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Full Length Article

Direct Pollination Efficiency of *Apis mellifera* on the Flowers of *Allium cepa* var. Chagari in Mokong Cameroon

Amadou Koffa[1], Denis Djonwangwé[2*], Jackson Dapsia Djakbé[3], Armel Socrate Kameni Balle[1] and Fernand-Nestor Fohouo Tchuenguem[4]

[1]*Faculty of Science, Laboratory of Biological Sciences, University of Maroua, P.O. Box 814 Maroua, Cameroon*
[2]*High Teachers' Training College, Laboratory of Life and Earth Sciences, University of Maroua, P.O. Box 55 Maroua, Cameroon*
[3]*Department of Agriculture, Livestock and Derived Products, National Advanced School Engineering, University of Maroua, P.O. Box 814, Maroua, Cameroon*
[4]*Faculty of Science, Department of Biological Sciences, Laboratory of Applied Zoology, University of Ngaoundéré, P.O. Box 454 Ngaoundéré, Cameroon*
[*]For correspondence: djonwangwedenis@gmail.com
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Abstract

The aim of this work was to study the foraging activity of *Apis mellifera* (Apidae) and to evaluate its direct pollination efficiency on fruit and seed yields of Chagari variety of *Allium cepa* (Liliaceae). The observations were carried out from November 2020 to September 2021 in Mokong (Far-North Region of Cameroon). Each year, 40 umbels were isolated at the flower bud stage and the activity of *A. mellifera* was noted on the 40 free umbels. During the flowering period, each isolated umbel was reopened and closed again after a single visit from *A. mellifera*. The numbers of fruits per umbel and seeds per fruit were counted. *A. mellifera* was the most frequent insect (29.94% of total visits) of the 40 visitors. During the flowering period, there was a high daily and seasonal frequency of visits of this Apidae which collected very largely the nectar and weakly the pollen. The direct pollination efficiency of *A. mellifera* on fruiting rate, the average number of seeds per fruit and the percentage of normal seeds were 74.61, 33.96 and 66.13%, respectively. A single visit of *A. mellifera* significantly increased the fruit and seed yields.

Keywords: Chagari; *Apis mellifera*; Pollination; Onion yields; Mokong

Introduction

Majority of African farmers are unaware of the role of insect pollinators during flowering (Djonwangwé *et al*. 2018; Taimanga and Tchuenguem 2018) even though they have a very important place in agricultural production (Klein *et al.* 2017). Onion (*Allium cepa* L.) is an entomophilous plant whose fruit and seed quality and quantity can be improved by the pollination activity of floricultural insects (Abrol 2012). Onion is a monocotyledonous and allogamous plant (Abdou *et al*. 2015). It is generally consumed as a condiment in salads for its therapeutic and nutritional properties and cosmetic uses (Kianian *et al*. 2020). It is a 60 to 100 cm high plant, with cylindrical and hollow leaves, green in color (Foury and Schweisguth 1992). The base of the leaves may bulge when conditions are favorable and form a bulb (Foury and Schweisguth 1992). The erect floral stem is hollow, cylindrical, and has a bulge that ends by an umbel composed with 200–700 greenish-white bisexual flowers (Abdou *et al*. 2015). Self-pollination of flowers is not possible due to protandry (Abrol 2012). Since pollen is sticky (Bareke and Addi 2019), wind and gravity have almost no effect on its pollination (Devi *et al.* 2015).

Little work is done on the relationship between *A. cepa* and insects. Some work has shown that floricultural insects improve *A. cepa* yields. In India and Germany, bees are the most active pollinators of *A. cepa* (Devi *et al.* 2015). In Pakistan, the average number of seeds per umbel visited by insect pollinators is higher than that of unvisited umbel (Sajjad *et al*. 2008). In Cameroon, *A. mellifera* contributed to 61.52% of normal *A. cepa* seeds (Tchindebe and Tchuenguem 2014). No work was done on relations between *A. mellifera* and the most cultivated varieties of *A.*

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cepa. Furthermore, although known as the major pollinator of this plant, the pollination efficiency of *A. mellifera* is not evaluated in this locality. The objectives were to study the foraging activity of *A. mellifera* on Chagari flowers and to evaluate its direct pollination efficiency in fruit and seed yields.

Materials and Methods

Site and biological materials

The investigations were carried out in Mokong, a village in the subdivision of Mokolo, Division of Tsanaga, Far-North Region of Cameroon. The climate is Sudano-Sahelian type, characterised 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). Rainfall varies between 800 and 1000 mm/year (Kuete *et al*. 1993).

Chagari bulbs (Fig. 1–2) were supplied by a planter in Mokong and identified at IRAD of Maroua and the plants derived from these bulbs formed the plant material. The experimental plot was an area 8 m long 4.50 m wide (Fig. 1b) with geographical coordinates: Latitude 10°58.69'N, Longitude 14°02.961'E and Altitude 517 m. The plot was ploughed and 12 subplots measuring 1.5 m^2 were formed. The onion bulbs were planted in rows, with one bulb per bunch. The distance between rows, with one bulb per bunch. The distance between rows was 50 cm and between bunches was 20 cm. The plot was watered every three days. From planting to the opening of the first flower, weeding was carried out regularly with a hoe. From the opening of the first flower to the maturity of the seeds, the weeds were regularly pulled out by hand. The animal material consisted of insects that visited the Chagari flowers.

Activity of *Apis mellifera* on the onion flowers

The investigations were carried out from 02 February to 04 April 2020 and from 04 February to 06 April 2021 on 40 umbels each left to pollinate freely (treatments 1 & 1'). The observations were made every two days according to six daily time frames: 7 A.M. – 8 A.M., 9 A.M. – 10 A.M., 11 A.M. – 12 A.M., 1 P.M. – 2 P.M., 3 P.M. – 4 P.M. and 5 P.M. – 6 P.M. For each time frame, one pass was made on each umbel. The floral products collected (nectar and pollen) were systematically marked with a distinguishing sign. The percentage of nectar or pollen foragers (p) was calculated according to the following formula:

$$P = \frac{nf}{Na} x100$$

Where nf and Na are respectively the number of harvests of the floral product and the total number of harvest of all floral products.

The duration of pollen collection or nectar collection

(a) (b)

Fig. 1: Bulbs of Chagari onion (a) and partial view of the experimental plot (b) in Mokong in 2020

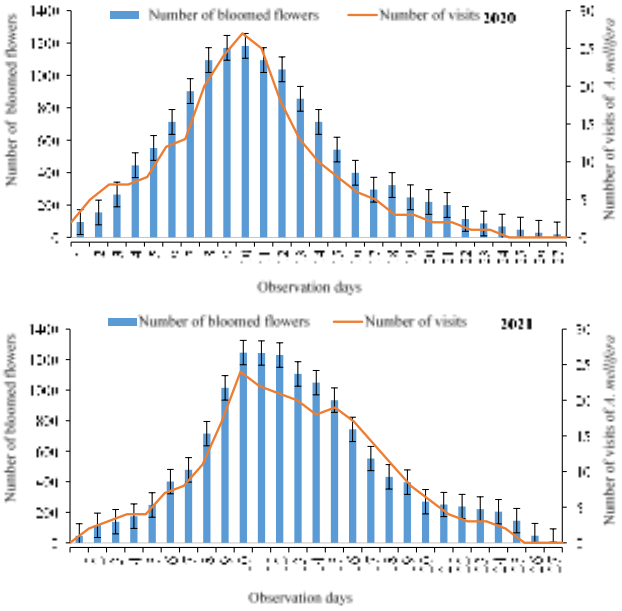

Fig. 2: Rhythm of visits of *A. mellifera* depending on bloomed flowers of Chagari onion in 2020 and 2021 experimental years

was recorded. The number of flowers visited by the forager was counted as she moved from one flower to another. The foraging speed (Fs) was calculated using the formula:

$$Fs = \frac{nf}{d} x60$$

Where d is duration in seconds and nf is the number of flowers visited during this duration (Tchuenguem *et al*. 2020). The temperature and hygrometry of the study station were recorded every 30 min from 7 A.M. to 6 P.M. using a Technoline portable thermo-hygrometer (WS9119) installed in the shade (Tchuenguem 2005).

Influence of direct pollination efficiency of *A. mellifera* on the yields of Chagari

Each year, when the flowers bloomed, each of the 40 umbels, previously isolated at the flower bud stage using gauze bags, was opened between 11 am and 12 pm to observe the flowers visited by *A. mellifera*. This was the time slot corresponding to the peak of *A. mellifera* activity

in Mokong. At each umbel, the gauze was carefully removed and the opened flowers were observed for 1 to 10 min. Opened flowers whose stigma was affected by *A. mellifera* were marked with thread. After this operation, the umbel was reprotected and not handled again. The flowers not visited formed treatments 2 & 2' and those visited formed treatments 3 & 3'. Ten days after the last labelled umbel bloomed, the number of fruits per umbel was counted. At maturity, the numbers of seeds per fruit and per treatment were counted. The direct pollination efficiency of *A. mellifera* in the fruiting rate (Dpefr) and the average seeds per fruit (Dpesfr) was calculated according to the following formula:

$$Dpegr = \frac{(gr3-gr2)}{gr3} \times 100 \text{ ---------- (Eq. 1)}$$

Where Dpep: direct pollination efficiency of *A. mellifera* in the parameter, V2 and V3: respectively are the values of parameter of treatments 2 & 3 (Tchuenguem *et al.* 2004).

One hundred seeds were collected and spread in a Petri dish with a cotton lining soaked with water (Rao *et al.* 2006). Each day, the number of germinated seeds was counted and removed from the dish. The cotton lining of the Petri dish was moistened whenever dryness was noted. Depending on seed availability, this operation was repeated three and two times respectively in treatments 2 and 3. The direct pollination efficiency of *A. mellifera* in the germination rate (Dpegr) was calculated according to the Eq. 1:

Data processing

Data processing was done using descriptive statistics (calculation of means, standard deviations and percentages) with IBM SPSS Statistics 20. Software and Microsoft Excel 2010 spreadsheet for four tests: Pearson Correlation coefficient (r) for the study of linear relationships between two variables; Student's t-test for the comparison of means of two samples and Chi-square (χ^2) for the comparison of percentages.

Results

Activity of *A. mellifera*

A. mellifera visited Chagari umbels between 7 am and 6 pm with the peak of activity located at 11 am –12 noon time frame for both years of observations (Table 1). The number of visits was proportional to the number of flowers bloomed (Fig. 3). Statistical analyses indicated a very highly significant positive correlation in 2020 ($P < 0.001$) and 2021 ($P < 0.001$) between the number of *A. mellifera* visits and the number of flowers bloomed. In 2020, out of 222 visits, 195 (87.84%) visits were for collecting nectar (Fig. 4) and 27 (12.16%) visits were for collecting pollen. In 2021, out of 248 visits, 221 (89.11%) visits were for collecting nectar and 27 (10.89%) visits for collecting pollen. The cumulative mean durations of nectar and pollen foraging visits were 3.66 sec (n = 217; s = 2.30; min = 1; max =10) and 1.64 sec (n = 226; s = 0.67; min = 1; max = 5) respectively (Table 2). The difference between the mean durations of nectar and pollen foraging visits was very high significant ($P < 0.001$).

In 2020 and 2021, the average foraging speed of *A. mellifera* was 23.77 flowers/min (n = 50; s = 9.99; min = 12.00; max = 60.00) and 24.35 flowers/min (n = 129; s =

Table 1: Rhythm of visits of *A. mellifera* on the Chagari onion according to daily time frames

Year	Visits	Daily time frames (h)						
		7–8	9–10	11–12	13–14	15–16	17–18	Total
2020	Number	6	56	69*	52	35	4	222
	%	2.70	25.23	31.08	23.42	15.77	1.80	100
2021	Number	7	70	97*	38	34	2	248
	%	2.82	28.23	39.11	15.32	13.71	0.81	100
Two cumulative years	Number	13	126	166*	90	69	6	470
	%	3.83	25.50	36.25	17.67	14.75	2.00	100

*Activity peak

Fig. 3: *A. mellifera* harvesting the nectar on the Chagari onion flower in Mokong in 2020

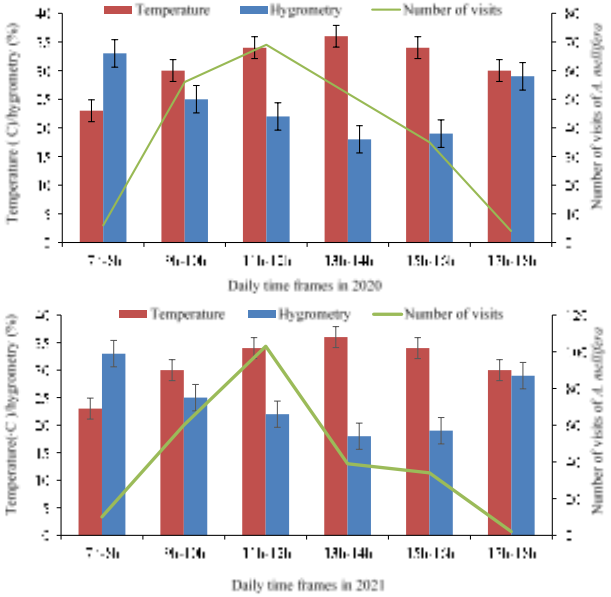

Fig. 4: Daily rhythm of visits of *A. mellifera* on the umbels of Chagari onion according to temperature and hygrometry in 2020 and 2021 experimental years

Table 2: Average duration of *A. mellifera* collecting floral products of Chagari in 2020 and 2021 in Mokong

Year	Floral products	Flower's time of visit (sec)				
		No. of samples	Mean	Standard deviation	Minimum	Maximum
2020	Nectar	50	3.82	2.72	1	10
	Pollen	50	1.70	1.68	1	3
2021	Nectar	167	3.61	2.17	1	10
	Pollen	176	1.63	0.67	1	5
Cumulative of years	Nectar	217	3.66	2.30	1	10
	Pollen	226	1.64	0.67	1	5

Table 3: Fruiting rate, average number of seeds per fruit, normal seeds rate, average mass of 100 seeds and germination rate of treatments 2, 3, 2' & 3' of Chagari in Mokong

Tr	Parameters studied														
	Fruiting rate			Seeds per fruit				No. of normal seeds		Average mass of 100 seeds			Germination parameters		
	NFS	NFF	FR (%)	NF	NS	M	SD	NNS	PNS (%)	N	M (g)	SD	NSS	NGS	GR (%)
2	11315	1986	17.55	400	881	2.20	1.74	159	18.05	8	0.34	0.01	400	85	21.25
3	284	214	75.35	214	770	3.60	1.41	419	54.42	7	0.36	0.02	400	116	29.00
2'	11821	2151	18.20	400	986	2.47	1.01	189	19.17	9	0.35	0.02	300	63	21.00
3'	136	90	66.18	90	312	3.47	0.95	173	55.45	4	0.37	0.02	300	84	28.00

Tr: treatment; 2 & 3: in 2020; 2' & 3': in 2021; NFS: number of flowers studied; NFF: number of fruits formed; FR: fruiting rate; NF: number of fruit; NS: number of seeds; M: mean; SD: standard deviation; NNS: number of normal seeds; PNS: Percentage of normal seeds; NSS: number of seeds sowed; N: size of sample, NGS Number of germinated seeds; GR: germination rate

10.43; min = 12.26; max = 60.00), respectively. The difference between these average foraging speeds was non-significant ($P > 0.05$). For two cumulative years the average foraging speed was 24.19 flowers/min (n = 179; s = 10, 28; min = 12.00; max = 60.00).

Fig. 4 reveals the number of visits of *A. mellifera* on Chagari flowers as a function of the daily variation of hygrometry and temperature during flowering. In 2020, the correlation between the number of visits and the temperature was positive and non-significant ($P > 0.05$) and the correlation between the number of visits and hygrometry was negative and significant ($P < 0.05$). In 2021, the correlation between the number of visits and the temperature was positive and non-significant ($P > 0.05$) and the correlation between the number of visits and hygrometry was negative and non-significant ($P > 0.05$).

Direct pollination efficiency of *A. mellifera* on the yields of Chagari

Fruiting rate of treatments 2 & 2' (flowers opened and reprotected without visit) was 17.55 and 18.20% in 2020 and 2021 respectively (Table 3). The fruiting rates of treatments 3 & 3' (flowers visited excusivly by *A. mellifera*) were 75.35 and 66.18% in 2020 and 2021 respectively. The difference was highly significant between the yields of treatments 2 & 3 ($P < 0.001$) and treatments 2' & 3' ($P < 0.001$). The direct pollination efficiency of *A. mellifera* in the fruiting rate (Dpefr) of Chagari was 76.71 in 2020 and 72.50 in 2021. The difference was non-significant ($P > 0.05$) between these direct pollination efficiencies. The direct pollination efficiency of *A. mellifera* in the fruiting rate for the two cumulative years was 74.61. The average number of seeds per fruit of treatments 2 & 2' was 2.20 (n = 400; s = 1.74) and 2.47 (n = 400; s = 1.01) respectively. The average numbers of seeds per fruit of treatments 3 & 3' were 3.60 (n = 214; s = 1.41) and 3.47(n = 90; s = 0.95) respectively. The difference was very highly significant between the yields of treatments 2 & 3 ($P < 0.001$) and treatments 2' & 3' ($P < 0.0001$). The direct pollination efficiencies of *A. mellifera* on the average number of seeds per fruit (Dpesf) of Chagari in 2020 and 2021 were 38.89 and 28.82 respectively. The difference between these direct pollination efficiencies was non-significant ($P > 0.05$). The direct pollination efficiency of *A. mellifera* on the average number of seeds per fruit of Chagari for two cumulative years was 33.96%. The germination rate of treatments 2 & 2' was 21.25 and 21.00 respectively. The germination rate in treatments 3 & 3' was 29.00 and 28.00 respectively. The difference was non-significant between the germination rate of treatments 2 & 3 ($P > 0.05$) and treatments 2' & 3' ($P > 0.05$).

Discussion

The peak of activity of *A. mellifera* corresponded to the maximum availability of nectar and/or pollen in the flowers as reported by De Andrade *et al.* (2014). Our results are similar to those of Yücel and Duman (2005) on onion from Pakistan. Tchindebe and Tchuenguem (2014) in Maroua showed that the peak of activity of *A. mellifera* on *A. cepa* was between 9:00 and 10:00 am. The variation of the peak activity could be explained by the variation of weather conditions which changed the maximum availability of flowers product. According to Abrol (2012), the peak activity of *A. mellifera* is a function of the availability of floral products in the flowers to be exploited. The attractiveness of Chagari onion fluctuated with the number

of flowers opened. The required number of foragers depends on the number of flowers available (Abrol 2012).

A very high harvest of nectar compared to pollen could be due to its availability. In addition, nectar is sweeter than pollen (Pesson and Louveaux 1984). According to Abrol (2012), nectar of onion is produced in large quantities and is easily digested. These results are in agreement with observations made by Tchindebe and Tchuenguem (2014) in Maroua, who listed *A. cepa* among the very strongly nectariferous and lowly polliniferous beekeeping plants.

The difference between the duration of nectar and pollen collection could be explained by the accessibility of these floral products. In fact, the pollen produced by the anthers is located at the top of the stamens. It would thus be easily accessible and take less time to harvest. The nectar, trapped between the base of the ovary and the inner stamens would be difficult to extract and waste more time (Tchuenguem *et al*. 2004). In Maroua, Tchindebe and Tchuenguem (2014) obtained 19.92 flowers/min. The difference was non-significant between the foraging speeds in Mokong and in Maroua ($P > 0.05$). The number of *A. mellifera* visits would be influenced by the hygrometry. Indeed, when the hygrometry drops, the nectar becomes sweeter and more attractive. Pesson and Louveaux (1984) reported that the attractiveness of flower products is affected by its concentration in sugar.

The foraging activity of the workers would shake the flowers by facilitating the optimal release of pollen for the occupation of the stigma and would thus play a positive role in geitonogamy and xenogamy (Pesson and Louveaux 1984; Brahim *et al*. 2018). These large amounts of pollen come in contact with the stigmas with possibilities of selecting pollen tubes in the style before fertilizing the ovules. According to Abrol (2012), the transfer of pollen grains from the stamens to the stigma involves vectors such as insects and the absence of pollination or failed pollination resulted in the absence of fruits and seeds.

Conclusion

A. mellifera collected nectar and pollen from the flowers of the *A. cepa* (Chagari variety) in Mokong. A single visit of *A. mellifera* significantly increased fruiting rate, average number of seeds per fruit and percentage of normal seeds of this variety of onion. The establishment of *A. mellifera* colonies near fields of *A. cepa* variety Chagari is recommended to improve its fruit and seed yield.

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Author Contributions

A Koffa and ASB Kameni collected the data. D Djonwangwé, FF-N Tchuenguem and J D Djakbé planned the experiments. D Djonwangwé and FF-N Tchuenguem performed the analysis. A koffa and D Djonwangwé interpreted the results and made illustrations. A koffa and D Djonwangwé and FF-N Tchuenguem and wrote the manuscript.

Conflicts of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

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