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# Diversity of insect pollinators of *Allium cepa* L. (Liliaceae) and assessment of its impact on yields at Gazawa (Cameroon)

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**ABSTRACT**

To evaluate the impact of insect pollinators on pod, seeds, and seed yields of *Allium cepa,* the pollinating activities of flowering insects were studied in Maroua, during two dry seasons in 2017 and 2018 (November-April). Observations were made on 40–120 flowers per treatment. The flowers were subjected to different treatments: Treatment 1 (Free flowers); treatment 2 (bagged flowers); treatment 3 (castrated and free flowers); and treatment 4 (castrated and bagged flowers). About 320 flowers of *A. cepa* (Liliaceae) were observed in 2017 and 2018, respectively, for the diversity and frequency of insects' visits. For results, 6581 visits of 32 insect species distributed in seven orders were recorded on *A. cepa* flowers. The most dominating Hymenoptera observed was *Apis mellifera* followed by *Lipotriches collaris* with 24.49% and 12.43% of the total insect visits, respectively. The highest number of insect pollinators harvested in the flowers of this Liliaceae was between 8 and 9 h. The studied insects have a positive impact on the yields of this plant. This positive impact of the pollinator insects on the yields was 81.09%, 87.79%, and 96.54% in fructification rate, number of seeds pod, and percentage of normal seeds, respectively. The avoidance of pesticide treatment of plants during flowering could be a good management strategy to improve on plant yield.

## 1. INTRODUCTION

Onion, *Allium cepa* L., is originated from south and Central America [1]. It is grown in all country of the World [2] for its bulbs [1]. Onion has been used in various forms food as salads, as a raw or cooked vegetable, and as a condiment [3]. Its bulbs are a major vegetable source of Vitamin C and B, potassium, flavonoids, folic acid, calcium, and iron for man [2,4]. The production in Cameroon is estimated at 112441 tons, with 14.77 tons/ha. The far north region is the largest Producers of onion in the country 87.13% [5]. The production is low and the demand of bulbs is high in this country [6]. The main problem that growers are facing is how to obtain optimum seed yield to provide the good production of bulbs. Self-pollinating is generally not observing in the pollination of onion due to its protandrous nature [7]. The flowers of *A. cepa* produce nectar and pollen, which attracts insects [8]. To increasing the production of this plant in Maroua (Cameroon), it is important to investigate on the possibilities of flowering insects. It can be possible if local insects of *A. cepa* are known and exploited. The researchers conducted in Kenya, in India and in Cameroun revealed that onion does not produce good seed without pollinators [8-10]. During the collect of nectar and pollen on the flowers, the insects increase quantity and quality of the seeds [9]; it is now that the activities of pollinator insects on the flowers can vary with region [11]. The main objective of this research was to collect more data on the relations between *A. cepa* and flowering insects. Specific objectives were (a) to determinate the diversity of flowering insects of *A. cepa*, (b) to evaluate the frequency of this insects on *A. cepa* flowers, and (c) to evaluate the impact of flowering insects on pollination and yield of this plant.

## 2. MATERIALS AND METHODS

### 2.1. Site and Biological Materials

The studies were conducted from November to April in 2017 and 2018, respectively, in the locality of Barza (Gazawa) Diamare division (Latitude 10°54.095 N, longitude 14°12.892 E, and altitude 387 masl) in the Far North Region of Cameroon. Insect pollinators naturally present in the environment of the study represented the animal

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material. The plant material was represented by the bulbs of *A. cepa* provided by the Institute of Agricultural Research for Development of Djarengol (Maroua).

## 2.2. Methods

### *2.2.1. Planting and maintenance of culture*

At the beginning of each dry season (November) the experimental field was divided into 24 subplots of 1.5 × 1.5 $m^2$ each. Thirty onions bulbs were planted as nursery. About a period of 1 month, the nursery was transfer to the 24 subplots [8]. During the growing period, 5 kg of fertilizer (20-10-10) was applied on the plants. Plants were watered once a week. Weeding was done manually at the beginning of flowering until harvest.

### *2.2.2. Diversity and frequency of flowering insects on the flowers of A. cepa*

On November 22, 2017, 24 subplots carrying 240 plants were labeled. Three subplots carrying 38 plants were left for open pollination (treatment 1), three subplots carrying the same number of plants like treatment 1 were protected with gauze mesh to prevent pollinator insects (treatment 2), 38 plants distributed in three subplots and only 40 flowers were destined to castration (treatment 3) and 38 plants carry by the last subplots and in the same subplot only 40 flowers were destined to be castrated and then protected with gauze mesh like treatment 2 (treatment 4). For castration, the stigmata were delicately remove using tongs.

The experiment was repeated in 2017. For each year, the pods were collected and the seeds were calculated.

The diversity of flowering insects that visited *A. cepa* flowers was appreciated; capture was done on flowers of treatment 1 and insects were conserved, described, and identified using the method of Borror and White [12], Eardley *et al*. [13], Eardley [14]. To know about the frequency of insect pollinators in the flowers of *A. cepa,* observations were done each day, from February 15 to March 16, 2017 and from February 12 to March 19, 2018. These observations were done during three slots per day (8–9 h, 12–13 h, and 16–17 h). The determination of the relative frequency of all insects that visited the *A. cepa* flowers was calculated using the formula: $Fi = \{[(Vi)/VI] \times 100\}$ (1), where *Vi* was the number of flowering insect *i* on flowers of treatment 1 and *VI* was the number of visits of all pollinator insects [11].

### *2.2.3. Impact of flowering insects on the pollination of A. cepa*

The evaluation of the impact of flowering insects on the pollination of *A. cepa* was done in the study and the frequency of insect visits was calculated. It was to record the number of times that the insect's body comes in contact with the anther of flower. This can indicate the possibility of flowering insect to participation in the self-pollination and cross-pollination [15]. To determine the different categories of pollinators, the regularity index (*Id*) was calculated using the formula: $Id = ([P/100] \times [f/100])$, where *P* and *f* are the percentage of insect visits and the relative frequency of insect visits.

### *2.2.4. Incidence of flowering insects on A. cepa yields*

Evaluation was based on the impact of visiting flowers on pollination, the impact of pollination on fructification of *A. cepa*, and the comparison of yields (fruiting rate, mean number of seeds per pod, and percentage of well-developed seeds) of treatments 1, 2, 3, and 4.

- The fruiting rate due to the activity of insects ($Fr_i$) was calculated as follows: $Fr_i = \{[(Fr_x - Fr_y)/Fr_x] * 100\}$. Where $Fr_x$ and $Fr_y$ are the fruiting rates in each treatment.
- The fruiting rate (*Fr*) is: $Fr = [(F_2/F_1) * 100]$. Where $F_2$ is the number of pods formed and $F_1$ the number of flowers initially set.
- The percentage of mean number of seeds per pod due to the activity of insects (*Spi*) was calculated using the formula: $Spi = \{[(Sp_x - Sp_y)/Sp_x] * 100\}$. Where $Sp_x$ and $Sp_y$ are the percentages of seeds per pods in different treatments.
- The percentage of normal seeds due to the activity of insects (*Nsi*) was calculated as follows: $Nsi = \{[(Ns_x - Ns_y)/Ns_x] * 100\}$. Where $Ns_x$ and $Ns_y$ are the percentages of normal seeds in different treatments.

### *2.2.5. Data analysis*

Data were analyzed using descriptive statistics, Student's *t*-test, correlation coefficient (*r*), Chi-square ($\chi^2$), ANOVA. We also used SPSS statistical software and Microsoft Excel.

## 3. RESULTS

### 3.1. Diversity and Frequency of Entomofauna Insects of *A. cepa*

Among the 3350 and 3231 visits of 31 and 32 insect species counted on *A. cepa* flower in 2017 and 2018. For the two cumulated years; five orders of anthophilous insects were found on *A. cepa* flowers including: Diptera, Coleoptera, Hemiptera, Hymenoptera, and Lepidoptera [Table 1 and Figure 1]. Thirty two flowering insects were represented on *A. cepa* flowers: Constant species that include (*Apis mellifera, Amegilla calens, Xylocopa olivacea, Lipotriches collaris, Chalicodoma rufipes, Belonogaster juncea, Xylocopa inconstans, Xylocopa nigrita, Lipotriches azarensis, Lasioglossum saegeri*, *Megachile bituberulata, Vespula vulgaris,* and *Lasioglossum atricrum*) and accidental species (*Pachnoda interrupta, Hypolimnas misippus*, *Aulacophora foveicollis, Danaus chrysippus, Eurema* sp.1, *Vanessa cardui, Catopsilia florella,* Reduviidae (1sp.), *Anoplocnemis curvipes, Ammophila* sp., *Philanthus triangulum, Camponotus flavomarginatus*, *Episyrphus balteatus, Chrysotoxum intermedium, Paragus borbonicus, Chrysomya chloropyga, Musca domestica, Coryna* sp., and *Mylabris* sp.) [Table 2]. Flowering insects have been dynamic on the flowers of *A. cepa* from 8 am to

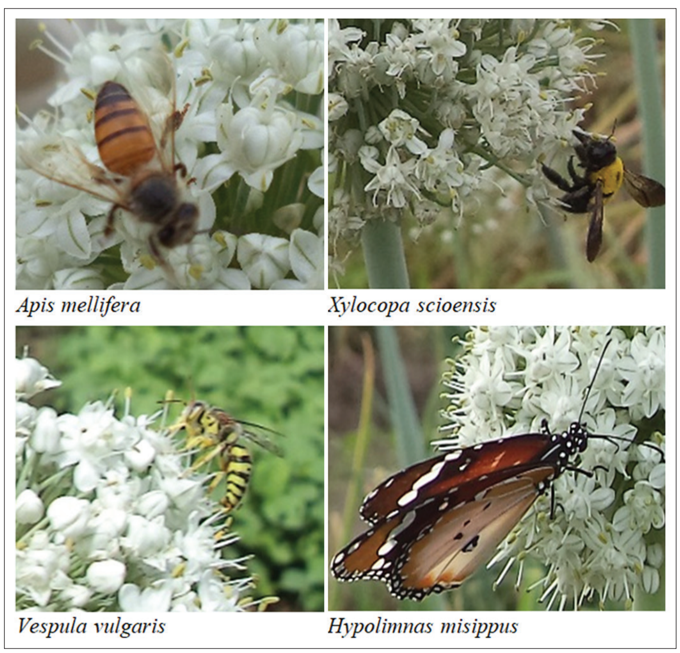


**Figure 1:** Some pollinators insects on flowers of *Allium cepa.*

**Table 1:** Diversity of flowering insects on *Allium cepa* in 2017 and 2018, number and percentage of visits of different insects.

| Insects | Family | Species | 2017 | | 2018 | | Total | |
|---|---|---|---|---|---|---|---|---|
| Order | | | $n_1$ | $P_1$ (%) | $n_2$ | $P_2$ (%) | $n_t$ | $P_t$ (%) |
| Hymenoptera | Apidae | *Apis mellifera* (N, P) | 773 | 23.07 | 839 | 25.97 | 1612 | 24.49 |
| | | *Amegilla calens* (N) | 201 | 6.00 | 153 | 4.74 | 354 | 5.38 |
| | | *Xylocopa olivacea* (N) | 179 | 5.34 | 418 | 12.94 | 597 | 9.07 |
| | | *Xylocopa inconstans* (N) | 142 | 4.24 | 257 | 7.95 | 399 | 6.06 |
| | | *Xylocopa nigrita* (N) | 187 | 5.58 | 49 | 1.52 | 236 | 3.59 |
| | Halictidae | *Lipotriches collaris* (P) | 321 | 9.58 | 497 | 15.38 | 818 | 12.43 |
| | | *Lipotriches azarensis* (P) | 108 | 3.22 | 45 | 1.39 | 153 | 2.32 |
| | | *Lasioglossum atricrum* (P) | 98 | 2.93 | 67 | 2.07 | 165 | 2.51 |
| | | *Lasioglossum saegeri* (P) | 76 | 2.27 | 98 | 3.03 | 174 | 2.64 |
| | Megachilidae | *Megachile bituberulata* (P) | 44 | 1.31 | 51 | 1.58 | 95 | 1.44 |
| | | *Chalicodoma rufipes* (N) | 276 | 8.24 | 170 | 5.26 | 446 | 6.78 |
| | Vespidae | *Belonogaster juncea* (N) | 114 | 3.40 | 98 | 3.03 | 212 | 3.22 |
| | | *Vespula vulgaris* (N) | 19 | 0.57 | 34 | 1.05 | 53 | 0.81 |
| | Sphecidae | *Ammophila* sp. (N) | 19 | 0.57 | 33 | 1.02 | 52 | 0,79 |
| | | *Philanthus triangulum* (N) | 67 | 2.00 | 16 | 0.50 | 83 | 1,26 |
| | Formicidae | *Camponotus flavomarginatus* (po) | 153 | 4.57 | 111 | 3.44 | 264 | 4,01 |
| Diptera | Syrphidae | *Episyrphus balteatus* (N) | 91 | 2.72 | 5 | 0.15 | 96 | 1,46 |
| | | *Chrysotoxum intermedium* (N) | 34 | 1.01 | 13 | 0.40 | 47 | 0,71 |
| | | *Paragus borbonicus* (P) | 58 | 1.73 | 44 | 1.36 | 102 | 1,55 |
| | Calliphoridae | *Chrysomya chloropyga* (N) | 41 | 1.22 | 31 | 0.96 | 72 | 1.09 |
| | Muscidae | *Musca domestica* (N) | 13 | 0.39 | 6 | 0.19 | 19 | 0.29 |
| Coleoptera | Meloidae | *Coryna* sp. (P) | 77 | 2.30 | 9 | 0.28 | 86 | 1.31 |
| | | *Mylabris* sp. (P) | 43 | 1.28 | 21 | 0.65 | 64 | 0.97 |
| | Cetoniidae | *Pachnoda interrupta* (P) | 11 | 0.33 | 64 | 1.98 | 75 | 1.14 |
| Lepidoptera | Chrysomelidae | *Aulacophora foveicollis* (P) | 8 | 0.24 | 17 | 0.53 | 25 | 0.38 |
| | | *Eurema* sp.1 (P) | 70 | 2.09 | 18 | 0.56 | 88 | 1.34 |
| | Pieridae | *Vanessa cardui* (N) | 47 | 1.40 | 19 | 0.59 | 66 | 1.00 |
| | | *Catopsilia florella* (N) | 66 | 1.97 | 40 | 1.24 | 106 | 1,61 |
| | Nymphalidae | *Danaus chrysippus* (P) | 10 | 0.30 | 4 | 0.12 | 14 | 0.21 |
| | | *Hypolimnas misippus* (N) | 2 | 0.06 | 1 | 0.03 | 3 | 0.05 |
| Hemiptera | Reduviidae | (1sp.) (P) | - | - | 2 | 0.06 | 2 | 0.03 |
| | Pentatomidae | *Anoplocnemis curvipes* (P) | 2 | 0.06 | 1 | 0.03 | 3 | 0.05 |
| | | | 3350 | 100 | 3231 | 100 | 6581 | 100 |

$n_1$: Number of visits on 320 flowers in 16 days; $n_2$: Number of visits on 320 flowers in 14 days; $n_t$: Number of visits on 640 flowers in 30 days; $p_1$, $p_2$ and pt: percentages of visits; $p_1 = (n_1/3350) *100$; $p_2 = (n_2/3231) *100$; pt=(nt/6581)*100; sp.: Undetermined species; (N): Nectar gather; (P): Pollen gather

17 pm, with a peak of visits between 8 and 9 am in 2017 and 2018 [Table 3].

### 3.2. Impact of Flowering Insects on Pollination of *A. cepa*

Three categories of pollinators were observed on flowers of *A. cepa* in 2017 and 2018 [Table 4]:

- Major pollinators (*Id* >0.05 and/or *P* > 50%) *A. mellifera, A. calens, X. olivacea, X. inconstans*, and *L. collaris*.
- Minor pollinators (0,05 ≤ *Id* < 0.001 and/or 50 ≤ *P* < 25) *X. nigrita, L. azarensis, L. atricrum*, *L. saegeri*, *M. bituberulata, C. rufipes, B. juncea, V. vulgaris, Ammophila* sp., *P. triangulum, C. flavomarginatus*, *E. balteatus, C. intermedium, P. borbonicus, C. chloropyga, M. domestica, Coryna* sp., *Mylabris* sp., *P. interrupta, Eurema* sp.1, *V. cardui*, and *C. florella.*
- Occasional pollinators (*Id* < 0.001 and/or *p* < 25) *H. misippus*, *A. foveicollis, D. chrysippus,* Reduviidae (1sp.), and *A. curvipes.*

### 3.3. Impact of Anthophilous Flowering Insects on Yield of *A. cepa*

During foraging behavior on flower of *A. cepa,* flowering insects always shook flowers and are regularly in contact with the anthers and stigma (*P* = 90.10%), increasing pollination possibility of *A. cepa* fruiting rate, number of seeds, and proportion of normal seeds [Table 5].

a - The comparison of the fruiting rate showed that the difference was very highly significant between treatments in 2017 ($F = 16.67$, $df = 3$, $P < 0.001$) and in 2018 ($F = 13.12$, $df = 3$, $P < 0.001$). The difference observed was highly significant between fruiting rate of free opened

**Table 2:** Distribution of flowering insects according to the seasonal frequency of visits in 2017 and 2018.

| Insects | 2017 | | 2018 | | Total | | Category of insects |
|---|---|---|---|---|---|---|---|
| | *n*1 | $f_1$(%) | $n_2$ | $f_2$(%) | $n_{1,2}$ | $f_{1,2}$(%) | |
| *Apis mellifera* | 16 | 100 | 14 | 100 | 30 | 100 | Constant species (f ≥50%) |
| *Amegilla calens* | 14 | 87.5 | 14 | 100 | 28 | 93.3 | |
| *Xylocopa olivacea* | 11 | 68.7 | 14 | 100 | 25 | 83.3 | |
| *Lipotriches collaris* | 16 | 100 | 14 | 100 | 30 | 100 | |
| *Chalicodoma rufipes* | 13 | 81.2 | 11 | 100 | 24 | 80 | |
| *Belonogaster juncea* | 9 | 56.2 | 8 | 57.14 | 17 | 65 | |
| *Xylocopa inconstans* | 8 | 50 | 8 | 57.14 | 16 | 53.33 | |
| *Xylocopa nigrita* | 9 | 56.25 | 9 | 64.28 | 18 | 60 | |
| *Lipotriches azarensis* | 10 | 62.5 | 11 | 78.57 | 21 | 70 | |
| *Lasioglossum saegeri* | 9 | 56.25 | 7 | 50 | 16 | 53.33 | |
| *Megachile bituberulata* | 11 | 68.75 | 9 | 57.14 | 20 | 66.66 | |
| *Vespula vulgaris* | 8 | 50 | 8 | 57.14 | 16 | 53.33 | |
| *Lasioglossum atricrum* | 9 | 56.25 | 9 | 57.14 | 18 | 60 | |
| *Pachnoda interrupta* | 3 | 18.7 | 2 | 20 | 5 | 26.15 | Accidental species (f <25%) |
| *Hypolimnas misippus* | 1 | 6.25 | 2 | 40 | 3 | 10 | |
| *Aulacophora foveicollis* | 1 | 6.25 | 2 | 20 | 3 | 10 | |
| *Danaus chrysippus* | 2 | 12.5 | 3 | 40 | 5 | 16.6 | |
| *Eurema* sp.1 | 3 | 18.75 | 6 | 42.86 | 9 | 30.00 | |
| *Vanessa cardui* | 3 | 18.75 | 5 | 35.71 | 8 | 26.67 | |
| *Catopsilia florella* | 4 | 25 | 5 | 35.71 | 9 | 30.00 | |
| Reduviidae (1sp.) | 1 | 6.25 | 3 | 21.43 | 4 | 13.33 | |
| *Anoplocnemis curvipes* | 3 | 18.75 | 4 | 28.57 | 7 | 23.33 | |
| *Ammophila* sp. | 2 | 12.5 | 4 | 28.57 | 6 | 20.00 | |
| *Philanthus triangulum* | 2 | 12.5 | 5 | 35.71 | 7 | 23.33 | |
| *Camponotus flavomarginatus* | 3 | 18.75 | 3 | 21.43 | 6 | 20.00 | |
| *Episyrphus balteatus* | 2 | 12.5 | 1 | 7.14 | 3 | 10.00 | |
| *Chrysotoxum intermedium* | 1 | 6.25 | 3 | 21.43 | 4 | 13.33 | |
| *Paragus borbonicus* | 2 | 12.5 | 1 | 7.14 | 3 | 10.00 | |
| *Chrysomya chloropyga* | 2 | 12.5 | 1 | 7.14 | 3 | 10.00 | |
| *Musca domestica* | 3 | 18.75 | 2 | 14.29 | 5 | 16.67 | |
| *Coryna* sp. | 2 | 12.5 | 2 | 14.29 | 4 | 13.33 | |
| *Mylabris* sp. | 1 | 6.25 | 2 | 14.29 | 3 | 10.00 | |
| | 16 | 100 | 14 | 100 | 30 | 100 | |

$n_1$: Number of observation days in 2017. $n_2$: Number of observation days in 2018. $n_{1,2}$: Number of observation days in 2017 and in 2018. $f_1$: Relative frequency of visits in 2017. $f_2$: Relative frequency of visits in 2018. $f_{1,2}$: Relative frequency of visits in 2017 and in 2018.

flowers (treatment 1) and that of bagged flowers (treatment 2) ($\chi^2 = 161.96$, $df = 1$, $P < 0.001$), free flowers (treatment 1) and castrated and bagged flowers (treatment 4) ($\chi^2 = 113.17$, $df = 1$, $P < 0.001$). The difference observed was not significant between fruiting rate of free opened flowers (treatment 1) and castrated and opened flowers (treatment 3) ($\chi^2 = 0.11$, $df = 1$, $P > 0.05$) in 2017 and ($\chi^2 = 0.11$, $df = 1$, $P > 0.05$) in 2018. In the 2nd year, the same results were ($\chi^2 = 138.76$, $df = 1$, $P < 0.001$) and ($\chi^2 = 101.44$, $df = 1$, $P < 0.001$). The fruiting rate of treatment 1 and 3 was higher than treatments 2 and 4 in 2017 and in 2018. The fruiting rate due to the action of insects was 80.51 and 81.67% in 2017 and 2018, respectively. For the two cumulated years, the fructification rate due to the influence of insects was 81.09%.

b - The comparison of the mean number of seeds per pod showed that the difference was highly significant between treatments in 2017 ($F = 9.35$, $df = 3$, $P < 0.001$) and in 2018 ($F = 8.72$, $df = 3$, $P < 0.001$). The difference observed was highly significant between mean number of seeds per pod in treatment 1 and treatment 2 ($t = 29.41$, $df = 133$, $P < 0.001$), the same observation was fund in treatment 1 and treatment 3 ($t = 9.12$, $df = 172$, $P < 0.001$), and the difference observed was significant between mean number of seeds per pod in treatment 1 and treatment 4 ($t = 22.21$, $df = 130$, $P < 0.001$) in the 1st year. In the 2nd year, the difference was significant between mean number of seeds per pod in treatment 1 and treatment 2 ($t = 29.41$, $df = 133$, $P < 0.001$) and between treatment 1 and treatment 3 ($t = 14.12$, $df = 176$, $P < 0.001$). The mean number of seeds per pod in treatment 1 was higher than treatments 2, 3, and 4 in 2017 as well as in 2018. The mean number

**Table 3:** Variation of number of visits on flowers of *Allium cepa* giving to the daily time.

| Insects | Number of visits | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6–7 h | | 8–9 h | | 10–11 h | | 12–13 h | | 16–17 h | | Total |
| | *n* | *P* (%) | *n* | *P* (%) | *n* | *P* (%) | *n* | *P* (%) | *n* | *P* (%) | |
| *Apis mellifera* | 223 | 13.83 | 812 | 50.37* | 362 | 22.46 | 119 | 7.38 | 96 | 5.96 | 1612 |
| *Amegilla calens* | 45 | 12.71 | 74 | 20.90* | 46 | 12.99 | 17 | 4.80 | 172 | 48.59 | 354 |
| *Xylocopa olivacea* | 46 | 7.71 | 215 | 36.01* | 189 | 31.66 | 93 | 15.58 | 54 | 9.05 | 597 |
| *Xylocopa inconstans* | 53 | 13.28 | 176 | 44.11* | 68 | 17.04 | 74 | 18.55 | 28 | 7.02 | 399 |
| *Xylocopa nigrita* | 82 | 34.75* | 52 | 22.03 | 61 | 25.85 | 24 | 10.17 | 17 | 7.20 | 236 |
| *Lipotriches collaris* | 210 | 25.67 | 479 | 58.56* | 103 | 12.59 | 15 | 1.83 | 11 | 1.34 | 818 |
| *Lipotriches azarensis* | 66 | 43.14 | 81 | 52.94* | 17 | 11.11 | 23 | 15.03 | 32 | 20.92 | 153 |
| *Lasioglossum atricrum* | 17 | 10.30 | 59 | 35.76* | 1 | 0.61 | 49 | 29.70 | 56 | 33.94 | 165 |
| *Lasioglossum saegeri* | 43 | 24.71 | 142 | 81.61* | 8 | 4.60 | 6 | 3.45 | 18 | 10.34 | 174 |
| *Megachile bituberulata* | 19 | 20.00 | 32 | 33.68 * | 28 | 29.47 | 38 | 40.00 | 16 | 16.84 | 95 |
| *Chalicodoma rufipes* | 93 | 20.85 | 206 | 46.19* | 111 | 24.89 | 25 | 5.61 | 11 | 2.47 | 446 |
| *Belonogaster juncea* | 2 | 0.94 | 193 | 91.04* | 15 | 7.08 | 6 | 2.83 | 2 | 0.94 | 212 |
| *Vespula vulgaris* | 3 | 5.66 | 24 | 45.28* | 8 | 15.09 | 11 | 20.75 | 7 | 13.21 | 53 |
| *Ammophila* sp. | 5 | 9.62 | 42 | 80.77 * | 5 | 9.62 | 0 | - | 0 | - | 52 |
| *Philanthus triangulum* | 8 | 9.64 | 72 | 86.75* | 1 | 1.20 | 1 | 1.20 | 1 | 1.20 | 83 |
| *Camponotus flavomarginatus* | 66 | 25.00 | 113 | 42.80* | 51 | 19.32 | 22 | 8.33 | 12 | 4.55 | 264 |
| *Episyrphus balteatus* | 15 | 15.63 | 61 | 63.54* | 11 | 11.46 | 9 | 9.38 | 0 | - | 96 |
| *Chrysotoxum intermedium* | 10 | 21.28 | 30 | 63.83* | 1 | 2.13 | 4 | 8.51 | 2 | 4.26 | 47 |
| *Paragus borbonicus* | 32 | 31.37 | 61 | 59.80* | 6 | 5.88 | 2 | 1.96 | 1 | 0.98 | 102 |
| *Chrysomya chloropyga* | 12 | 16.67 | 33 | 45.83* | 23 | 31.94 | 3 | 4.17 | 1 | 1.39 | 72 |
| *Musca domestica* | 3 | 15.79 | 11 | 57.89* | 4 | 21.05 | 1 | 5.26 | 0 | - | 19 |
| *Coryna* sp. | 2 | 2.33 | 44 | 51.16* | 21 | 24.42 | 11 | 12.79 | 8 | 9.30 | 86 |
| *Mylabris* sp. | 11 | 17.19 | 23 | 35.94* | 16 | 25.00 | 11 | 17.19 | 3 | 4.69 | 64 |
| *Pachnoda interrupta* | 2 | 2.67 | 31 | 41.33* | 22 | 29.33 | 18 | 24.00 | 2 | 2.67 | 75 |
| *Hypolimnas misippus* | 0 | - | 2 | 66.67* | 1 | 33.33 | 0 | - | 0 | - | 3 |
| *Aulacophora foveicollis* | 2 | 8.00 | 14 | 56.00* | 5 | 20.00 | 4 | 16.00 | 0 | - | 25 |
| *Eurema* sp.1 | 18 | 20.45 | 39 | 44.32* | 14 | 15.91 | 9 | 10.23 | 8 | 9.09 | 88 |
| *Vanessa cardui* | 7 | 10.61 | 41 | 62.12 * | 12 | 18.18 | 4 | 6.06 | 2 | 3.03 | 66 |
| *Catopsilia florella* | 31 | 29.25* | 30 | 28.30 | 8 | 7.55 | 4 | 3.77 | 33 | 31.13 | 106 |
| *Danaus chrysippus* | 2 | 15.38 | 3 | 23.08 | 1 | 7.69 | 4 | 30.77* | 3 | 23.08 | 13 |
| Reduviidae (1sp.) | 0 | - | 0 | - | 1 | 33.33 | 0 | - | 2 | 66.67* | 3 |
| *Anoplocnemis curvipes* | 0 | - | 1 | 33.33* | 1 | 33.33* | 1 | 33.33* | 0 | - | 3 |
| Total | 1128 | 17.14 | 3196 | 48.56* | 1221 | 18.55 | 608 | 9.24 | 598 | 9.09 | 6581 |

*n* : number of visits ; *p*(%) : percentage of visits ; (*) : peak of visits

of seeds per pod due to the action of insects was 85.59% in 2017 and 90% in 2018. For the two cumulated years, the mean number of seeds per pod due to the influence of insects was 87.79%.

c – By comparing the percentage of normal seeds, we obtained that the difference was highly significant between treatments in 2017 ($\chi^2 = 216$, $df = 2$, $P < 0.001$) and in 2018 ($\chi^2 = 344.19$, $df = 2$, $P < 0.001$). The difference observed was highly significant between the percentage of normal seeds of in treatment 1 and treatment 2 ($\chi^2 = 91.43$, $df = 1$, $P < 0.001$), the same observation was fund in treatment 1 and treatment 3 ($\chi^2 = 19.87$, $df = 1$, $P < 0.001$) in the 1st year. In the 2nd year, the results were $\chi^2 = 129.68$, $df = 1$, $P < 0.001$ in treatment 1 and treatment 2 and $\chi^2 = 221.13$, $df = 1$, $P < 0.001$ in treatment 1 and treatment 3. The percentage of normal seeds of treatment 1 was higher than treatments 2 and 3 in 2017 as well as in 2018. The mean percentage of normal seeds due to the action f insects was 97.02% in 2017 and 96.07% in 2018. For the two cumulated years, the mean number of seeds per pod due to the influence of insects was 96.54%.

## 4. DISCUSSION

In Maroua during our observation period the must flowering insects visited the *A. cepa* flowers is representing by the order of the Hymenoptera witch 86.81% of all visits; in Cameroun [8,10], in India [3] found that the Hymenoptera were most abundant insects on the flowers of this Liliaceae witch respectively 60 and 83%. Some particular pollinators insect's like *A. mellifera* was the main

**Table 4:** Regulator index, number, and percentage of visits with stigmata contact of flower of *Allium cepa.*

| Insects | 2017 | 2018 | Total | NPV | | |
|---|---|---|---|---|---|---|
| | $Id_1$ | $Id_2$ | $Id_T$ | *SV* | *n* | *P* (%) |
| *Apis mellifera* | 0.2307 | 0.2597 | 0.2449 | 1612 | *1612* | 100.00 |
| *Amegilla calens* | 0.0525 | 0.0474 | 0.0501954 | 354 | 354 | 100.00 |
| *Xylocopa olivacea* | 0.0366858 | 0.1294 | 0.0755531 | 597 | 597 | 100.00 |
| *Xylocopa inconstans* | 0.0424 | 0.0795 | 0.0606 | 399 | 399 | 100.00 |
| *Xylocopa nigrita* | 0.0453096 | 0.0152 | 0.02872 | 236 | 236 | 100.00 |
| *Lipotriches collaris* | 0.0538396 | 0.08788132 | 0.080795 | 818 | 818 | 100.00 |
| *Lipotriches azarensis* | 0.0161 | 0.00794246 | 0.01237256 | 153 | 153 | 100.00 |
| *Lasioglossum atricrum* | 0.01648125 | 0.01330596 | 0.01506 | 165 | 165 | 100.00 |
| *Lasioglossum saegeri* | 0.0141875 | 0.02380671 | 0.01848 | 174 | 174 | 100.00 |
| *Megachile bituberulata* | 0.00736875 | 0.0079 | 0.00767952 | 95 | 95 | 100.00 |
| *Chalicodoma rufipes* | 0.05665 | 0.03005564 | 0.04519548 | 446 | 446 | 100.00 |
| *Belonogaster juncea* | 0.017 | 0.01731342 | 0.01717226 | 212 | 116 | 54.72 |
| *Vespula vulgaris* | 0.00320625 | 0.0059997 | 0.00486 | 53 | 34 | 64.15 |
| *Ammophila* sp. | 0.0010659 | 0.00204 | 0.00206585 | 52 | 44 | 84.62 |
| *Philanthus triangulum* | 0.00125 | 0.002 | 0.00126 | 83 | 83 | 100.00 |
| *Camponotus flavomarginatus* | 0.00285625 | 0.00688 | 0.00401 | 264 | 264 | 100.00 |
| *Episyrphus balteatus* | 0.0034 | 0.0006 | 0.0024236 | 96 | 96 | 100.00 |
| *Chrysotoxum intermedium* | 0.00189375 | 0.0017144 | 0.00213 | 47 | 47 | 100.00 |
| *Paragus borbonicus* | 0.00324375 | 0.00485656 | 0.00413385 | 102 | 102 | 100.00 |
| *Chrysomya chloropyga* | 0.00305 | 0.00342816 | 0.00327 | 72 | 72 | 100.00 |
| *Musca domestica* | 0.00024375 | 0.00040717 | 0.00038657 | 19 | 19 | 100.00 |
| *Coryna* sp. | 0.0043125 | 0.00079996 | 0.00305623 | 86 | 67 | 77.91 |
| *Mylabris* sp. | 0.0016 | 0.00185705 | 0.00194 | 64 | 52 | 81.25 |
| *Pachnoda interrupta* | 0.0004125 | 0.00707058 | 0.00265962 | 75 | 75 | 100.00 |
| *Hypolimnas misippus* | 0.0001125 | 0.00006429 | 0.0001 | 3 | 3 | 100.00 |
| *Aulacophora foveicollis* | 0.0003 | 0.00037842 | 0.00038 | 25 | 25 | 100.00 |
| *Eurema* sp.1 | 0.00130625 | 0.00120008 | 0.00178622 | 88 | 66 | 75.00 |
| *Vanessa cardui* | 0.00175 | 0.00042126 | 0.001 | 66 | 34 | 51.52 |
| *Catopsilia florella* | 0.0024625 | 0.00088536 | 0.00161 | 106 | 89 | 83.96 |
| *Danaus chrysippus* | 0.00050625 | 0.00017148 | 0.0003334 | 13 | 10 | 76.92 |
| Reduviidae (1sp.) | 0.0000375 | 0.00008574 | 0.00006665 | 3 | 2 | 66.67 |
| *Anoplocnemis curvipes* | 0.0000375 | 0.00004287 | 0.00005 | 3 | 2 | 66.67 |

*Id* = (*P*/100) × (*f*/100); *P*: Percentage of visits; *f*: Relative frequency of visits; *SV*: Study visits; *NPV*: Number and percentage of visits with stigmata contact; n: Number of visits with contact; *P* (%): Percentage of visits with contact.

**Table 5:** Fruiting rate, number of seed per pod, and percentage of normal seeds according to different treatments of *Allium cepa* in 2017 and 2018.

| Treatments | Year | NF | NPd | FR | Sd/Pd | | | TSd | NSd | % NSd |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *n* | *m* | *s* | | | |
| $T_1$ (Fr) | 2017 | 120 | 118 | 98.33 | 118 | 3.78 | 0.21 | 411 | 403 | 98.05 |
| $T_2$ (Ba) | | 120 | 17 | 14.16 | 17 | 1.11 | 0.17 | 32 | 12 | 37.50 |
| $T_3$ (COp) | | 60 | 56 | 93.33 | 56 | 3.44 | 0.14 | 128 | 113 | 88.28 |
| $T_4$ (CBa) | | 60 | 14 | 23.33 | 24 | 3.17 | 0.18 | 23 | 9 | 39.13 |
| $T_1$ (Fr) | 2018 | 120 | 120 | 100 | 120 | 3.91 | 0.23 | 421 | 408 | 96.91 |
| $T_2$ (Ba) | | 120 | 22 | 18.33 | 22 | 2.15 | 0.22 | 45 | 16 | 35.55 |
| $T_3$ (COp) | | 60 | 58 | 96.66 | 58 | 3.74 | 0.24 | 124 | 118 | 95.16 |
| $T_4$ (CBa) | | 60 | 10 | 16.66 | 30 | 2.45 | 0.38 | 26 | 8 | 30.76 |

Fr: Free flowers, Ba: Bagged flowers, COp: Castrated and opened flowers, CBa: Castrated and bagged flowers, NF: Number of flowers, NPd: Number of pod, FR: Fruiting rate, Sd/Pd: Seeds per pod, TSd: Total of seeds, NSd: Normal seeds, %NSd: Percentage of normal seeds.

floral visitor of *A. cepa* during the flowering periods; our result confirms other findings reported by [16] on *A. cepa* in India, by Venkatesh *et al*. [17] and Kasina *et al*. [18]. The most common insect pollinator in onion fields is the honeybee [19]. Moreover, in other parts of the world such as the India [20,21], the bees *A. florea* have been reported as the main floral visitors of this crop. Many others results Ahmed and Abdalla, Mayer and Lunden, Tolon and Duman, [22-24] clearly showed that the genus *Apis* was found to be the most abundant on onion flowers. Through the abundance and diversity of pollinator fluctuate depending on the areas [25]. The peak of the activity of flowering insects on *A. cepa* flowers was located between 08am and 09am, which could be associated with the highest availability period of nectar on *A. cepa* flowers. The studies conducted by Asif *et al*. [26] showed the same results in Pakistan. For this research, it has been indicated that *A. mellifera, X.* olivacea, and *L. collaris* offer benefits to pollination management of *A. cepa*. During the collection of nectar and pollen on each flower, the bee regularly come into contact with the stigma (100%) and they have the most important regulator index ($Id > 0.05$). The significant contribution of insect pollinators in pods and seed yield of *A. cepa* is in agreement with the similar findings in India [27], in the far north Region of Cameroon in Maroua [8,10] and in Pakistan [28]. The impact of insect pollinators of to *A. cepa* production was significantly higher than that of protected flowers. The weight of some insect pollinators such as *A. mellifera, A. calens, X. olivacea, L. collaris, C. rufipes, B. juncea, X. inconstans, X. nigrita,* and *L. azarensis* played a positive role during nectar and or pollen collection. The pollinator insects shook flowers and could ease the liberation of pollen by anthers for the optimal occupation of the stigma. The higher productivity of pods, seeds, and normal seeds in the treatment with unlimited visits when compared to treatment with protected flowers showed that pollinator insect visits were effective in increasing cross-pollination. Our results confirmed those of [29] who revealed that *A. cepa* flowers set little pods in the absence of insect pollinators. Similar observations done in Poland [30], the presence of honeybees and other pollinating insects is needed for a good setting and high seed yield. According to Zdzislaw *et al*. [31], self-pollination is not possible in onion; therefore, pollen must reach from another flower of the same or different plant. The same author showed that onion does not produce seed if insects do not pollinate flowers. In commercial production of seed, the industry depends on the honeybee for pollination [23].

## 5. CONCLUSION

This study revealed that the flowers of the variety of *A. cepa* studied attracted insect pollinators and the plant obtained profits from the pollination by those insects. *A. mellifera* is the most frequent pollinator followed by *L. collaris* which harvested nectar and pollen. By comparison, of pods, and seeds, between unprotected flowers and protected flowers, it was observed that insect pollinators contribute positively in increasing pods, seed, and seed weight yields as well as seed quality. It is suggested to avoid pesticide treatment of plants during flowering for a good management strategy to improve on plant yield.

## 6. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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