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Foraging and pollination activity of *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae) on flowers of *Allium cepa* L. (Liliaceae) at Maroua, Cameroon

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Abstract

To evaluate the impact of *Apis mellifera adansonii* (Hymenoptera: Apoïdae) on fruit and seed of *Allium cepa* its foraging and pollinating activities were studied in Maroua, from November 2010 to April 2011 and 2012. Treatments included unlimited floral access by all visitors, bagged flowers to avoid all visits and limited visits of *A. m. adansonii*. Observations were made on 120 flowers per treatment. Flowers of *Al. cepa* were prospected four days per month, between 07.00 and 18.00 h, for recording of the nectar and/or pollen foraging behaviour of each pollinator. The worker bee's seasonal rhythm of activity, its pollination efficiency, the fruiting rate, the number of seeds per fruit and the percentage of seeds well developed were recorded. Results show that honey bee intensely and preferably foraged for nectar, almost throughout the day, with a peak between 8 and 9 am. The foraging speed was 47.12 ± 7.19 flowers per minute. Individuals from 22 species of insects were recorded on flowers of *Al. cepa*. *A. m. adansonii* was the most frequent with 40.62% and 51.48% of visits in 2010 and 2011 respectively. Its foraging resulted in a significant increase in the fruiting rate by 62.5% in 2010 and 53.8% in 2011, as well as the number of seeds per fruit by 86.44 in 2010 and 89.77% in 2011, and the percentage of normal seeds by 63.26 in 2010 and 59.78% in 2011. The use of *A. m. adansonii* colonies is suggested to increase fruits, seeds and honey production.

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Introduction

The majority of pollinators are insects (Pesson & Louveaux, 1984, Philippe, 1991), and the majority of those are Anthophila bees (Grimaldi & Engel, 2005). Bees collect pollen and nectar from flowers for food (Axelrod, 1960; Ollerton *et al.,* 2011). Nectar and pollen are the basic foods of each honey bee colony (Crane, 1999; Weidenmüller & Tautz, 2002, Jha & Vandermeer, 2009). Nectar is transformed into honey (Tchuenguem Fohouo *et al.,* 2004). Pollen and honey are store in the hive for future use (Riedacker, 1996). These products have been exploited by humans for thousands of years (Crane, 1999). During insects' visits they usually pollinate plant host flowers (Sabbahi *et al.*, 2005, Klein *et al.,* 2007, Tchuenguem Fohouo *et al.,* 2007, 2008a, 2008b, 2009a). The majority of wild plants are insect pollinated (Klein *et al.* 2007), as are most commercial crops (Buchmann & Nabhan 1996; Constanza *et al.* 1997; Jablonski *et al.*, 1982; Wójtowski *et al.* 1980). Without pollinators production of crops may decrease drastically (Tchuenguem Fohouo, 2005, Phillipe, 1991; Shaw and Bourne, 1936; Gallai *et al.,* 2009).

Onion is a monocotyledonous crop it belongs to the genus *Allium,* and to the family Liliaceae (Messiaen, 1994; Purseglove, 1988). Onion is a major ingredient of cooked food; people use it in salads, as raw and as a condiment (Munawar *et al.,* 2011). Florets are not self-fertile (Delaplane and Mayer 2000). Wind and gravity take part in minimal roles in pollination (Free, 1993). *Al. cepa* flowers cannot usually fertilize themselves and its stalks can reach 150 cm in height (Brickell *et al.,* 1992). Onion does not produce quality seed without insects' pollination (Chandel *et al.*, 2004; Kumar *et al.,* 1989). Pollen is shed within 2-3 days before the receptivity of the stigma (Lesley and Ockendon 1978). Onion produces seed in the second year while bulb is form in the first year (Michel Pitrat & Claude Foury, 2003). For vegetative growth onion need temperatures around 20–22 °C and around 12 °C for seed stalk formation (Rashid & Singh, 2000). World production is more than 53 million tons of which 32% is produced in China (FAO, 2007). Cameroon produce more than 65 409 tons of onion and demand for onion is estimated at over 120 000 tons annually (MINADER, 2010).

The entomofauna floriculture *Al. cepa* is very little studied. The few studies obtained in the literature review have been out of Cameroon were particularly in California by Ronald *et al.,* (1999), in Mexico (Corgan *et al.,* 1997), in France (Collin, 1996) in Ghana kyei-boahesn (1986), in Pakistan (Mohammad, 2011; Asif, 2008) and in USA (Kelly & George, 1998, Erickson & Gobelman, 1956). According to Gallai *et al.*, (2009), Roubik (2000) and Tchuenguem (2005), floriculture entomofauna of a plant species varies from one region to another. The aim of this work was to study the activity of *A. m. adansonii* on the flowers of *Al. cepa* and to evaluate the effectiveness of bee pollination that yields this Liliaceae. Many authors have shown that honey bee visits onions' flowers (Ahmed and Abdullah, 1984; Tolon & Duman, 2003). In addition, a preliminary study on the relationship insect flowers in Maroua before 2010 (unpublished data) showed that *A. m. adansonii* intensely visit the flowers of the plant. This insect can be used to pollinate *Al. cepa*.

Materials and methods

Site and biological materials

The studies were conducted from November to April in 2010 and 2011 respectively in the locality of Maroua (Latitude 10°37.496 N, longitude 14°26.481 E and altitude 374 masl) in the Far North Region of Cameroon. This Region belongs to the ecological zone with three phytogeographical areas (Sahel-Sudanian, Sahelian and Sudanian altitude) periodically flooded, with unimodal rainfall (Letouzey, 1985). It has a Sahel-Sudanian climate type, characterized by two annual seasons: a long dry season (November to May) and a short rainy season (June to October); August is the wettest month of the year (Kuete *et al.,* 1993). Annual rainfall varies from 400 to 1100 mm (Kuete *et al.,* 1993). The annual average temperature varies between 29 and 38° C and a daily temperature range between 6 and 7℃ (Kuete *et al.*,1993). The experimental plot is an area of 145 m2. The animal material was represented by insects naturally present in the environment and a colony of *Apis mellifera adansonii* Latreilles (Hymenoptera: Apidae). Vegetation was represented by wild species and cultivated plants. The plant material was represented by the seeds of *Al. cepa*.

Planting and maintenance of culture

On 8th November 2010 and 17th November 2011, the experimental plots (that have been previously plowed) was divided into 24 sub - plots of 1.5 x 1.5 m^2 each, with a row of two meters between the left and subplots. This field received seedlings of 10 lines per sub – plot. 80 onion bulbs were planted as nursery on each of the two experimental plots. Each plot was made up of four rolls of 10 on onion dome planted 15 cm apart. After a period of 1 (one) month, the young plants were transplanted from the nursery site onto the 24 subplots. During the investigation period, 15 kilograms of garden fertilizer (20-10-10) was applied on the plants and they were watered once a week. Manual weeding was performed regularly at the beginning of flowering until harvest, which ended April 17, 2010 for the first growing season and April 25, 2011 for the second growing season.

Determining the mode of reproduction

On February 14th, 2010, 240 flowers of *Al. cepa* at the bud stage were labeled; of these, 120 were left unattended (Treatment 1) and 120 were bagged (treatment 2) to prevent visitors (Figure 1) On, February 17th 2011, 240 flowers of *Al. cepa* at bud stage were labeled; of these, 120 were left unattended (Treatment 3) and 120 were bagged (treatment 4) to prevent visitors. For each year, ten days after the wilting of the last flower, the number of fruit formed in each treatment was counted. For each treatment, the fruiting index *(Ifr)* was calculated using the following formula: *Ifr = (F1/F2),* where *F1* is the number of boll formed and the number of flowers *F2* initially labeled (Tchuenguem *et al.,* 2004). The out crossing rate (*TC*) was calculated using the formula: *TC= {[(IfrX - IfrY/IfrX]x100},* Where *IfrX* and *IfrY* are mean fruiting indexes of free treatment and bagged treatment respectively (Demarly, 1977). The rate of self-pollination in the broad sense (*TA*) was calculated using the formula:

TA = (100 - TC).

Study of the activity of insects on the flowers of Allium cepa

Observations were made every two days, on flowers of treatments 1 and 3, according to six slots: 7-8 h, 9-10 h, 11-12 h, 13-14 h, 15-16 h and 17-18 h. February 18 to 25, 2010 and from February 18 to 27, 2011, the blooming periods labeled flower buds. Insects found on flowers were counted at each daily time frame. Data obtained were used to determine the frequency *(Fx)* of visits *A. m. adansonii* on flowers of *Al. cepa*.

For each year of study, *Fx = [(Vx / Vt) x 100],* where *Vx* is the number of visits to *A. m. adansonii* on flowers of free treatment and Vt the total number of insect visits on flowers of the same treatment.

The floral products (nectar and / or pollen) collected by the bee were recorded for the same dates and time slots as that of insect counts. The study of this parameter indicates whether *A. m. adansonii* is strictly pollinivorous, or nectarivore, or pollinivorous and nectarivore. This can give an idea on its involvement in the pollination of this plant. The duration of visits and foraging speed (number of flowers visited per minute) (Tchuenguem *et al.,* 2004) were timed at the same dates and in six time slots. Abundances (larger numbers of individuals simultaneously active) per flower and per 1000 flowers 1000 (*A1000*) were recorded on the same dates and time slots as the registration of the duration of visits. The first parameter was recorded as a result of direct counts. For *A1000*, *A. m. adansonii* were counted on a known number of open flowers; *A1000* was then calculated by the formula: *A1000* = [(Ax / *Fx) x 1000],* where *Fx* and *Ax* are respectively the number of flowers and the number of *A. m. adansonii* effectively counted on these flowers at time x (Tchuenguem *et al.,* 2004).

The influence of the surrounding flora was assessed by direct observation: the number of times the bee went from *Al. cepa* flowers to another plant species and vice versa was noted throughout the period of investigation.

Measuring the temperature and humidity of the experimental site

During the days of investigation, the temperature and humidity of the study site were recorded every 30 min, 7-18 h, using a thermo hygrometer installed in the shade.

Evaluation of the impact of flower-feeding insects on the yield of Allium cepa

At fruit maturity, harvesting was done in all treatments. For each year of study, the digital input *(Pf)* of insects on fruiting is $Pf = \{[(fx-fy) / fx] \times 100\}$, where *fx* and *fy* are the fruiting rate in treatments x (treatments 1 or 3) and y (treatments 2 or 4). For a treatment, the fruiting rate *(Tfr)* is $Tfr = [(\text{number of boll} / \text{number of flowers}) \times 100]$. The digital input *(Pf)* of insects *(Pg)* on the number of seeds is $Pg = \{[(gx-gy) / gx]\} \times 100$ where *gx* and *gy* are the mean number of seeds per pod in treatments *x* and *y*. The digital input (Pgn) of insects on normal seeds is $Pgn = \{[(gnx-gny) / gnx]\} \times 100$ where *gnx* and *gny* are the percentages of normal seed in treatments *x* and *y*.

Measuring the effectiveness of pollination by Apis mellifera adansonii on Allium cepa

Along with the development of treatments 1 and 2, 100 flowers were isolated (treatment 5) as those of treatment 2. Along with the development of treatments 3 and 4, 100 flowers were isolated (treatment 6) as those of treatment 4. Between 7- 9 am, the gauze bag was gently removed from each newly bloomed flower and the flower observed for up to twenty minutes. Flowers visited by *A. m. adansonii* were marked and unattended flowers were conserved. After this manipulation, the flowers were protected once more.

At boll maturity, harvesting was done in treatments 5 and 6. For each year of study, the digital input *(Pfx)* of *A. m. adansonii* on fruiting is $Pfx = \{[(fz-fy) / fz] \times 100\}$, where *fz* and *fy* are the fruiting rate in treatment z (protected flowers and visited exclusively by *A. m. adansonii*) and *y* (protected flowers) (Tchuenguem *et al*., 2004). The digital input *(PGX)* of *A. m. adansonii* in the the number of seeds is $PGX = \{[(gz-gy) / gz]\} \times 100$ where *gz* and *gy* are the average number of seeds per boll in treatments *z* and *y* (Tchuenguem *et al.,* 2004). The digital input *(PGNX)* of *A. m. adansonii* on normal seeds formation is $PGNX = \{[(GNZ-GNY) / GNZ]\} \times 100$ where *GNZ* and *GNY* are the percentages of normal seeds in treatments *z* and *y* (Tchuenguem *et al.,* 2004).

Data analysis

SPSS software and Microsoft Excel were used for three tests: Student's (t) for comparison of means, correlation coefficient (r) for the study of linear relationship between two variables, Chi-square ($\chi 2$) for the comparison of percentages.

Results

Reproductive system

The mean fruiting indexes were 0.93, 0.19, 0.95 and 0.13 in treatments 1, 2, 3 and 4 respectively. Thus in 2010, the allogamy rate was 2 5 .83% and the autogamy rate was 74.17%. In 2011, the corresponding figures were 1 6 .67 and 83.33%.

It appears that *Al. cepa* has a mixed mating system, autogamous-allogamous, with the predominance of allogamy.

Activity of A. m. adansonii on the flowers of Allium cepa

Seasonal frequency of visits

For 30 and 27 days of the flowering periods in 2010 and 2011, 1519 and 1680 visits of 22 and 18 species of insects were counted on 120 and 120 flowers of *Al. cepa* respectively in 2010 and 2011. *A. m. adansonii* comes with 617 and 865 visits spread over all periods of flowering, that is 40.62% and 51.48% of all visits recorded in 2010 and 2011 respectively; this bee species ranked first in whatever year of investigation

(Table 1). The difference between these two percentages is highly significant (χ2 = 12.80 [df = 1, P<0.001]). This insect has been active on the flowers of A. cepa from 6 am to 17 pm, with a peak of visits between 6 am and 7 am in 2010 as well as in 2011 (Figure 2).

Abundance of bees

In 2010, the highest average number of *A. m. adansonii* simultaneously active was one bee per flower (n = 50, s = 0) and 450.66 per 1000 flowers (n = 35 s = 326.7, max = 1200). In 2011, the corresponding figures were 1 per flower (n = 50, s = 0) and 514.10 per 1000 flowers (n = 35, s = 378.11, max = 1625). The difference between the average number of bees per 1000 flowers in 2010 and 2011 is highly significant (t = - 3.09 [df = 68, P <0.01]).

Table 1. Diversity of floral insects on *Allium cepa* flowers in 2010 and 2011, number and percentage of visits of different insects.

	Insects			*2010*		*2011*		
	Order	Family	Genus, species, Sub species	n	p%	n	p%	
1	Hymenoptèra	Apidae	*Apis mellifera adansonii*	617	40,62	865	51,48	np
2			*Amegilla* sp. 1	213	14,02	304	18,09	p
3			*Amegilla* sp. 2	65	4,28	48	2,85	p
4			*Xylocopa* sp. 1	56	3,69	33	1,96	p
5			*Xylocopa* sp. 2	97	6,39	51	3,03	p
6		Formicidae	*Polyrachis* sp. 1	11	0,72	46	2,73	res
7		Halictidae	*Lipotriches collaris*	6	0,39	24	1,42	p
8			*Macronomia vulpina*	32	2,11	21	1,25	p
9		Megachilidae	*Chalicodoma* sp.1	73	4,81	0	0	p
10			*Chalicodoma* sp.2	14	0,92	39	2,32	p
11			*Megachile* sp. 1	1	0,07	0	0	p
12			*Megachile* sp. 2	3	0,20	15	0,89	p
13		Sphecidae	*Philanthus triangulum*	8	0,53	0	0	pr
14			(1 sp.)	47	3,09	25	1,48	pr
15		Vespidae	*Synagris cornuta*	1	0,07	9	0,53	n
16			(1 sp.)	5	0,33	2	0,11	n
17	Diptera	Calliphoridae	(sp. 1)	23	1,51	16	0,95	p
18			(sp. 2)	11	0,72	28	1,66	p
19		Syrphidae	(1 sp.)	19	1,25	0	0	p
20	Coleoptera	Meloidae	*Coryna* sp.	24	1,58	13	0,77	p
21	Lepidoptera	Acraeidae	*Acraea acerata*	1	0,07	12	0,71	n
22		Pieridae	*Catopsilia florella*	1	0,07	3	0,17	n
	Total		22 espèces	1519	100	1680	100	

Comparison of percentages of *Apis mellifera adansonii* visits for two years: χ^2 = 18.80 ([ddl = 1; P < 0.001]). n_1: number of visits on 100 flowers in 10 days.

n_2: number of visits on 100 flowers in 10 days. p_1 et p_2: percentages of visits.

$p_1 = (n_1 / 1519) \times 100$.

$p_2 = (n_2 / 1680) \times 100$.

NP: Visitor collected nectarand pollen.

N: Visitor collected nectar.

P: Visitor collected pollen.

Pr: Predation.

sp.: Undetermined species.

The flowers of *Al. cepa* are visited by other Apidae *Amegilla* sp. 1, *Amegilla* sp. 2, *Xylocopa* sp. 1, *Xylocopa* sp. 2), Halictidae (*Lipotriches collaris*, *Macronomia vulpina*) and Megachilidae

(*Chalicodoma* sp.1, *Chalicodoma* sp. 2, *Megachile* sp. 1, *Megachile* sp. 2, *Megachile* sp. 3) to collect pollen. Other insects such as Vespidae *Synagris cornuta* Calliphoridae eat pollen on flowers. A predator of Apidae, Halictidae and Megachilidae was Sphecidae (*Philanthus triangulum*). There were also Lepidoptera and Coleoptera.

Floral substances taken

During each period of flowering of *Al. cepa, A. m. adansonii* harvest preferably and nectar. The exclusive collection of nectar and simultaneous harvest of nectar and pollen during a foraging trip were less frequent (Table 2).

Table 2. Products harvested by *Apis mellifera adansonii* on flowers of *Allium cepa* in 2010 and 2011.

Year	*Number of visits studied*	*Vnec.*		*Vpol.*		VNP	
		number	%	number	%	number	%
2010	617	478	77.47	54	8.75	85	13.77
2011	861	782	90.82	31	3.60	48	5.57

Vnec. : visits for nectar harvest; Vpol. : visits for pollen harvest; VNP: visits for nectar and pollen harvest.

Rate of visits according to the flowering stages

Generally, visits of *A. m. adansonii* were more numerous on treatments 1 and 3 when the number of open flowers was highest (Figures 1). The correlation between the number of visits of *A. m. adansonii* and the number of opened flowers was positive and highly significant in 2010 (r = 0.96 [df = 13, P <0.05]) as well as in 2011 (r = 0.92 [df = 13, P < 0.05]).

Duration of visits per flower

The average duration of a visit of *A. m. adansonii* per flower of *Al. cepa* varied significantly depending on the substance taken. In 2010, the average duration of a visit for pollen collection was 12.31 sec (n = 60, s = 6.17, max = 21); for the collection of nectar, it was 22.75 sec (n = 60, s = 5.55, max = 2 9). In 2011, the corresponding results were 5.32 sec (n = 68, s = 5.98, max = 18) and 13.64 sec (n = 81, s = 6.07, max = 23) for pollen and nectar harvest respectively. The difference between the two mean durations is highly significant in 2010 (t = 51.68 [df = 118, P <0.001]) as well as in 2011 (t = 42.52 [df = 147, P<0.001]). The difference between the duration of the visit to harvest nectar in 2010 and 2011 is highly significant (t = - 19.74 [df = 1258, P<0.001). Also, the difference between the duration of visit for pollen in 2010 and 2011 is highly significant (t = - 16.21 [df = 83, P <0.001]).

Table 3. Daily distribution of *Apis mellifera adansonii* visits on 80 and 100 *Allium cepa* inflorescences over 17 days in 2010 and 20 days 2011 respectively, mean temperature and mean humidity of the study site.

Year	*Parameter registered*	Daily period (hours)					
		7 - 8	9 - 10	11 - 12	13 - 14	15 - 16	17 - 18
2010	Number of visits	243	713	316	98	118	31
	Percentage of visits (%)	15.99	46.93	20.80	6.45	7.76	2.04
	Temperature (°C)	25.9	34.5	36.6	38.7	35.6	34.7
	Hygrometry (%)	28	26	19	14	16	22
2011	Number of visits	295	819	403	73	66	24
	Percentage of visits (%)	17.55	48.75	23.98	4.34	3.92	1.42
	Temperature (°C)	26.1	35.3	37.4	38.5	35.2	35.1
	Hygrometry (%)	24	22	20	19	18	20

Foraging speed of A. m. adansonii on the flowers of Allium cepa

On the plot of *A. cepa* , *A. m. adansonii* visited 7-32 flowers / min in 2010 and 5 to 28 flowers / min in 2011. The average speed is 21.64 foraging flowers / min (n = 70, s = 7.65) in 2010 and 18.21 flowers / min (n = 70, s = 7.14) in 2009. The difference between these two means is highly significant (t =

18.43 [df = 138, P < 0.001]).

Influence of wildlife

Workers of *A. m. adansonii* are disturbed in their foraging by other workers or other arthropods which are either predators or competitors for the search of pollen or nectar.

These disturbances have resulted in the interruption of certain visits. In 2010, for 617 visits of *A. m. adansonii* 15 (2.43%) were interrupted by the same worker bees and in 2011, for 865 visits of *A. m. adansonii*, 22 (2.54%) were interrupted by the same worker bees. For their load of pollen foragers who suffered such disturbances are forced to visit more flowers and / or plants during the corresponding foraging trip. In pollen foragers, these disturbances resulted in partial loss of carried pollen.

Table 4. *Allium cepa* yields in different lots.

Characteristic of the lot	*Year*	*Nfs*	*Npf*	*Fr*	*Seeds/pod*		*Nsf*	*Nns*	*Pns*
					Mean seeds/ pod	s			
Free flowers	2010	120	112	93.33	3.56	0,57	399	390	97,74
Protected flowers	2010	120	23	19.16	1.27	0,31	29	10	34.48
Free flowers	2011	120	115	95.83	4.19	0.34	482	455	94,39
Protected flowers	2011	120	15	12.50	1.74	1,07	26	09	34.61
Fvap	2010	40	40	100	3.12	0,35	125	116	92,80
Fvap	2011	40	38	95	3.55	0,29	135	122	90,37

Fvap: flowers visited exclusively by *A.mellifera*, Nfs: number of flowers studied, Npf: number of pods formed, Fr: fructification rate, m: mean, s: standard deviation, Nsf: number of seeds formed, Nns: number of normal seeds, Pns: percentage of normal seeds.

During the study period, other plant species located near the experimental field of onion were also visited by *A. m. adansonii* for nectar (N) and / or pollen (P). Among these plants, there were: *Arachis hypogaea* (Papilionaceae, P), *Mitracarpus villosus* (Rubiaceae, N and P), *Jathropha gossipiifolia* (Euphorbiaceae, N), *Striga hermonthica* (Scrophulariaceae, N), *Hibiscus asper* (Malvaceae, N and P), *Sesamum indicum* (Pedaliaceae, N), *Sorghum bicolor* (Poaceae, P). During *A. m. adansonii* foraging trips of 2010, on 183 visits, only 13 (7.10%) were made by individuals from any of these plants. In 2011, the corresponding values were 264 visits, 24 (9.09%).

Table 5. Daily distribution of *Apis mellifera adansonii* visits on 100 *Allium cepa* flowers over 10 days of observation in 2010 and 2011 respectively, mean temperature and mean humidity.

Year	*Parameter registered*	Daily period (hours)					
		7 - 8	9 - 10	11 - 12	13 - 14	15 - 16	17 - 18
2010	Number of visits	124	335	26	15	21	96
	Percentage of visits (%)	15.99	46.93	20.80	6.45	7.76	2.04
	Temperature (°C)	25.9	34.5	36.6	38.7	35.6	34.7
	Hygrometry (%)	28	26	19	14	16	22
2011	Number of visits	219	397	59	32	39	119
	Percentage of visits (%)	17.55	48.75	23.98	4.34	3.92	1.42
	Temperature (°C)	26.1	35.3	37.4	38.5	35.2	35.1
	Hygrometry (%)	24	22	20	19	18	20

2010: for temperature and hygrometry, each figure represents the mean of 50 observations.

2011: for temperature and hygrometry, each figure represents the mean of 50 observations.

Daily rate of visits

A. m. Adansonii has been active on the flowers of *A. cepa* from 6 am to 17 pm, with a peak of visits between 8 and 9 am in 2010 and 2011. Strong winds disrupted visits *A. m. adansonii* on the flowers of *Al. cepa*. Thus, of the 617 and 865 visits recorded in 2010 and 2011 respectively, 19 (3.07%) and 27 (3.12%) were interrupted by such winds. Climatic factors have influenced the activity of *A. m. adansonii* on the flowers of *Al. cepa* in field conditions (Table 3). The correlation was negative and significant between the number of visits of *A. m. adansonii* on the flowers of *Al. cepa* and temperature in 2010 ($r = -0.11$ [$df = 4$, $P < 0.05$]) and 2011 ($r = -0.14$ [$df = 4$, $P < 0.05$]). The correlation between the number of visits and the relative humidity of the air was positive and significant in 2010 ($r = 0.53$ [$df = 4$, $P < 0.05$]) and 2011 ($r = 0.57$ [$df = 4$, $P < 0.05$]) (figure 2).

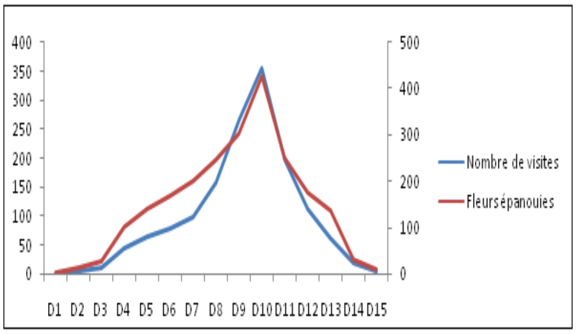

Fig. 1. Variation of number of flowers and number of visits of *Apis mellifera adansonii* on the flowers *Allium cepa* in 2010 and 2011.

Beekeeping value of Allium cepa

During the dry season in Maroua, we noted an activity developed in workers of *A. m. adansonii* on *Al. cepa* flowers. In particular, there was a very good harvest of nectar, a low harvest of pollen and fidelity to flowers of *Al. cepa*. These data highlight the high attractiveness of nectar of this Liliaceae to *A. m. adansonii*. They allow the classification of *Al. cepa* as a highly nectariferous and slightly polliniferous bee plant.

Impact of flower-feeding insects in pollination and yields of Allium cepa

During pollen and/or nectar harvest, flower-feeding insects of *Al. cepa* are in regular contact with the anthers and stigma. These flower-feeding insects therefore increase the possibilities of this Liliaceae pollination. Table 4 presents the results on fruiting rate, number of seeds per pod and percentage of normal seeds in different treatments. It is clear from this table that:

a) Comparison of rates of fruiting shows that the differences are highly significant between treatments 1 and 2 ($\chi 2 = 78.07$ [$df = 1$, $P < 0.001$]), treatments 3 and 4 ($\chi 2 = 91.17\ 22$ [$df = 1$, $P < 0.001$]) and not significant between treatments 1 and 3 ($\chi 2 = 0.61$ [$df = 1$, $P > 0.05$]). Therefore, in 2010 and 2011, the fruiting rate of flowers from open pollination (treatment 1 and 3) was higher than that for protected flowers (treatments 2 and 4). In 2010 and 2011, the percentage of fruiting rate due to the action of the flower-feeding insects was 74.17% and 83.33% respectively. For the two years of investigations, the rate of boll due to the influence of the flower-feeding insects including *A. m. adansonii* is 78.75%;

b) Comparison of the average number of seeds per fruit showed a highly significant difference between the treatments 1 and 2 ($t = 41.76$ [($df = 133$, $P < 0.001$]) treatments 3 and 4 ($t = 41, 24$ [($df = 128$, $P < 0.001$]), and treatments 1 and 3 ($t = 6.34$ [($df = 225$, $P < 0.001$]). Consequently, in 2010 and 2011, the number of seeds boll for open pollinated flowers (treatments 1 and 3) was higher than that for protected flowers (treatments 2 and 4). The percentages of the number of seeds per fruit due to the action of insects including *A. m. adansonii* were 86.44 and 89.77% respectively in 2010 and 2011. For both years of study, this percentage is 88.10%;

c) Comparison of the percentages of normal seeds showed highly significant difference between treatments 1 and 2 ($\chi 2 = 11.98$ [$df = 1$, $P < 0.0005$]), treatments 3 and 4 ($\chi 2 = 11.92$ [$df = 1$, $P < 0.0006$]) and non significant difference between treatments 1 and 3 ($\chi 2 = 0.4$ [($df = 1$, $P > 0.05$]). Consequently, in 2010 and 2011, the percentage of normal seeds of flowers from open pollination (treatment 1 and 3) was higher than that for protected flowers (treatments 2 and 4).

For 2010 and 2011, the percentages of normal seeds due to the action of insects including *A. m. adansonii* were 63.26 and 59.78% respectively. For two cumulative years, this percentage is 61.52%.

Pollination efficiency of A. m. adansonii on Allium cepa

From Table 4, it appears that:

a) Comparison of fruiting rates shows a highly significant difference between treatments 2 and 5 ($\chi2$ = 77.60 [df = 1, P <0.0001]) and treatments 4 and 6 ($\chi2$ = 91.05 [df = 1, P <0.0001]). Therefore, the rate of fruit set of flowers isolated and visited exclusively by *A. m. adansonii* (treatments 5 and 6) is higher than that of protected flowers (treatments 2 and 4). In 2010 and 2011, the percentagees of fruiting rate due to the efficiency of pollinating *A. m. adansonii* were 80.84 and 82.50% respectively. For the two years of experiments, the percentage is 81.67%;

b) Comparison of the average number of seeds per fruit shows a highly significant difference between treatments 2 and 5 (t = - 3.71 [(df = 61, P <0.01]) and treatments 4 and 6 (t = - 22.32 [(df = 51, P <0.001]). Consequently, in 2010 and 2011, the number of seeds per boll of flowers isolated and visited exclusively by *A. m. adansonii* (treatments 5 and 6) was higher than that of protected flowers (treatments 2 and 4). Percentages of the number of seeds per boll due to the pollination efficiency of *A. m. adansonii* were 60.06 and 58.13% in 2010 and 2011 respectively. For the two seasons of study, this percentage is 59.09%;

c) Comparison of the percentage of normal seeds showed a highly significant difference between treatments 2 and 5 ($\chi2$ = 12.51 [df = 1, P <0.0004]) and treatments 4 and 6 ($\chi2$ = 11.62 [df = 1, P <0.0006]). Therefore, in 2010 and 2011, the percentage of normal seeds from flowers isolated and visited exclusively by *A. m. adansonii* (treatments 5 and 6) was higher than that protected flowers (treatments 2 and 4). The percentages of normal seeds due to pollination efficiency of *A. m. adansonii* were 58.32 and 55.76% in 2010 and 2011 respectively. For the two years of experimentation, this percentage was 57.04%.

In summary, the influence of *A. m. adansonii* on boll and grain yields was positive. A positive and significant correlation has been found between the number of seeds and the number of visits of *A. m. adansonii* in 2010 (r = 0.93 [df = 97, P <0.05]) and in 2011 (r = 0.92 [df = 82, P <0.05]).

Discussion

Results obtained from these studies indicated that bee *A. mellifera adansonii* was the main floral insect frequent on *Al. cepa*. The role of managed honey bee in onion pollination has extensively been documented by many authors (Kumar *et al.* 1989; Rao & Suryanarayans, 1989; Ahmed & Abdalla, 1984; Mayer & Lunden, 2001; Tolon & Duman, 2003). *Apis mellifera* was the dominant species representing 77.5%of all individuals (Walker *et al.* 1998). In New Zealand honey bee is specifically placed in onion seed fields to increase pollination efficiency (Crane & Walker 1984).

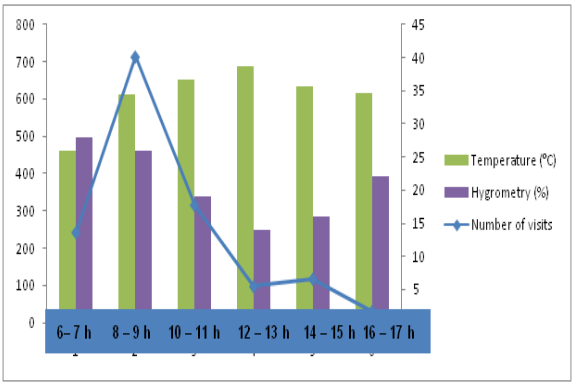

Fig. 2. Mean daily temperature and humidity and mean number of visits of *Apis mellifera adansonii* on the flowers of *Allium cepa* in 2010 and 2011.

In our experiment Hymenoptera and Diptera were the main pollinators. Jablonski *et al.*, 1982 and Wójtowski *et al.*, 1980 have shown that onion flowers are visited by honey bees, bumble bees, dipterans and butterflies. Moreover, the study by Howlett *et al.* (2009) recorded dipteran families as the most abundant in fields. Bees are abundant in flowering *Al. cepa* fields grown for seed production (Walker *et al.*, 1998). The dominance of bee and fly individuals indicate that these taxa are also regarded as important insect pollinators of native flora (Howlett *et al*., 2005, Godley 1979; Primack 1983; Newstrom & Robertson 2005).

Fig. 3. *Allium cepa* flowers at the.

Priti (1998) supports our observations that *A florae* was the most abundant pollinator of onion followed by *A. mellifera* in lowland conditions. Al-sahaf (2002) showed that mainly honeybee *(Apis mellifera* L.), blowfly (*Caliphora vomitoria* L.), and housefly *(Musca domestica* L.) visits onion flowers. The results of Chandel *et al.* (2004) in which *A. dorsata* was a more frequent pollinator of onion than *A. florea* and than *A. mellifera* in mountainous Hindu Kush Himalayan areas of India. Asif sajjad (2008) showed *Apis dorsata* proved to be an abundant onion pollinator.

Fig. 4. *Allium cepa* experimental.

The high abundance of *A. mellifera* foragers on 1000 flowers and the positive and significant correlation between the number of *Al. cepa* flowers coming into bud and number of *A. mellifera* visits, underscore the attractiveness of *Al. cepa* nectar and/or pollen with respect to this bee. The attractiveness for *Al. cepa* nectar could be partially explained by its high production and its total sugar concentration (Koltowski, 2004; Proctor *et al.,* 1996) of the plant species.

Fig. 5. *Allium cepa* flowers Visited by *Apis mellifera adansonii.*

The type of floral products harvested by *A. m. adansonii* from a given plant species can vary with the region and year (Moffet *et al.,*1976; Tchuenguem Fohouo, 2005). The significant difference observed between the duration of pollen harvest visits and that of nectar collection visits could be explained by the accessibility of each of these floral products and by the needs of the colonies of the foraging bees (Tchuenguem *et al.,* 2009b, 2010). The attractiveness for nectar of onion flowers can be partially explained by its properties and accessibility to insects (McGregor, 1976).The peak of *A. m. adansonii* activity on the flowers was in the morning, which may corresponds to the period of the high availability of nectar or/ and pollen on flowers of onion. Pollen is produced by the anthers, which are situated on the summit of the stamen and are so easily accessible to insects. Whereas nectar is between the base of style and stamens and is consequently with a reduction of accessibility.

In the present study, Data indicate that the foraging activity of the above mentioned insects is adversely correlated to the increased temperature during the day time. The number of insects foraging early in the morning (7.00 - 10.00 am) and late in the afternoon (5.00 - 7.30 pm) was greater than those foraging from 10.00 am to 5.00 pm when the day temperature rises drastically. The foraging activity by bees and flies started at around 6:00 a.m., which is supported by the findings of Chandel *et al.* (2004). The foraging activity of *A. mellifera* and others pollinators reach it high point between 10:00 - 12:00. Peak activity for *A. dorsata* and *A. cerana* was observed between 12:00 - 14:00 h (Partap and Verma, 1994; Priti, 1998; Chandel *et al.,* 2004). Dowker *et al.* (1985) recorded similar observations on the adverse effects of high temperatures on the movement and pollination activities of honeybee and blowflies on onion flowers.

The genus *Apis* proved to be the most effective onion pollinator, which is supported by the work of several authors (Kutjatnikova, 1969; Martin, 1978; Lazic *et al.,* 1985; Kumar *et al.,* 1989; Priti, 1998; Chandel *et al.,* 2004). On the other hand, from a closely related plant species, Stephen *et al.* (2007) harvested a higher *Al. ampeloprasum* L. seed yield contributed by *Calliphora vicina* as compared from *M. domestica*. Many other factors also contribute such as body size, shape of an insect, its thurst for nectar or pollen, or the chances to be in contact with the stigma of the flowers and pollen deposition.

The increases in the number of seeds probably was due to the increases in the number of pollen grains resulting from intensive foraging of insects (Currah & Ockendon, 1984, Doweker *et al.,* 1985; Delaplane & Mayer 2000; Chandel *et al.,* 2004). *A. m. adansonii* workers could induce self-pollination by applying the pollen of a flower on the stigma of the same flower (Free, 1993). Foragers carried pollen from a flower of one tree to the stigma of another flower of the same tree (geitonogamy) or to that of another tree (xenogamy) (Moffett *et al.,* 1975). Many crops are completely or partly dependent on arthropods for pollination (Free 1993; Cunningham *et al.,* 2002). Onion contributed to strengthening of the honeybee colonies so should be planted and protected. The comparison of yield obtained from open and self-pollinated crop represents a significant difference of the yield in open pollinated crop. Similar results were also observed by Zdzislaw *et al.* (2004) who found 699% more yield in open pollinated crop than self pollinated crop. For an effective pollination, pollen must come from another flower of the same or a different plant (Zdzislaw *et al.*, 2004).

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Conclusion

This study makes known that *Al. cepa* is a highly polliniferous bee plant that obtained benefits from the pollination by insects among which *A. m. adansonii* is of great importance. The comparison of fruits and seeds located on unprotected flowers with that of flowers visited exclusively by *A. m. adansonii* underscores the value of this bee in increasing fruits and seed yields as well as seed quality. The installation of *A. m. adansonii* hive at the nearness of *Al. cepa* fields should be recommended for the increase of fruit and seed yields of this valuable crop, and to improve pollen production as a hive product.

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