lobreau-Callen and Coutin, 1987) [43] by applying the pollen of a flower on the stigma of the same flower. They could also be involved in geitonogamy (Lobreau-Callen and Coutin, 1987) [43] by putting the pollen of one flower on the stigma of another flower of the same plant species or xenogamy by putting the pollen of a given plant species on the stigma of another plant species. The impact of *A. mellifera* on fruit or grain yields of each of these plant species via its pollination efficiency will be studied in future work.

Conclusion

At Ngaoundéré, *A. mellifera* workers harvested intensely and regularly nectar in flowers of *B. ulugurica*, *Cae. pulcherrima*, *Cal. tweedii* and *T. stans*. This bee strongly harvested pollen of *B. ulugurica*, *Cae. pulcherrima* and *Cal. tweedii* and slightly collected pollen on *T. stans* flowers. All these plant species contributed more or less to the feeding and therefore to the strengthening of the honey bee colonies. *Apis mellifera* workers increased the pollination possibilities of each plant species. The installation of beehives sheltering honey bee colonies in gardens while respecting certain measures (using of living hedges) is recommended for the production of honey or pollen and the maintenance of animal and vegetal biodiversity in urban area of Ngaoundéré.

Acknowledgments

We are grateful to Prof. Pierre Marie Mapongmetsem and Prof. Tchobsala for the identification of plant species.

References

1. Reyes-Carrillo JL, Eischen FA, Cano-Rios P, Rodriguez-Martinez R, Camberos UN. Pollen collection and honey bee forage distribution in Cantaloupe. Acta Zoologica Mexicana 2007;23(1):29-36.
2. Blazyte-Cereskiene L, Vaitkeviciene G, Venskutonyte S, Buda V. Honey bee foraging in spring oilseed rape crops under high ambient temperature conditions. Zemdirbyste-Agriculture 2010;97(1):61-70.
3. Sushil SN, Stanley J, Hedau NK, Bhatt JC. Enhancing seed production of three brassica vegetables by honey bee pollination in north-western Himalayas of India. Universal Journal of Agricultural Research 2013;1(3):49-53.
4. Yucel B, Duman I. Effects of foraging activity of honeybees (*Apis mellifera* L.) on onion (*Allium cepa*) seed production and quality. Pakistan Journal of Biological Sciences 2005; 8(1):123-126.
5. Mishra A, Afik O, Cabrera ML, Delaplane KS, Mowrer JE. Inorganic nitrogen derived from foraging honey bees could have adaptive benefits for the plants they visit. PLoS ONE 2013;8:1-6.
6. Kebede H, Gebrechirstos S. Floral establishment of major honey plants in north western zone of Tigray, Ethiopia. International Journal of Scientific and Engineering Research 2016;7(9):543-550.
7. Crane E. The world history of beekeeping and honey hunting. Duckworth, London 1999, 682.
8. PRODEL (Project of Development of Livestock). Management executive of environmental and project of livestock development. Report of Ministry of Livestock, Fisheries, and Animal Industries 2016, 161.
9. Bogdanov S. Beeswax: quality issues today. Bee World 2004;85(3):46-50.
10. Morton JM. Honeybee plants of South Florida. Florida State Horticultural Society Proceedings 1964, 22.
11. Bakenga M, Bahati M, Balagizi K. Inventory of bee plants of Bukavu and their surroundings (South-Kivu, East of Congo Democratic Republic). Tropicultura 2000;18(2):89-93.
12. 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.
13. Roubik DW. Ecology and natural history of tropical bees. Ashton PS, Hubbell SP, Janzen DH, Raven PH, Tomlinson PB (eds), Cambridge University Press, Cambridge 1989, 514.
14. Potts SG, Dafni A, Ne'eman G. Pollination of a core flowering shrub species in Mediterranean phrygana: variation in pollinator diversity, abundance and effectiveness in response to fire. Oikos 2001; 92:71-80.
15. Potts SG, Vulliamy B, Robert S, O'Toole C, Dafni A, Ne'eman G, *et al*. Nectar resource diversity organises flower-visitor community structure. Entomologia Experoimentalis et Applicata 2004;113:103-107.
16. Djoufack V, Fontaine B, Martiny N, Tsalefac M. Climatic and demographic determinants of vegetation cover in northern Cameroon. International Journal of Remote Sensing 2012;21:6904-6926.
17. Tchuenguem FFN. Foraging and pollination activity of *Apis mellifera adansonii* (Hymenoptera: Apidae, Apinae) on flowers of three plants at Ngaoundéré (Cameroon): *Callistemon rigidus* (Myrtaceae), *Sygygium guineense* var. *macrocarpum* (Myrtaceae) and *Voacanga africana* (Apocynaceae). Thesis of State Doctorate, University of Yaoundé I 2005, 103.
18. Amougou JA, Abossolo SA, Tchindjang M. Variability of precipitations at Koundja and Ngaoundéré based on temperature changes of Atlantic Ocean and El NINO. Ivory Coast Review of Science and Technology 2015;25:110-124.
19. Tchuenguem FFN, Djonwangwé D, Messi J, Brückner D. Exploitation of *Entada africana*, *Eucalyptus camaldulensis*, *Psidium guajava* and *Trichillia emetica* flowers by *Apis mellifera adansonii* at Dang (Ngaoundéré, Cameroon). Cameroon Journal of Experimental Biology 2007;3(2):50-60.
20. Tchuenguem FFN, Fameni ST, 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.
21. Philippe JM. The pollination by bees: installation of colonies in the field during flowering for crops yield increase. EDISUD, Aix-in-Provence 1991, 178.
22. 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 2011; 10(3):1325-1333.
23. Nye WP, Pedersen MW. Nectar sugar concentration as a measure of pollination of alfalfa [*Medicago sativa* L.]. Entomology Research Division and Crops Research Division, Agricultural Research Service, U.S.D.A 1962;1:24-27.
24. Villières B. The apiculture in Tropical Africa. Documents "The point on" n°11, GRET, Paris 1987, 220.
25. Tchuenguem FFN, Djonwangwé D, Brückner D. Foraging behaviour of the African honey bee (*Apis mellifera adansonii*) on *Annona senegalensis*, *Croton macrostachyus*, *Psorospermum febrifugum* and *Syzygium guineense* var. *guineense* flowers at Ngaoundere (Cameroon). Pakistan Journal of Biological Sciences 2008a;11(5):719-725.
26. Tchuenguem FFN, Djonwangwé D, Messi J, Brückner D. 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 2008b;28(4):225-233.
27. Jacob-Remacle A. Foraging behavior of domestic and wild bees within the apple ochards in Belgium. Apidologie 1989;20(4):271-285.
28. Zumba JX, Myers GO, Clawson EL, Miller DK, Danka RG, Blanche SB. Developing hybrid cotton (*Gossypium* spp.) using honeybees as pollinators and the roundup ready phenotype as the selection trait. Journal of Cotton Science 2013;17(4):293-301.
29. Potts S, Biesmeijer K, Bommarco R, Breeze T, Carvalheiro L, Franzén M, *et al.* Status and trends of European pollinators. Key findings of the STEP project. Pensoft Publishers, Sofia 2015, 72.
30. Louveaux J. Domestic bee In their relations with cultivated plants. *In*: Pollination and vegetal productions, Pesson P. and Louveaux J. (eds), INRA, Paris 1984, 527-555.
31. Basualdo M, Bedascarrasbure E, De Jong D. Africanized honey bees (Hymenoptera: Apidae) have a greater fidelity to sunflowers than european bees. Journal of Economic Entomology 2000;93(2):304-307.
32. Tchuenguem FFN, Wékéré C, Dongock ND, Fameni ST. Exploitation of *Acacia sieberiana*, *Allophylus africanus* and *Flacourtia indica* flowers by *Apis mellifera* (Hymenoptera: Apidae) at Dang (Ngaoundéré, Cameroon). Journal of Biodiversity and Environmental Sciences (JBES) 2018;13(5):71-82.
33. Iritie BM, Eboua NW, Armand AP, Agathe F, Lucas LG. Identification of bee plants of agroforestry area of Higher Training Agronomy of Yamoussoukro (Ivory Coast). European Scientific Journal 2014;10(30):444-458.
34. Pamminger T, Becker R, Himmelreich S, Schneider CW, Bergtold M. The nectar report: quantitative review of nectar sugar concentrations offered by bee visited flowers in agricultural and non-agricultural landscapes. Peer J 2019;7:1-15.
35. Kim W, Gilet T, Bush JWM. Optimal concentrations in nectar feeding. PNAS 2011;108(40):16618-16621.
36. Roubik DW, Buchmann SL. Nectar selection by *Melipona* and *Apis mellifera* (Hymenoptera: Apidae) and the ecology of nectar intake by bee colonies in a tropical forest. Oecologia 1984; 61(1):1-10.
37. Cnaani J, Thomson JD, Papaj DR. Flower choice and learning in foraging bumblebees: effects of variation in nectar volume and concentration. Ethology 2006;112:278-285.
38. Frisch KV. Life and habits of bees Michel. A. (ed.), Paris 1969, 556.
39. Schneider SS, Hall HG. Diet selection and foraging distances of African and European-African hybrid honeybee colonies in Costa Rica. Social Insects 1997;44:171-187.
40. Wékéré C, Kingha BMT, Dongock ND, Djakbé JD, Faibawa E, Tchuenguem FFN, *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.
41. Egono NCC, Kingha TMB, Fameni ST, Dounia, Tchuenguem FFN. 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.
42. 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 snapgragon flowers (*Antirrhinum majus*). Journal of Chemical Ecology 2002;28(4):721-740.
43. Lobreau-Callen D, Coutin R. Flower resources exploited by some Apoïdes of cultivated zones in arboreous savannah Senegalese during a rainy season. Agronomie 1987;7(4):231-246.