

Foraging and pollination behaviour of the African honey bee (*Apis mellifera adansonii*) on *Callistemon rigidus* flowers at Ngaoundere (Cameroon)

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ABSTRACT

To determine the apicultural value of *Callistemon rigidus* R. Br. (Myrtaceae) and to evaluate *Apis mellifera adansonii* Latreille (Hymenoptera : Apidae) activity on fruit and grain yields of the plant species, bee foraging and pollinating activities were observed in the area of Ngaoundere (Cameroon). In the University of Ngaoundere Campus, two lots were determined by the marking of 210 inflorescences differentiated according to the presence or absence of the inflorescence protection regarding insect visits. The honey bee's seasonal rhythm of activity, its foraging behaviour on flowers, the fructification index and the number of grain per fruit were evaluated. Results showed that *A. m. adansonii* foraged on *C. rigidus* all day and throughout the whole blooming period of each tree. Worker bees intensively harvested nectar whereas pollen collection was low. The mean greatest number of workers foraging at the same time was 522 per 1000 flowers. The mean foraging speed was 13.05 flowers/min. Data obtained allow the classification of *C. rigidus* as a highly nectariferous bee plant. The fructification index and the number of seeds per fruit of unprotected inflorescences were significantly higher than those of inflorescences protected from insects. *A. m. adansonii* contributed 71.29% and 30.04% to the fruit and seed yields respectively, through the pollinating action of workers. The installation of *A. m. adansonii* colonies near the populations of *C. rigidus* should be recommended to increase honey, fruit and seed production.

Key words: *Apis mellifera adansonii*, *Callistemon rigidus*, bee plant, foraging, pollination

RESUME

Afin de déterminer la valeur apicole de *Callistemon rigidus* R. Br. (Myrtaceae) et d'évaluer l'impact d'*Apis mellifera adansonii* Latreille (Hymenoptera : Apidae) sur les rendements en fruits et en grains, les activités de butinage et de pollinisation des fleurs par l'abeille ont été observées dans la région de Ngaoundéré au Cameroun. Dans le campus de l'Université de Ngaoundéré, deux lots ont été déterminés à partir du marquage de 210 inflorescences divisées en deux lots selon la présence ou l'absence de protection de ces inflorescences vis-à-vis des insectes. Le rythme saisonnier d'activité des insectes, le comportement de butinage de l'abeille domestique sur les fleurs, l'indice de fructification et le nombre de grains par fruit des inflorescences marquées ont été évalués. Les résultats ont montré que *A. m. adansonii* butinait *C. rigidus* toute la journée et pendant toute la période de floraison de chaque arbre. Sur les fleurs les ouvrières récoltaient le pollen et le nectar. La récolte du nectar était intense et régulière, alors que le prélèvement du pollen était faible. Le plus grand nombre moyen d'ouvrières simultanément en activité sur 1000 fleurs était de 522. La vitesse moyenne de butinage était de 13,05 fleurs/min. Les données obtenues indiquent que *C. rigidus* est une plante apicole fortement nectarifère et faiblement pollinifère. L'indice de fructification et le nombre de grains par fruit des inflorescences non protégées ont été significativement supérieurs à ceux des inflorescences protégées des insectes. La contribution d'*A. m. adansonii* dans les rendements en fruits et en grains ont été de 71,29% et de 30,04% respectivement. Cette amélioration des rendements était due à l'action des ouvrières sur la pollinisation. L'installation des colonies d'*A. m. adansonii* à proximité des populations de *C. rigidus* est recommandée, pour l'augmentation de la production du miel, des fruits et des grains.

Mots clés : *Apis mellifera adansonii*, *Callistemon rigidus*, plante apicole, butinage, pollination.

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INTRODUCTION

Apis mellifera is the bee species that produces the highest quantity of honey in the world. This hymenopteran species lives in the wild or is kept by man. All the bees of each hive constitute a colony. The basic foods of each colony are nectar and pollen (Louveaux, 1984 ; Weidenmüller & Tautz, 2002). Nectar is transformed into honey. Pollen and honey are stored in the hive for future use. These substances have been exploited by humans for millions of years (Crane, 1999). Honey and pollen production depends mainly on the abundance of some plant species; thus sustainable beekeeping in a given region needs a detailed knowledge of the bee plants which grow in the environment of the hives (Villières, 1987; Bakenga & Mapatamo, 1994 ; Riedacker, 1996 ; Bakenga *et al.*, 2000).

The genus *Callistemon* is native to Australia. It is now established in many regions of the world. In Cameroon, *C. rigidus* is planted for ornamental purposes. It is an evergreen tree. Its flowers are red, hermaphrodite, and produce both nectar and pollen, which attract insects (Tchuenguem Fohouo *et al.*, 1997). Each flower opens in the morning and remains open until it fades three to seven days later. The relationships between *C. rigidus* and anthophilous insects such as honey bees have not been well studied. Preliminary studies by Tchuenguem Fohouo *et al.* (1997) have shown that at Ngaoundere, *A. m. adansonii* visits *C. rigidus* flowers and harvests both nectar and pollen. This work was done during the peak of the rainy season, during which honey bees do not produce great quantities of honey in Cameroon. It did not report on the impact of the bees on the yields of the plant species.

In tropical Africa, beekeeping needs to be developed (Hepburn & Radloff, 1998). The demand for hive products (mainly honey and wax) is growing and the knowledge of bee - plants relationships is still weak. Furthermore, in Cameroon, and particularly in the Adamaoua region, deforestation is in progress (INADES, 2000), demand for *C. rigidus* plants is high and their seed yields are low. In addition, it is well known that honey bees usually increase the fruit and seed yields of many plants species, by pollinating the flowers during foraging (e.g: Free, 1970 ; Mc Gregor, 1976 ; Faegri & Pijl, 1979 ; Pesson & Louveaux, 1984 ; Philippe, 1991; Proctor *et al.*, 1996 ; Messi & Tchuenguem Fohouo, 1998 ; Vaissière & Pierre, 1998 ; Crane, 1999 ; Michener, 2000 ; Tchuenguem Fohouo *et al.*, 2001). The main objective of this research undertaken in Ngaoundere during the dry season and at the beginning of the rainy season (the period of the highest honey production by honey bees in this region) of

1999-2000 was to contribute to the knowledge of the relationships between *C. rigidus* and its anthophilous insects, for an efficient management of this plant species. Specific objectives were the registration of the activity of *A. m. adansonii* on *C. rigidus* inflorescences, the estimation of the apicultural value of this Myrtaceae, and the evaluation of the impact of *A. m. adansonii* on the pollination and on the fruit and seed yields of *C. rigidus*.

MATERIALS AND METHODS

1- Site and biological materials

The studies took place from December 1999 to March 2000 (dry season) and in April at the University of Ngaoundere Campus (latitude: 07°25'N; longitude: 13°32'E; mean altitude: 1116 m). During the period of study, flowers of many other plant species growing near *C. rigidus* were observed to attract *A. m. adansonii*. Among these plants species were: *Eucalyptus camaldulensis*, *Persea americana*, *Tridax procumbens* and *Voacanga africana*. Plants chosen for observations were located on an area of 1.5 km in diameter, centred on an apiary of three experimental *A. m. adansonii* top-bar hives. There were a total of 22, 25, 24 and 24 honey bee colonies located in this area, in December, January, February and March respectively. At the study site, there were 487 *C. rigidus* trees.

2- Methods

On 27 December 1999, 15 *C. rigidus* plants which had started to bloom were labelled on the University campus. On these plants, 210 inflorescences were labelled, from 29 to 31 December 1999. Half of these inflorescences were left to exposed pollination (lot 1), whereas the other half were protected from insects using gauze bags (25 x 25 cm) (lot 2). The evaluation of the rhythm of activity of the insects was done from 1st to 22 January 2000, by observation of the inflorescences every three or four days, once for each of the following daily periods: 6 – 7 h, 8 – 9 h, 10 – 11 h, 12 – 13 h, 14 – 15 h, and 16 – 17 h. The number of *A. m. adansonii* visits and those of the other insect species were thus counted by direct observation, at a distance of one to two metres from the flowers, six times per day, on each labelled inflorescences of lot 1. In the morning of each sampling day, the number of opened flowers carried by each labelled inflorescence was counted. During the same days, the duration of individual flower visits was recorded (using a stopwatch) at least three times, for each of the following daily periods: 7 – 8 h, 9 – 10 h, 11 – 12 h, 13 – 14 h, 15 – 16 h, and 17 - 18 h.

On the profusely flowering trees, the density (greatest number of individuals foraging simultaneously) of workers per flower and per 1000 flowers were registered : honey bee workers were recorded on a known number of opened flowers, from 5 to 15 January, with one day interval between two observation days, three times for each of the following daily periods: 8 – 10 h , 12 – 14 h, and 16 – 18 h. The density per flower was then noted; the number of foragers per 1000 flowers (A_{1000}) was calculated by the formula $A_{1000} = [(A_x / F_x) \times 1000]$, where F_x and A_x are the number of flowers and the number of workers effectively counted on a given tree at time x. The floral products (nectar or pollen) harvested during each floral visit and the foraging speed (number of flowers visited per minute) were noted.

The sugar content of *C. rigidus* nectar was estimated on 30 inflorescences carried by 20 trees. On 8 January, these inflorescences were bagged to exclude flower visitors. Then from 10 to 15 January, each day, between 6 and 16 h, the bags were removed from the inflorescences and the nectar harvested using a syringe (1 ml). The sugar content of the nectar (g per 100g dry matter) was directly measured (at least three times for each daily sampling period, if the quantity was measurable) with a hand - held refractometer (0 - 90° Brix).

During each daily period of observations, the temperature and the humidity of the station were registered using a portable thermohygrometer. The results of all these investigations allowed the apicultural value of *C. rigidus* to be estimated.

Flower constancy was assessed by direct observation of the relationships between honey bee workers foraging on *C. rigidus* and other plant species in flower near the plants under observation. To measure the ability of *A. m. adansonii* to act directly as a pollinator of *C. rigidus* flowers, visits during which the honey bee came into contact with the stigma and / or the anthers were counted while the duration of the flower visits were recorded.

The flower and fruit counts on each labelled inflorescence permitted the evaluation of the ability of the trees to bear fruits, using the fraction [number of fruits/number of flowers carried by the inflorescence]. This fraction, which corresponds to the fructification index (I_{fr}) (Tchuenguem Fohouo *et al.*, 2001) and which was calculated for each inflorescence, was used for the comparison of lots 1 and 2. For the fructification index, 84 and 89 inflorescences were studied, in lots 1 and 2 respectively. The percentage of the fructification index ($\% I_{fr}$) due to the influence of for-

aging insects was calculated using the formula ($\% I_{fr}$) = $\{[(m_1 - m_2) / m_1] \times 100\}$, where m_1 and m_2 are the mean fructification indices in lot 1 (exposed inflorescences) and lot 2 (bagged inflorescences) (Tchuenguem Fohouo *et al.*, 2001). The contribution of *A. m. adansonii* to fructification was then quantified by the formula $\{(\% I_{fr}) \times [V_a / 100]\}$, where V_a is the percentage of *A. m. adansonii* visits on flower clusters of lot 1, if the number of visits by the insect species that showed pollinating behaviour (notably, no damage to flowers, frequent contact with anthers and stigma, aptitude to fly from flower to flower) is considered.

In March 2000, when the fruits were ripe, 100 fruits were harvested in each lot and the number of seeds per fruit were counted. The mean number of seeds per fruit was then calculated for each lot. The impact of *A. m. adansonii* on seed yields was evaluated using the same method as for the fructification index.

Data were analysed using descriptive statistics, correlation coefficient (r) for the evaluation of the association between two variables, Student's t -test for the comparison of means of two samples and Microsoft Excel. Values are given as mean \pm standard deviation (SD).

RESULTS

1- *A. m. adansonii* activity on *C. rigidus* flowers

1.1- Dry seasonal frequency of visits

In 12 days of the flowering period of January 2000, 6016 visits of 16 insect species were counted on 105 *C. rigidus* inflorescences. *A. m. adansonii*, with 1673 visits distributed on 12 days, that is 27.81% of the total number of visits counted, was the second most frequently observed insect species.

Of all the insect visits, 1760 were made by insect species that behave as effective pollinators of *C. rigidus* flowers. Within this category of anthophilous insects, *A. m. adansonii* visited most frequently, with 95.06 % of the total number of visits.

1.2- Floral products harvested

On *C. rigidus* flowers, *A. m. adansonii* workers collected both nectar and pollen. Nectar collection was regular and intense whereas pollen collection was low: for 1484 visits counted on flowers, 1377 (92.78%) were for nectar collection and 107 (7.21%) for pollen collection. Nectar collection occurred all day long whereas pollen collection occurred only in the morning.

Some *A. m. adansonii* workers scarcely collected both nectar and pollen during a single flower visit. But none of such workers were observed during the visit count on labelled inflorescences.

Table I. Dry seasonal distribution of the number of *C. rigidus* opened flowers (f) and the total number of *A. m. adansonii* visits (v).

D	01 j	02 j	05 j	06 j	09 j	10 j	13 j	14 j	17 j	18 j	21 j	22 j
f	550	809	2049	2196	2308	2016	1924	1901	1884	1752	876	292
v	68	105	110	567	279	195	107	69	15	118	33	7

D : day and month ; j : January 2000 ; statistical analysis : $r = + 0.54$ ($df = 10$; $P < 0.05$)

Table II. Daily distributions of *A. m. adansonii* visits on 108 *C. rigidus* inflorescences over 12 days, mean temperature (T) and mean humidity (H) of the study site.

	Daily periods (hours)						Total
	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15	16 - 17	
Number of visits	0	291	412	334	342	294	1673
% visits	0	17.39	24.63	19.96	20.44	17.57	100
T (°C)	11	20	25	29	30	28	-
H (%)	71	50	32	20	20	22	-

for temperature and humidity, each figure represents the mean of 36 observations.

Statistical analysis: (a) Number of visits and T : $r = + 0.85$ ($df = 4$; $P < 0.05$)

(b) Number of visits and H : $r = - 0.82$ ($df : 4$; $P < 0.05$)

1.3- Rhythm of visits according to the flowering stages

Visits were most numerous on an inflorescence when the number of opened flowers that it carried was highest (Table I). Furthermore, a positive and significant correlation was found between the number of *C. rigidus* open flowers and the number of *A. m. adansonii* visits ($r = + 0.54$; $df = 10$; $P < 0.05$).

1.4- Daily rhythm of visits

Table II indicates the daily distribution of the number of *A. m. adansonii* visits on *C. rigidus* inflorescences. From this table, it appears that: i) honey bees foraged on *C.*

rigidus flowers all day long; ii) the activity was highest between 10 h and 11 h and zero between 6 h and 7 h.

1.5- Density of foragers and sugar content of the nectar

The greatest number of *A. m. adansonii* workers foraging at the same time was 2 per flower and 522 ± 111 per 1000 flowers ($n = 54$). The concentration in total sugars (g/100g dry matter) of *C. rigidus* nectar varied from 17.2% to 61.80%, with a mean of $46.19 \pm 13.12\%$ ($n = 229$). It increased daily (Table III) and it changed from hour to hour through the day. It was highest between 15 and 16 h and lowest between 10 h and 11 h (Table IV).

Table III. Dry seasonal distribution of the concentrations in total sugars (MCS) (g/100g dry matter) of *C. rigidus* nectar.

Concentration in sugar	Days (January 2000)					
	10	11	12	13	14	15
MCS	32.35	39.02	45.48	48.34	53.45	55.46
SD	12.80	9.09	3.36	1.87	2.54	0.52
n	64	29	17	15	11	3

Table IV. Daily distributions of the mean concentrations in total sugars (MCS) (g/100g dry matter) of *C. rigidus* nectar in January 2000.

	Daily periods (h)								
	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	15-16
MCS	52.06	47.41	55.32	51.96	32.48	54.93	49.49	50.71	61.15
SD	0.09	0.03	5.4	1.18	14.93	2.73	6.91	3.98	0.22
n	3	12	16	5	58	18	23	29	20

1.6- Duration of visits per flower

The duration of a bee's visit on a *C. rigidus* flower varied from 1 sec to 101 sec, the mean being 3.40 ± 5.16 sec ($n = 1484$). This duration varied according to the type of food harvested: i) for the nectar, the mean duration was 3.51 ± 5.27 sec ($n = 1376$), the maximum being 1 min 41 sec; ii) for the pollen, the mean duration was 1.66 ± 0.79 sec ($n = 108$), the maximum being 4 sec. The difference between these means is highly significant ($t = 11.48$; $P < 0.001$). Thus *A. m. adansonii* spent more time on a flower for nectar collection than for pollen collection.

1.7- Foraging speed

On *C. rigidus*, worker bees visited between 3 and 26 flowers per min. The mean foraging speed was 13.05 ± 4.46 flowers per min ($n = 517$).

1.8- Influence of neighbouring flora

During the observation period, flowers of many other plant species growing near *C. rigidus* were visited by *A. m. adansonii* workers, for nectar (ne) and/or for pollen (po). Among these plants were: *E. camaldulensis* (ne + po), *P. americana* (ne + po), *T. procumbens* (ne + po) and *V. africana* (ne). During one foraging trip, an individual bee foraging on *C. rigidus* scarcely visited another plant species. In effect for more than 72 hours of observation time distributed over 12 days, *A. m. adansonii* nectar foragers were seen only three times (in two days) moving from *C. rigidus* to *P. americana* flowers before coming back to *C. rigidus*.

2- Apicultural value of *C. rigidus*

During the whole of the blooming period of *C. rigidus*, we noted a well elaborated activity of *A. m. adansonii* workers on the flowers. In particular, there were high daily and dry seasonal frequencies of visits, high densities of workers per 1000 flowers, high nectar collection and low pollen collection. Furthermore, our field observations revealed that in the dry season (main pe-

riod of honey flow), each *C. rigidus* tree can produce more than 30 000 flowers and that each *C. rigidus* flower has 24 to 41 stamens (mean = 32.9; SD = 0.49; $n = 50$) which produce small quantity of pollen and this pollen is easily accessible to bees. In addition, according to our investigations, during three to seven days, each *C. rigidus* flower (mean volume of the corolla tube: 0.02 ± 0.009 ml; $n = 50$) produces nectar, which is abundant (up to 0.23 ml during three to five days), rich in sugar (up to 61.8%) and easy for honey bees to harvest.

These data point to the strong attractiveness of *C. rigidus* nectar and to the low attractiveness of its pollen to *A. m. adansonii*. They allow *C. rigidus* to be classified in the category of highly nectariferous and slightly polliniferous bee plants.

3- Impact of *A. mellifera* activity on pollination and on the fruit and seed yields of *C. rigidus*

On the majority of the visited flowers, foragers contacted anthers and carried pollen. With this pollen, they flew frequently from flower to flower. On 1484 flower visits, worker bees came into contact with the stigma during 341 visits, that is 22.97%. Thus *A. m. adansonii* increased the pollination of *C. rigidus* flowers.

The mean fructification index was 0.96 ± 0.08 for lot 1 and 0.24 ± 0.26 for lot 2. A comparison of these means showed that the observed difference between lots 1 and 2 is significant ($t = 7.89$; $P < 0.001$). Consequently, the fruit set of exposed inflorescences (lot 1) was higher than that of the protected inflorescences (lot 2). The percentage of the fructification index due to the activity of insects was 75% and the contribution of *A. m. adansonii* on the fructification of *C. rigidus* was 71.29%.

The mean number of seeds per fruit was 212 ± 58 for lot 1 and 145 ± 62 for lot 2. A comparison of these means has shown that the observed difference between lots 1 and 2 is highly significant ($t = 9.5$; $P < 0.001$). Consequently, the seed set of exposed inflores-

cences (lot 1) was higher than that of the protected inflorescences (lot 2). The percentage of the seed production due to insect activity was 38.16% and the contribution of *A. m. adansonii* to the seed yield of *C. rigidus* was 30.04%. Thus the influence of *A. m. adansonii* on fruit and seed yields is positive. The yield increase was due to the activity of *A. m. adansonii* workers in the pollination of *C. rigidus*.

DISCUSSION

1- *A. m. adansonii* activity on *C. rigidus* flowers and apicultural value of the plant species

Our study shows a high nectar collection and a low pollen collection on *C. rigidus* flowers by *A. m. adansonii*. The same observations were also made in 1996 at the same study site, during the rainy season, by Tchuenguem Fohouo *et al.* (1997). These authors found that 99.7% and 0.3% of *A. m. adansonii* visits were devoted to nectar and pollen collection respectively. In the present study, pollen collection occurred during the morning only whereas nectar collection occurred throughout the day. This result is in agreement with that obtained during the rainy season by Tchuenguem Fohouo *et al.* (1997).

According to Philippe (1991), honey bees generally forage only when the temperature is between 12°C and 38°C. Our study shows that at dawn, ambient temperature was low, with a mean of 10°C ($n = 36$; $SD = 1.69$) and the humidity was high, with a mean of 71% ($n = 36$; $SD = 15.47$) (Table II). These conditions probably affected the activity of workers negatively. This could explain the absence of bees on *C. rigidus* flowers between 6 h and 7 h. Around 10 h and 11 h temperature and humidity were probably more favourable for bee activity. We found a positive and significant correlation between the number of visits and the temperature ($r = + 0.85$; $df = 10$; $P < 0.05$), but a negative correlation between the number of visits and the humidity ($r = - 0.82$; $df = 10$; $P < 0.05$) (Table II).

The high abundance of workers per 1000 flowers, and the positive and significant correlation between the number of *C. rigidus* flowers and the number of honey bee visits, underscore the attractiveness of *C. rigidus* nectar for *A. m. adansonii*. The attractiveness for *C. rigidus* nectar could be partially explained by its sugar content, which was high, given the range in sugar content of many plants, from 15 to 75% (Proctor *et al.*, 1996). According to Proctor *et al.* (1996), the nectar of bee flowers often contains more than 50% sugar. Thus *C. rigidus* seems to have one of the typical bee

flowers, since the sugar content of its nectar can be more than 60%. Philippe (1991) and Butler (cited by Proctor *et al.*, 1996) suggested that honey bees may not make a net energy gain for the colony if the sugar content of the nectar collected is less than 20% or 30% respectively. Considering these limits, *A. m. adansonii* workers gain a lot of energy for their colony when they collect *C. rigidus* nectar. The sugar concentration of *C. rigidus* nectar is higher than that reported for many other bee plants, e.g. 30% for *Citrus sinensis* (Free, 1970), 24-33% for cotton and 10-15% for pear tree (Philippe, 1991).

The observed high density of foragers and the positive correlation between the number of flowers and the number of visits are due to the ability of honey bees to recruit a great number of workers for the exploitation of high yield food sources (Frisch, 1969; Louveaux, 1984; Schneider & Hall, 1997).

The significant difference observed between the duration of pollen collection visits and that of nectar collection visits could be explained by the accessibility of each of these floral products. Pollen is produced by the anthers, which are situated on the top of the flower and are thus easily accessible to bees whereas nectar is between the base of the style and the stamens and is thus less accessible. Under these conditions an individual bee must spend much more time on flowers to obtain its nectar load, compared to the time she needs for her pollen load. Similar results were found during the rainy season (Tchuenguem Fohouo *et al.*, 1997).

The fact that an individual bee foraging on *C. rigidus* scarcely visited another plant species indicates that honey bees show flower constancy (Louveaux, 1984; Backhaus, 1993; Basualdo *et al.*, 2000) for *C. rigidus* flowers. This flower constancy could be partially due to the high sugar content of the nectar. In effect, *A. mellifera* workers are known to be generally constant to a plant species during one or several foraging trips (Louveaux, 1984), particularly when the sugar content of its nectar is more than 15% (Philippe, 1991). In the USA, for example, it was observed that some honey bee workers were constant to flowers of a single avocado tree for at least 24 h and this constancy was explained by the high sugar content (42-46%) of this plant species (Valdeyron, 1984).

As a highly nectariferous and slightly polliniferous bee plant, *C. rigidus* should be planted and protected to increase honey production and to strengthen honey bee colonies. Besides, *C. rigidus* pollen was identified in the honey collected in the study area in February 2000 (Mbofung *et al.*, 2000).

2- Impact of *A. m. adansonii* activity on the pollination and yields of *C. rigidus*

During the collection of nectar and pollen on each flower, *A. m. adansonii* workers regularly come into contact with the stigma. They could thus induce self-pollination, by applying the pollen of a flower on the stigma of the same flower. *A. m. adansonii* workers carried pollen from flower to flower on different trees. They could consequently carry the pollen from a flower of one tree to the stigma of another flower of the same tree (geitonogamy) or to that of another tree (xenogamy). Self-pollination and cross-pollination exist in *C. rigidus* (Noubissié *et al.*, 2002). During our investigations, the falling of the pollen carried by the foragers and the deposition of this pollen on the stigma and stamens of the flowers to be visited by the action of gravity and that of wind have been observed 28 times in 11 days. Such pollen losses by bees are frequent at the end of single flower or inflorescence visits, especially during the hovering flight of foragers above these organs. Thus in addition to their direct pollination role, *A. m. adansonii* workers also indirectly effected self-pollination and cross-pollination of *C. rigidus* flowers. Moreover, their foraging speed and density per 1000 flowers were high. In addition, their daily period of intense activity on *C. rigidus* flowers, which was in the morning, coincided with the period of optimal receptivity of the stigma of this plant species (Noubissié *et al.*, 2002). The significant contribution of *A. m. adansonii* to the fructification of *C. rigidus* is thus due to the action of the forager bees in self-pollination and cross-pollination of visited flowers. The morphology of *C. rigidus* flowers seems to avoid self-pollination and favour cross-pollination (pollen is sticky; the style is longer than the stamens). The latter mode of pollination could mainly explain the contribution of *A. m. adansonii* to fruit and seed yields. In flowers which rely on insects for cross-pollination, the pollen is difficult to carry by the wind, and anthers and stigma are usually separated by at least a small gap (Faegri & Pijl, 1979 ; Proctor *et al.*, 1996). Thus *C. rigidus* appears to be a typical insect cross-pollinated plant on which honey bees play the major pollinator role.

CONCLUSION

C. rigidus is a highly nectariferous and slightly polliniferous bee plant which benefits from pollination by insects among which *A. m. adansonii* is by far the most important. Comparison of the fruit and seed sets of unprotected inflorescences with that of inflorescences protected from insects underscores an increase of 71.29 % of the fructification index and

30.04% of the number of seeds per fruit, due to *A. m. adansonii*. Thus *C. rigidus* should be planted and protected to increase honey production and to strengthen honey bee colonies. Installation of *A. m. adansonii* colonies near the populations of *C. rigidus* should be recommended for horticulturists, to increase fruit and seed production.

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