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Full length Research Paper

Foraging and pollination activities of *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) on *Ximenia americana* (Olacaceae) flowers at Ngaoundéré (Cameroon)

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To determine the apicultural value of *Ximenia americana* L. 1927 (Olacaceae) and to evaluate the *Apis mellifera adansonii* Latreille 1804 (Hymenoptera: Apidae) activity on its fruit yield, the bee foraging and pollination activities were studied in the Ngaoundéré in the gallery forests and savannah of Tchabal-Bambi and Béka, for two seasons (February - March, 2006 and 2007). One hundred and twenty and 200 flower clusters subdivided in two lots based on the presence or absence of protection of flower clusters from insects using gauze bags. The bee's seasonal rhythm of visits, the daily activity of workers, the abundance of foragers on 1000 flowers and the fruiting index of labelled inflorescences were evaluated. Results show that *A. m. adansonii* foraged on plant all day and during all periods of blooming. Each year, worker bees intensely harvested nectar and pollen. The greatest mean numbers of workers foraging simultaneously were 513 per 1000 flowers in 2006 and 447 per 1000 flowers in 2007. The rhythm of *A. m. adansonii* visits was positively correlated to the rhythm of *X. americana* flowers blooming. The fructification index of the unprotected flower clusters was significantly higher than that of flower clusters protected from insects. The contribution of *A. m. adansonii* in the fructification index was 87.34% in 2006 and 59.38% in 2007. This study allows the classification of the Olacaceae as a very highly nectariferous and highly polliniferous bee plant. The installation of *A. m. adansonii* colonies near the populations of *X. americana* is recommended to improve fruit and honey production in the region.

Key words: *Apis mellifera adansonii, Ximenia americana*, foraging, pollination.

INTRODUCTION

In the literature, it exist very little information on relations between anthophilous insects and several plants growing to Cameroon. Yet, it is known that anthophilous insects in general and bees in particular increase outputs in fruits or in seeds of several plant species, via the pollination of flowers during their activity of foraging (Kendal and Smith, 1976; Vanderborght and Rasmont, 1987; Ibarra-Perez, 1999; Tchuenguem Fohouo, 2005; Tchuenguem Fohouo et al., 2004, 2007, 2008a, 2008b, 2009a, 2009b, 2010; Philippe, 1991; Fluri and Frick, 2005; Sabbahi et al., 2005; Eardley et al., 2006).

Ximenia americana is an Olacaceae of savannah and of dry forest undergrowth, distributed from Senegal to Cameroon; its roots, almonds and leaves are used in the treatment of wounds, leprosy, sexual impotence and stiffness (Arbonnier, 2000). The man consumes the pulp of fruits raw (figure 1) or under shape of drink fermented; the oil of almonds is used in the kitchen (Arbonnier, 2000). The species is threatened by genetic erosion (Magdi et al., 2003).

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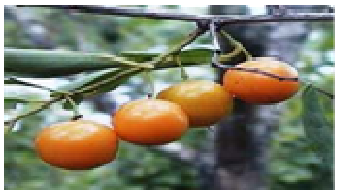

Figure 1. Branch of *Ximenia americana* carrying the mature fruits.

Figure 2. Baskets of *Ximenia americana* on sale at Dang market.

In Cameroon, the demand of *X. americana* fruits is strong and its fruit outputs is weakness. Very few data were published on *X. americana* relationships with anthophilous insects. However, Tchuenguem Fohouo et al. (1997) found that *X. americana* is an apicultural plant highly nectariferous. These works were done during only one season; nevertheless the activity and the diversity of anthophilous insects of a plant vary with seasons (Faegri and Pijl, 1979; Tchuenguem Fohouo, 2005). These studies don't treat the impact of the pollination by these bees on the outputs of *X. americana* which are scarce and highly sold by human populations of its area of distribution and provide them with additional incomes via the sale (figure *2*). Besides, the apicultural value of a plant species can vary with the localities (Segeren et al., 1996).

The objective of this research is to contribute to the mastery of the relationship between *X. americana* and the honey bee for their optimal management.

The specific objectives are: (a) the registration of the *A. m. adansonii* activities on flowers of *X. americana*; (b) the evaluation of the apicultural value of this plant; (c) the assessment of the effects of foraging behaviour of *A. m. adansonii* on fruit yields of *X. americana*.

MATERIALS AND METHODS

Site and biological material

This study was conducted in savannah and galleries forest, situated between Tchabal-Bambi and Béka, villages of Ngaoundéré in the Adamawa region (Cameroon) from February 2006 to March 2007. This region belongs to the high altitude Guinean savannah agro-ecological zone (Tchuenguem Fohouo et al., 2007). The climate is 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 relative humidity is 70% (Tchuenguem Fohouo et al., 2007). The plants chosen for observation were located on an area of 3000 m in diameter centred on a cylindrical traditional hive whit to two openings inhabited by *A. m. adansonii* (Tchuenguem Fohouo et al., 2007). The hive is located at the latitude 7°31.557'N, the longitude 13°33.645'E and the altitude 1258 masl. The number of *A. m. adansonii* colonies located in this area was 73 in February 2006, 94 in March 2006, 47 in February 2007 and 52 in March 2007. Vegetation was represented by the native plants species of the savannah and the gallery forests. The number of plants of *X. americana* blooming was 118 in 2006 and 104 in 2007.

Methods

Determination of the reproduction system of *X. americana*

Before our works, no data on this parameter existed in the literature. In 2006, January 18th, 120 flower clusters of *X. americana* of which the flowers were to the bud stage was marked and two lots were constituted: - lot 1 made of 60 free flower clusters; - lot 2 made of 60 flower clusters protected from insects using gauze bags. In 2007,

February 20th, 200 flower clusters to the bud stage were marked and two lots were constituted: - lot 3 made of 100 flower clusters; - lot 4 made of 100 flower clusters protected from insects using gauze bags. Each season, ten days after the last flower faded, the number of fruits formed by each marked flower was counted and the capacity of trees to bear fruits was estimated. The report [number of fruits/number of flowers carried by flower clusters] was calculated. This fraction, which corresponds to the fruiting index I_{fr} (Tchuenguem Fohouo et al., 2001) and which was calculated for each of the flower clusters was use for the comparison of fruit yields of different lots.

The allogamy rate (*TC*) was calculated using the formula the *TC* formula = {[($I_{fr}X$ - $I^{fr}Y$) / $I_{fr}X$] x 100}, where $I_{fr}X$ and $I_{fr}Y$ are the mean fruiting indexes of free lot and in the protected lot respectively (Demarly, 1977). The autogamy rate (*TA*) was calculated by the formula *TA* = 100 - *TC*.

In 2006, two more lots were added: - lot 5: 10 flower clusters which the number of flower buds was reduced to four, emasculated and then bagged; - lot 6: 10 flower clusters which the number of flower buds was reduced to four, emasculated and then pollinated manually before being bagged. In 2007, two supplementary lots were added: - lot 7: 10 flower clusters which the number of flower buds was reduced to four, emasculated and then bagged; - lot 8: 10 flower clusters which the number of flower buds was reduced to four, emasculated and then pollinated manually before being bagged. For every season, 14 days after the emasculation, the number of fruits formed by each flower clusters was counted and the fruiting index was calculated. The comparison of fruit yields of these last four lots permitted to evaluate the impact of pollination on fruiting of the Olacaceae.

Study of the foraging activity of *A. m. adansonii* on the *X. americana* flowers

The observations were done on the 150 flower clusters of lots 1 and 3, from the opening of the first flower bud (3th February 2006 and 11th February 2007) to the fading of the last flower (19th February 2006 and 21st March 2007), during at least five days per week. This was done in six hourly periods: 6 - 7 h, 8 - 9 h, 10 - 11 h, 12 - 13 h, 14 - 15 h and 16 - 17 h. The identity of all insects that visited *X. americana* flowers was recorded. Specimens of all insect taxa were caught with an insect net on unlabelled flower clusters and conserved for subsequent taxonomy determination. All insects encountered on flowers were registered and the cumulated results expressed in number of visits to determine the relative frequency of *A. m. adansonii* in the anthophilous entomofauna of *X. americana* (Tchuenguem Fohouo, 2005).

The floral products (nectar or pollen) harvested by this bee during each floral visit were registered based on its foraging behaviour, during the same dates and same daily periods as for the counting of the insects.

The duration of floral visits, the foraging speed (number of flowers visited per minute (Jacob-Remacle, 1989)) and the abundances of workers per 1000 flowers (greatest number of individuals foraging simultaneously on 1000 opened flowers) were recorded at the same dates and during each of the following daily periods: 7 - 8 h, 9 - 10 h, 11 - 12 h, 13 - 14 h and 15 - 16 h.

Abundance per flower and per plant was recorded following the direct counting, during the same dates and daily periods as for the registration of the duration of visits. For the abundance per 1000 flowers (A_{1000}) some workers were counted on a known number of flowers. A_{1000} was then calculated by the formula: $A_{1000} = [(A_x / F_x)$ x 1000], where F_x and A_x are the number of opened flowers and the number of workers effectively counted on these flowers at time *x* (Tchuenguem Fohouo, 2005).

Evaluation of the total sugars concentration in the nectar of *X. americana*

This parameter was recorded using a portable refractometer (0 - 90° Brix) provided with a thermometer that gives the ambient temperature (WS - 9400). Since the nectar of *X. americana* is not directly accessible to the investigator, the *A. m. adansonii* workers in full activity of harvest nectar were captured on the flowers of this Olacaceae. Thus harvested individuals were anesthetized by introduction in a small bottle containing cotton moistened of chloroform. Then, by experienced pressures on the bee abdomen placed between the thumb and the forefinger of the experimenter, the nectar of the crop was expelled and its concentration in total sugars (in dry matter g/100g) measured. The collected values were corrected according to the ambient temperature. The data was recorded every day, from the 19th to the 25th February, 2006, then from the 17th to the 23th February, 2007; during the same daily periods as for the registration of the abundance of foragers. Ten to 30 values were registered for each daily period, according to the bee's rhythm of activity.

Evaluation of the apicultural value of *X. americana*

Like for other plants species (Guerriat, 1996; Tchuenguem Fohouo et al., 2004, 2007 and 2008), the apicultural value was evaluated using data on the flowering intensity of *X. americana* and the attractiveness of *A. m. adansonii* workers with respect to nectar and the pollen.

Assessment of the impact of the anthophilous insects on *X. americana* yields

The percentage of the fruiting index due to the influence of the foraging of the insects (Fi) was calculated by the formula: % Fi = {[(mx - my) / mx] x 100}, where mx and

Table 1. Average mean of fructification index (I_{fr}) of inflorescences in *Ximenia americana* lots.

Number of lots	Characteristics of lots	Number of flower clusters studied	Fructification indices[1]	
			Mean	Standard deviation
1	Unprotected flower clusters in 2006	60	0.13	0.13
2	Protected flower clusters in 2006	60	0.01	0.02
3	Unprotected flower clusters in 2007	100	0.08	0.11
4	Protected flowers cluster in 2007	100	0.01	0.04
5	Emasculated flowers and bagged in 2006	10	0.00	0.00
6	Emasculated, pollinated manually and bagged in 2006	10	0.05	0.11
7	Emasculated flowers and bagged in 2006	10	0.00	0.00
8	Emasculated, pollinated manually and bagged in 2006	10	0.08	0.12

[1] (I_{fr}) = number of fruits / number of flowers on inflorescence.

my are the mean fruiting indexes in lot x (flower clusters without protection) and lot y (flower clusters protected). The contribution of *A. m. adansonii* in the fruiting (Fa) was quantified by the formula: Fa = [Pi x (Va/100)], where Va is the percentage of *A. m. adansonii* visits on free flower clusters of lot 1 or lot 3.

Data analysis

Data were analysed using descriptive statistics, Student's t-test for the comparison of means of two samples, Correlation coefficient (r), Chi - Square (□2), and Microsoft Excel.

RESULTS

Reproduction system of X. americana

The mean fruiting indexes were 0.13 (s = 0.13; n = 60) for the lot 1; 0.01 (s = 0.02; n = 60) for the lot 2; 0.08 (s = 0.11; n = 100) for the lot 3 and 0.01 (s = 0.04; n = 100) for the lot 4 (table 1). Thus for the 2006, TC = 95.55% and TA = 4.45%; for 2007, TC = 82.70% and TA = 17.30%. For the two accumulated years, TC = 89.13% and TA = 10.87%. Consequently *X. americana* has a mixed reproduction regime allogamous - autogamous, with the predominance of the allogamy.

The means fruiting indexes were 0.00 (s = 0; n = 10) for the lot 5; 0.05 (s = 0.11; n = 10) for the lot 6; 0.00 (s = 0; n = 10) for the lot 7 and 0.08 (s = 0.12; n = 10) for the lot 8. Thus pollination is indispensable for the fruiting of X. americana.

Activity of *A. m. adansonii* on *X. americana* flowers

Seasonal and daily frequencies of visits

During 12 and 14 days of the flowering periods in 2006 and 2007, 6017 and 5088 visits of 32 and 29 insects' species were counted on 60 and 100 free flower clusters of *X. americana* respectively. A. m. adansonii, with 5693 and 3570 visits on 12 and 14 days, that is 94.62% and 71.80% of the total number of visits counted respectively in 2006 and 2007, was the more frequently observed insect whatever the year of survey. The difference between these two percentages is highly significant (c2 = 1191.15; P < 0.001). The honey bee workers bee were active on flowers of the Olacaceae all day long, with two peaks of visits, the highest situated between 8 h and 9 h and the lowest situated between 14 h and 15 h (table 2).

A positive and not significant correlation exists between the number of *A. m. adansonii* visits and the ambient temperature (r = + 0.26; ddl = 4; P> 0.05 for 2006 and r = + 0.57; ddl = 4; P> 0.05 for 2007). A negative and not significant correlation exist between the number of visits of *A. m. adansonii* visits and the ambient relative humidity (r = - 0.48; ddl = 4; P> 0.05 for 2006 and r = - 0.40; ddl = 4; P> 0.05 for 2007).

Floral product harvested

During each of the two periods of flowering of X. americana, the workers of *A. m. adansonii* harvested regularly and intensely the nectar and pollen (figure 3). The harvest of the nectar is more frequent than the pollen: in 2006, the number of visits dedicated to the harvest was 4666 (81.96%) for the nectar; 212 (3.72%) for the pollen and 815 (14.32%) for the two floral products (table 3). In 2007, the number of visits dedicated to the harvest was 2801 (78.46%) for the nectar; 267 (7.48%) for the pollen and 502 (14.06%) for the two floral products (table 3). On the 9263 visits recorded during the two seasons of observation, the number of visits dedicated to the harvest was 7467 (80.61%) for the nectar, 479 (5.17%) for the pollen and 1317 (14.22%) for the two floral products (table 3).

Table 2. Daily distribution of *Apis mellifera adansonii* visits on *Ximenia americana* flower clusters according to the years and consistent on 12 days in 2006 and 14 days in 2007.

Years	Visit	Time frames						
		6-7 h	8-9 h	10-11 h	12-13 h	14-15 h	16-17 h	Total
2006	Number	283	2165	1369	734	868	274	5693
	%	4.97	38.03	24.05	12.89	15.25	4.81	100
2007	Number	167	1021	920	584	755	123	3570
	%	4.68	28.60	25.77	16.36	21.15	3.45	100

Figure 3. Worker of *Apis mellifera adansonii* having a basket of pollen and harvesting the nectar in *Ximenia americana* a flower.

Table 3. Seasonal distribution of *Apis mellifera adansonii* visits on *Ximenia americana* flower clusters according to the floral product harvested and consistent on 12 days in 2006 and 14 days in 2007.

Years	Visit	floral product harvested			
		Nectar	Pollen	Nectar and pollen	Total
2006	Number	4666	212	815	5693
	%	81.96	3.72	14.32	100
2007	Number	2801	267	502	3570
	%	78.46	7.48	14.06	100
2006 &	Number	1467	479	1317	9263
2007	**%**	80.61	5.17	14.22	100

Rhythm of the visits according to the flowering stages

Visits were most numerous when the number of open flowers was highest. The correlation between the number of flowers in full bloom and the number of visits of *A. m. adansonii* is positive and highly significant in 2006 ($r = + 0.71$; ddl = 10, $P < 0.01$) as well as in 2007 ($r = + 0.87$; ddl = 12; $P < 0.01$).

Density of the foragers

In 2006, the greatest number of *A. m. adansonii* workers foraging at the same time was one per flower (n = 100; s = 0; maximum: 1), 513 per 1000 flowers (n = 111; s = 159; maximum: 850) and 608 per plant (n = 100; s = 342; maximum: 1410). In 2007, the corresponding figures were one per flower (n = 112; s = 0; maximum: 1), 447 per 1000 flowers (n = 112; s = 199; maximum: 833) and 599 per plant (n = 112; s = 356; maximum =1490). The difference between the two mean abundances per 1000 flowers is not significant ($t = 1.30$; $P \square 0.05$).

Duration of the visits per flower

In 2006, the mean duration of a visit for nectar harvest by *A. m. adansonii* on a flower of *X. americana* was 5.58 sec (n = 300; s = 3.74; maximum: 36 sec), and 5.80 sec (n = 312; s = 3.96; maximum: 37 sec) in 2007 (table 4). The difference between these two means is not significant (t =

Table 4: *A. m. adansonii* visits on the *X. americana* flowers according to the floral product harvested.

Year	Harvested aliment	n	Visiting time per flower (sec)			
			m	s	mini	maxi
2000	Nectar	300	5.58	3.74	1	36
	Pollen	121	3.36	2.03	1	9
2001	Nectar	312	5.80	3.96	1	37
	Pollen	156	4.06	2.40	1	13

Table 5. Distribution of the concentration in total sugars of the nectar (CTS) of *Ximenia americana* during the day according to the years and consistent on 5 days.

Years	Parameters recorded	Time frames					
		6-7 h	8-9 h	10-11 h	12-13 h	14-15 h	16-17 h
2006	CTS (%)	40.71	40.59	42.92	45.10	42.10	43.66
	Temperature (°C)	25.20	27.80	28.27	30.73	29.60	26.80
	Hygrometry (%)	23.53	20.07	19.09	18.27	20.67	21.30
2007	CTS (%)	37.61	38.71	39.03	41.94	38.92	40.64
	Temperature (°C)	24.71	29.04	29.45	29.31	29.33	29.10
	Hygrometry (%)	24.43	20.56	21.35	21.13	20.60	20.10

The temperature and the hygrometry are the means of five observations. Data analysis for 2006: (a) CTS and T: $r = 0.64$; $ddl = 4$; (b) CTS and H: $r = -0.57$; $ddl = 4$. Data analysis for 2007: (a) CTS and T: $r = 0.59$; $ddl = 4$; (b) TNS and H: $r = -0.55$; $ddl = 4$. $P > 0.05$ for all the correlations.

0.03; P> 0.05).

In 2006, the mean duration of a visit for pollen harvest by *A. m. adansonii* on a flower of *X. americana* was 3.36 sec (n = 121; s = 2.03; maximum: 9sec) and 4.06 sec (n = 156; s = 2.40; maximum: 13sec) in 2007 (table 4). The difference between these two means is significant (t = 2.63; P <0.05).

The difference between the means duration of a visit for pollen and nectar harvest in 2006 was highly significant (t = 7.82; P <0.001). The difference between the means duration of a visit for pollen and nectar harvest in 2007 was highly significant (t = 5.89; p <0.001).

Foraging speed

On a flower cluster of X. americana, a worker of *A. m. adansonii* visited between 4 and 29 flowers/min in 2006, and between 4 and 30 flowers/min in 2007. The mean foraging speed was 10.46 flowers/min (n = 180; s = 3.43) in 2006 and 10.74 flowers/min (n =180; s = 3.77) in 2007. The difference between these averages was highly significant (t = 0.74; P □0.001). For the two accumulated years, the mean foraging speed was 10.60 flowers / min.

Influence of the neighbouring flora

During the period of observation, flowers of many other plant species situated near *X. americana* were also visited for the nectar (ne) and / or the pollen (po) by *A. m. adansonii* workers. The most representative of these plants were: *S. g. var. guineense* (Willd.) DC.1828 (Myrtaceae) (ne + po), *Combretum nigricans* Lep. ex. Guill. and Perr. 1932 (Combretaceae) (ne+po), *Terminalia macroptera* Guill. and Perr. 1911 (Combretaceae) (ne+po), *Vitex doniana* Sweet 1827 (Verbenaceae) (ne), *Vitex madiensis* Oliv. 1862 (Verbenaceae) (ne), *Hymenocardia acida* Tul. 1899 (Hymenocardiaceae) (po). During one foraging trip, an individual bee foraging on *X. americana* was not observed moving to the neighbouring plant and vice-versa.

Sugars content in Ximenia americana nectar

The mean concentration in total sugars of the *X. americana* was 42.52% (n = 100; s = 5.04) in 2006 and 39.36% (n = 100; s = 5.07) in 2007. The difference between these averages is highly significant (t = 4.42; P< 0.05).

The influence of the temperature and the hygrometry of air on the sugars concentration of *X. americana* nectar was not significant (table 5).

Apicultural value of X. americana

During the two periods of flowering of X. americana, a well elaborated activity of *A. m. adansonii* workers was registered on flowers. In particular, there were high daily

and seasonal frequency of visits, high density of the workers per plant, very good nectar harvest, good pollen collection and fidelity of the workers to the flowers. Besides, every plant of *X. americana* tree can produce 1500 to more than 5000 flower clusters, the mean number of flowers carried by a flower cluster being 24 (n = 320; s = 14). In addition, according to our investigations, during one to two days (m = 2; s = 0.36; n = 50), each flower of *X. americana* produces nectar that is rich in sugars (up to 40.94%) and its pollen is easy for *A. m. adansonii* to harvest. These data point out the strong attractiveness of *X. americana* nectar and the good attractiveness of its pollen to A. m. adansonii. They allow *X. americana* to be classified in the category of very highly nectariferous and highly polliniferous bee plants.

Effect of *A. m. adansonii* on *X. americana* pollination and the fruit yields

During the nectar and the pollen harvest on flowers, *A. m. adansonii* workers were always in contact with the stigma and the anthers. Therefore, they greatly increase the pollination possibilities of X. americana.

The comparison of the mean fruiting indexes (table 1) showed that observed differences were highly significant between the lots 1 and 2 (t = 6.45; P <0.001), non significant between lots 2 and 4 (t = 0.00; P> 0.05), highly significant between lots 3 and 4 (t = 5.98; P <0.001) and significant between the lots 1 and 3 (t = 2.33; P <0.05). Consequently:

- in 2006, fruiting of flower clusters in free pollination (lot 1) were high than that of bagged flower clusters (lot 2);
- in 2007, the inflorescences output in free pollination (lot 3) were raised more than the inflorescences that were protected (lot 4);
- Trees were more productive in 2006 than in 2007.

In 2006, the percentage of the fruiting index due to the action of insects (Fi for 2006) was 92.31%. In 2007, this rate (Fi for 2007) was 82.70%. For the two years of survey, the percentage of the fructification index due attributable to the influence of the insects was: Fi = {[(Fi for 2006) + (Fi for 2007)] / 2} = 87.51% and the contribution of *A. m. adansonii* in the fructification of *X. americana* was 73.36%. The influence of the African honey bee on the fruiting of *X. americana* was therefore positive. Besides, a positive and highly significant correlation coefficient was found between the number of *A. m. adansonii* visits on *X. americana* flower clusters and the fruiting index of the Olacaceae, in 2006 (r = + 0.51; ddl = 98; P <0.001) as well as in 2007 (r = + 0.49; ddl = 98; P <0.001).

The contribution of *A. m. adansonii* in the fruiting of the Olacaceae was 87.34% in 2006, 59.38% in 2007 and 73.36% for the two accumulated years of survey. The difference between the contribution of the African honey bee in the fructification of *X. americana* in 2006 and 2007 is highly statistically significant (χ^2 = 18.91; P <0.001).

The African honey bee is therefore the main insect that positively influences the fruiting of X. americana. Besides, a positive and highly significant correlation exists between the number of visits of *A. m. adansonii* on the flower clusters and the index of fruiting, in 2006 (r = + 0.51; n = 60; P <0.001) as well as in 2007 (r = + 0.49; n = 100; P <0.001).

DISCUSSION

Activity of *A. m. adansonii* on the flowers of *X. americana* and apicultural value of the Olacaceae

The nectar harvest on *X. americana* by *A. m. adansonii* was also registered in the West Africa (Villières, 1987), in Dang (Tchuenguem Fohouo et al., 1997) and in Ethiopia (Fichtl and Adi, 1994). In this last country, the pollen harvest on this Olacaceae by honey bees has been mentioned too (Fichtl and Adi, 1994). The high nectar and pollen harvest could mainly be explained by the carbohydrate and protein needs of colonies of which are descended workers.

Results showed that there are two peaks of activity of *A. m. adansonii* on flowers X. americana. The first peak appears in the morning (8-9h each year) and the second in the afternoon (14-15h in 2006 and 12-13h in 2007). Peaks of visits could correspond to the periods of high availability of nectar and pollen in flowers of X. americana. The high abundance of workers per 1000 flowers and the positive and significant correlation between the number of *A. m. adansonii* visits and the number of *X. americana* flowers bloomed reveals the high attraction exerted by the nectar and the pollen of this Olacaceae on the African honey bee. The attractiveness of the *X. americana* nectar could be explained by its high concentration in total sugars (mean 40.94%), considering the range of 15 to 75% for several plant species (Proctor et al., 1996). It is known that workers of *A. mellifera* could not allow its colony to record a clean gain in energy if the sugars concentration of the nectar harvested is lower to 20% (Philippe, 1991) or 30% ((Proctor et al., 1996). Considering these limits, workers of *A. m. adansonii* can certainly allow their colony to win a lot of energy when they harvest the nectar of X. americana. The high density of workers per 1000 flowers, the positive and significant correlation between the number of *A. m. adansonii* visits and the number of *X. americana* flowers is due to the natural faculty of honey bees to recruit a high number of workers to exploit an interesting food source (Frisch, 1969; Louveaux, 1984; Schneider & Hall, 1997). The lower abundance per flower of *X. americana* (one honey bee per flower) could be explained by the weak diameter of the corollary tube: 7.14 mms (s = 0.67; n = 50).

The longer duration of visit observed for the harvest of

nectar than the harvest of pollen could be explained by the accessibility of each of these substances. The pollen produced by anthers situated over the stamens is easily accessible to the bee; when nectar is located in the corollary tube between the basis of the style and stamens and consequently hardly accessible. The bee foragers had a high affinity with respect to *X. americana* compared to the neighbouring plant species, indicating their faithfulness to this Olacaceae, a phenomenon known as «floral constancy» (Louveaux, 1984; Backhaus, 1993; Basualdo et al., 2000; Tchuenguem Fohouo et al., 2008). This flower constancy could be partially due to the high sugar content of the nectar. Indeed, it is known that the workers of *A. mellifera* are generally constant on a plant species when the concentration in sugars of its nectar is more than 15% (Philippe, 1991). The fidelity of this bee has been demonstrated on flowers of several other plants among which *Helianthus annuus* (Basualdo et al., 2000, Tchuenguem Fohouos et al., 2009b), *Persea americana* (Valdeyron, 1984), *Callistemon rigidus* (Tchuenguem Fohouo et al., 2004), *Prunus dulcis* (Danka et al., 2006) and *Vigna unguiculata* (Tchuenguem Fohouo et al., 2009a).

The activity of *A. m. adansonii* on *X. americana* flowers was more intense in 2006 that in 2007. The highest activity recorded in 2006 could be explained by the fact that the number of *A. m. adansonii* colonies in the station of survey was high for a smaller number of plants of *X. americana* in bloom.

The activity of *A. m. adansonii* on flowers of *X. americana* was more intense in 2006 than in 2007. The strongest activity recorded in 2006 could be justified by the more elevated number of *A. m. adansonii* than 2007 during the period of research.

As a very highly nectariferous and highly polliniferous apicultural plant, *X. americana* could be cultivated and protected to increase honey production and to strengthen *A. m. adansonii* the colonies.

Impact of the *A. m. adansonii* activity on the pollination and output of *X. americana*

During the collection of nectar and pollen on each flower, *A. m. adansonii* workers regularly come into contact with the stigma and anthers. They could thus enhance auto-pollination which has been demonstrated in the present study. *Apis mellifera adansonii* workers could provide allogamous pollination through carrying of pollen with their furs, legs and mouth accessories, which is deposited on another flower belonging to the same plant (geitogamy) or to a different plant of the same species (xenogamy).

The workers of *A. m. adansonii* transport the pollen from one flower to another notably with their fur, their paws and their oral pieces. Consequently, they can transport pollen from a flower of a plant of *X. americana* on the stigma of another flower of the same plant (geitogamy) or another plant (xenogamy).

The intervention of *A. m. adansonii* workers on the pollination of *X. americana* is especially probable since their density per 1000 flowers and their foraging speed are high.

CONCLUSION

This study reveals that, *X. americana* is a very highly nectariferous apicultural plant that benefits from the pollination by insects among which *A. m. adansonii* is the most important.

The comparison of the fruits set of unprotected flower clusters with that of floral clusters protected from insects in the gallery forests and savannah of Tchabal-Bambi and Béka underscore a significant increase of 73,36% of the fruiting index due to A. m. adansonii.

Thus, *X. americana* should be planted and protected to increase honey production and to strengthen honey bee colonies.

Installation of *A. m. adansonii* colonies near the population of *X. americana* is recommended to increase fruits production.

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