

Pollination Efficiency of *Ceratina cyanea* (Hymenoptera: Apidae) on *Helianthus annuus* (Asteraceae) Flowers at Dang (Ngaoundere, Cameroon)

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Abstract

To evaluate the impact of *Ceratina cyanea* on fruit and seed yields of sunflower, experimental field was set up from June to July in 2016 and 2017 at Dang. Observations were done on 540 capitula divided in four treatments: two treatments differentiated according to the presence or absence of protection on capitula regarding *Ceratina cyanea* and other flowering insects' visits; the third with capitula protected and uncovered when florets were opened, to allow *C. cyanea* visits and flowers bagged uncovered and rebagged without the visit of insects or any other organisms. Bee's daily rhythm of activity, its foraging behavior on florets and its pollination efficiency were evaluated. Bee's daily rhythm of activity, its foraging behavior on flowers and its pollination efficiency were evaluated. Results show that, *C. cyanea* foraged on *Helianthus annuus* flowers throughout its whole blooming period. Among 32 insect species recorded on *H. annuus* capitula, *C. cyanea* ranked second accounting for 10.79% all visits, after *Apis mellifera* (76.06%). On florets, individual bees intensely harvested nectar and slightly collected pollen. The mean duration of a visit per floret was 3.62 sec for nectar harvest and 9.58 sec for pollen collection. For the two years, through its pollination efficiency on *H. annuus*, *C. cyanea* has increased the fruiting rate by 65.90%, the percentage of fruit with seed by 63.56% and the percentage of normal seeds by 76.11%. Based on these results, we recommend the protection of *C. cyanea* nests at the vicinity of sunflower fields to increase its fruit and seed yields in the Adamaoua Region of Cameroon.

Keywords

Ceratina cyanea, *Helianthus annuus*, Pollination Efficiency, Yields, Dang

1. Introduction

The small carpenter bees (genus *Ceratina* Latreille), often with metallic colors are solitary bees of small size (3 - 15 mm) belonging to the family Anthophoridae [1]. They are a widespread and moderately diverse lineage of Xylocopinae with approximately 350 species [2]. They have submarginal cells with anterior wings, unlike their neighbors, the Allodapini which have only two [1]. Species typically nest in pithy stems, forming relatively simple linear nests therein [3], making them ideal for observation of intra-nest behaviors and studies of social interaction [4]. All collect pollen [1].

The sunflower, *Helianthus annuus* is native of eastern North America [5]. It is widely distributed in Western Canada, Northern, Central and Southern regions of the United States and Northern Mexico [6]. This plant provides the fourth oilseed consumed in the world after palm, soybean and rapeseed oils [7]. The sunflower is resistant to drought, cold and heat [8]. It is also used in food and medicine [5]. It is a plant cultivated mainly for its seeds which constitute a source of oil [5] and its meal used in human and animal food [9]. Global production of this oilseed is estimated at 18,891 million tons in 2017 and Ukraine is the leading producer [10].

In Africa in general and in Cameroon in particular, the demand in seed oil of sunflower is very highly whereas its seed yield is weak because notably of the insufficiency of knowledge on the relations between this plant and the anthophilous insects in many agro ecological zones.

The few data published at the end of in-depth studies carried out on the interactions between insects and *H. annuus* are those of [11] in Bulgaria, [12] and [13] in Soudan, [14] in America, [15] and [16] in Pakistan, [17] in Kenya, [18] and [19] in Turkey, [20] in Cameroon, [21] and [8] in India, [22] in Israel, [23] in France. In all these investigations, foraging and pollination activity was carried out in detail only on *Apis mellifera* bees. Other Apoids such as bumble bees and wild bees visit the sunflower flowers and participate in their pollination [23] [19]. In all these investigations, the foraging behavior and pollination activity was carried out in detail on *A. mellifera*.

The flowering insects and their impact on pollination and fruit and/or seed yields of a plant species may vary with the species of insect, time and space [3] [24]. Hence there is a need of other studies in the Adamaoua region, to supplement existing data.

The general objective of this work is to contribute to the understanding of the relationships between *H. annuus* and *C. cyanea*, for their optimal management. Specific objectives were to: 1) determine the place of *Ceratina cyanea* in *H. an-*

nuus entomofauna; 2) study the activity of this Apidae on florets of this Asteraceae; 3) evaluate the impact of the flowering insects including *C. cyanea* on pollination and fruit and seed yields of this plant species; 4) estimate the pollination efficiency of *Ceratina cyanea* on this Asteraceae.

2. Materials and Methods

2.1. Study Site, Experimental Plot and Biological Material

The experiment was carried out from April to August, in 2016 and 2017 at Dang within an experimental field of the Unit of Applied Apidology (latitude: 7°42.264N; longitude: 13°53.945E; altitude: 1106 a.s.l.) of the Faculty of Science, University of Ngaoundere. This region belongs to the high altitude Guinean savannah agro-ecological zone [25]. The climate is characterized by a rainy season (April to October) and a dry season (November to March), with an annual rainfall of about 1500 mm. The mean annual temperature is 22°C, while the mean annual relative humidity is 70% [26]. The vegetation was represented by crops, ornamental plants, hedge plants and native plants of savanna and gallery forests. The experimental plot was a field of 437 m².

The vegetation near the *H. annuus* field had various wild and cultivated species. The experimental plant material was represented by fruit of *H. annuus* sampled from the surrounding of the Unit of Applied Apidology. *Ceratina cyanea* individuals of the experimental station were recruited among the arthropods naturally present in the environment.

2.2. Sowing and Weeding

Each year from April to May 2016 and 2017, the experimental plot was delimited, ploughed and divided into 8 subplots, each measuring 8 * 4.5 m². Four seeds were sown per hole on 9 lines. There were 20 holes per subplot. Holes were separated 40 cm from each other, while lines were 50 cm apart. Weeding was performed manually as necessary to maintain plots weeds-free.

2.3. Estimation of the Frequency of *Ceratina cyanea* Visits on *Helianthus annuus* Capitula

On 25th June 2016 and 02nd June 2017, 240 *H. annuus* capitula with florets at bud stage were labelled (15 plants per subplot) among which 240 were left unattended [treatment X (1 in 2016 or 5 in 2017)] [27].

The frequency of *Ceratina cyanea* visits on *H. annuus* flowers was determined based on observations on capitula of treatments 1 and 5, every day, from 26th June to 16th July 2016 and from 3rd to 18th July according to the following times slot 6 - 7 h, 8 - 9 h, 10 - 11 h, 12 - 13 h, 14 - 15 h and 16 - 17 h. In a slow walk along all labelled capitula of treatments 1 and 5, the identity of all insects that visited *H. annuus* florets was recorded [28]. All insects encountered on flowers were registered and the cumulated results expressed as the number of visits to determine the relative frequency of *Ceratina cyanea*.

Specimens of all insect taxa were caught using insect net on unlabeled flowers and conserved in 70% ethanol, excluding butterflies that were preserved dry [29], for subsequent taxonomic identification.

2.4. Study of the Activity of *Ceratina cyanea* on *Helianthus annuus* Florets

In addition to the determination of the flower visiting insect frequency, direct observation of the foraging activity of *Ceratina cyanea* on florets was made in the experimental field. The floral products (nectar or pollen) harvested by *C. cyanea* during each floret visit were registered based on its foraging behavior. Nectar foragers were seen extending their proboscis on to the base of the corolla and the stigma, while pollen gatherers scratched the anthers using their mandibles and their legs [29] [30].

In the morning of each sampling day, the number of opened florets carried by each labelled capitula was counted. During the same days as for the frequency of visits, the duration of individual floret visits was recorded (using a stopwatch) according to six times: 7 - 8 h, 9 - 10 h, 11 - 12 h, 13 - 14 h, 15 - 16 h and 17 - 18 h. Moreover, the number of pollinating visits which was defined as visits with contact between the bees and stigma [31], the abundance of foragers (highest number of individuals foraging simultaneously per floret, per capitula and per 1000 florets) [20] and the foraging speed (number of florets visited by individual bee per minute [31]) were recorded during the same dates and daily periods as the registration of the duration of visits. The abundance of foragers per floret and per capitula was noted following the direct counting. For the abundance per 1000 florets (A_{1000}), the number of individuals of *C. cyanea* was counted on a known number of florets at the moment x . The abundance per 1000 florets is calculated using formula: $A_{1000} = [(A_x/F_x)*1000]$, where F_x and A_x are respectively the number of bloomed florets and the number of active foragers at the moment x [28]. The foraging speed (F_s) was calculated using the formula: $F_s = (F_i/d_u)*60$, where d_u is the duration (sec) given by a stopwatch, and F_i the number of florets visited during d_u [28].

2.5. Evaluation of the Effect of Insects Including *Ceratina cyanea* on *Helianthus annuus* Production

Parallel to the installation of treatments 1, and 5, 840 capitula with florets at bud stage were protected in 2016 and 2017, to form three treatments:

- treatment Y [treatment 2 in 2016 or 6 in 2017]: 240 capitula protected using gauze bags net to prevent insect visitors;
- treatment C [treatment 3 in 2016 or 7 in 2017]: 400 capitula protected using gauze bag nets to prevent insect or any other organism visits and destined to be visited exclusively by *Ceratina cyanea*. As soon as the first florets were opened on each capitulum of treatments 3 and 7, the gauze bag was gently removed and this capitulum was observed for up to 10 minutes; the visited capitula was marked and protected again;

- treatment Z [treatment 4 in 2016 and 8 in 2017]: 200 capitula protected using gauze bag nets and destined to be uncovered then rebagged without the visit of insects or any other organism. As soon as the first florets were opened on each capitulum of treatments 4 and 8, the gauze bag was carefully removed and this capitulum observed for up to 10 minutes, while avoiding insect or any other organism visits.

At the maturity, achenes were harvested and counted from each treatment. The fruiting rate, the percentage of fruits with seed and the percentage of normal (well developed) seeds of unprotected capitula were then determined for each treatment.

The evaluation of the effect of insects including *C. cyanea* on *H. annuus* production was based on the impact of flowering insects on pollination, the impact of pollination on *H. annuus* fruiting, and the comparison of fruiting rate, the percentage of fruits with seed and the percentage of normal seeds of treatments 1, 2, 4, 5, 6 and 8.

For each year, the fruiting rate due to the foraging insects including *Ceratina cyanea* (*Fri*) was calculated using the following formula:

$$Fri = \left\{ \left[\frac{(FX + Eg) - FY}{(FX + Eg)} \right] * 100 \right\}$$
, where *FX* and *FY* are the fruiting rates in treatment *X* (capitula left for free pollination) and treatment *Y* (capitula protected from insect visits), and *Eg* the effect of the gauze bag net which can be calculated using the formula $Eg = FZ - FY$, where *FZ* is the fruiting rate in treatment *Z* (capitula protected then unbagged and rebagged without insect or any other organism visit).

Finally,
$$Fri = \left\{ \left[\frac{(FX - FZ)}{(FX + FY - FZ)} \right] * 100 \right\}$$
.

The fruiting rate of treatment (*F*) is $F = \left[\frac{b}{a} * 100 \right]$, where *b* is the number of achenes formed and *a* the number of viable florets initially set [20].

The impact of flower visiting insects including *C. cyanea* on fruits with seed and normal seeds were evaluated using the same method as mentioned above for the fruiting rate.

2.6. Assessment of the Pollination Efficiency of *Ceratina cyanea* on *Helianthus annuus*

The contribution of *C. cyanea* in the fruiting rate and the percentage of normal achenes was calculated using data of treatments 3 and 4 in 2016 and those of treatments 7 and 8 in 2017.

For each year, the contribution of *C. cyanea* in fruiting rate (*Frc*) was calculated using the formula $Frc = \left\{ \left[\frac{(FC - FZ)}{FC} \right] * 100 \right\}$, where *FC* is the fruiting rate in treatment C (capitula visited exclusively by *C. cyanea*).

2.7. Data Analysis

Data were analyzed using descriptive statistics, student's *t*-test for the comparison of means of two samples, Pearson correlation coefficient (*r*) for the study of the association between two variables, chi-square (χ^2) for the comparison of two percentages, using Microsoft Excel 2010 software and R—commander, version 2.13.0.

3. Results and Discussion

3.1. Frequency of *Ceratina cyanea* Visits on *Helianthus annuus* Flowers

Among the 2744 and 8756 visits of 21 and 31 insect species recorded on *H. annuus* flowers in 2016 and 2017 respectively, *Ceratina cyanea* ranked second with 8.12% and 11.60% of visits. The first place was occupied by *Apis mellifera* both years (74.06% and 76.53%) (Table 1). The difference between the percentages of *C. cyanea* visits in 2016 as well as in 2017 is highly significant ($\chi^2 = 26.56$; $df = 1$; $P < 0.001$).

The weak frequency of visit of *C. cyanea* on *H. annuus* capitula compare to that of *A. mellifera* could be explained by the strategies adopted by this social bee that consist of recruiting a great number of workers for the exploitation of an interesting food source [32]. Consequently, there might be a limitation of the number of individuals *C. cyanea* (1241) on *H. annuus* capitula due to the occupation of the majority of open florets by *A. mellifera* workers (8747) [20].

The presence of other plants species with bloomed flowers able to attract *Ceratina cyanea* could also explained the weak frequency of this solitary bee on *H. annuus* florets. The significant difference between the percentages of *Ceratina cyanea* visit in 2016 and 2017, could be explained by the presence of a significant number of its nests (10 nests) in 2016 than in 2017 (6 nests) close to the experimental plot.

3.2. Floral Products Harvested

Individuals of *Ceratina cyanea* were seen collecting nectar (Figure 1) and pollen (Figure 2) on *H. annuus* florets. Nectar collection was regular and intensive whereas pollen collection was less intensive. On 639 visits recorded in 2016, 545 (85.29%) were devoted to exclusive nectar harvest and 94 (14.71%) to pollen harvest. In 2017, on 526 visits, 411 (78.14%) were devoted to exclusive nectar harvest and 115 (21.86%) to pollen collection. For the two cumulated years of 1165 visits recorded, 1075 (82.06%) were devoted to exclusive nectar harvest and 209 (17.94%) to pollen harvest. Nectar and pollen were harvested during all scheduled time frames.

3.3. Daily Rhythm of Visits

Ceratina cyanea was active on *H. annuus* florets from 8 am to 5 pm in 2016 and in 2017, with a peak of visits between 12 and 13 pm in 2016 as well as in 2017 (Figure 2). In 2016, the correlation was significant between the number of *Ceratina cyanea* visits and the temperature ($r = 0.81$; $df = 4$; $P < 0.05$) and not significant between the same number of visits and relative humidity ($r = -0.71$; $df = 4$; $P > 0.05$) (Figure 3(a)). In 2017, the correlation was not significant between the number of *C. cyanea* visits and the temperature ($r = 0.75$; $df = 4$; $P < 0.05$) and between the number of these visits and relative humidity ($r = -0.76$; $df = 4$; $P < 0.05$) (Figure 3(b)).

Table 1. Diversity of flowering insects on *Helianthus annuus* in 2016 and 2017, number and percentage of visits of different insects.

Insects			2016		2017		Total	
Order	Family	Genus and Species	<i>n</i> 1	<i>P</i> 1 (%)	<i>n</i> 2	<i>P</i> 2 (%)	<i>N</i> <i>t</i>	<i>P</i> <i>t</i> (%)
Diptera	Calliphoridae	<i>Calliphora</i> sp. (ne)	102	3.72	62	0.71	164	1.43
		<i>Sarcophaga</i> sp. (ne)	4	0.15	5	0.06	9	0.08
	-	(3 sp.) (ne)	29	1.17	65	0.75	94	0.82
	Syrphidae	(sp.) (ne)	3	0.11	9	0.10	12	0.10
	-	(1 sp.) (ne)	-	-	2	0.02	2	0.02
	Muscidae	<i>Musca domestica</i> (ne)	-	-	1	0.01	1	0.01
Hemiptera	Pentatomidae	(sp.) (ne)	7	0.26	8	0.09	15	0.13
	-	(2 sp.) (ne)			5	0.06	4	0.04
Hymenoptera	Apidae	<i>Apis mellifera</i> (ne, po)	2033	74.06	6714	76.53	8747	76.06
		<i>Braunsapis</i> sp. (ne, po)	268	9.76	610	6.95	878	7.63
		<i>Ceratina cyanea</i> (ne, po)	223	8.12	1018	11.60	1241	10.79
		<i>Xylocopa olivacea</i> (ne)	13	0.47	31	0.36	44	0.39
		<i>Xylocopa inconstans</i> (ne)	-	-	8	0.09	8	0.07
	Formicidae	(sp.) (ne)	14	0.51	18	0.2	32	0.28
		<i>Polyrachis</i> sp. (ne)	2	0.07	4	0.05	6	0.05
	Halictidae	<i>Lasioglossum</i> sp. 1 (ne, po)	9	0.33	26	0.30	35	0.30
		<i>Lasioglossum saegeri</i> (ne, po)	3	0.11	30	0.34	33	0.29
	Megachilidae	<i>Chalicodoma refupes</i> (ne)	10	0.36	40	0.46	50	0.43
		<i>Chalicodoma cincta</i> (ne)	7	0.26	6	0.07	13	0.11
		<i>Megachille</i> sp. (ne)	-	-	29	0.33	29	0.25
	Hymenoptera	Sphecidae	(sp.) (ne)	-	-	22	0.25	22
Vespidae		<i>Synagris</i> sp. (ne)	-	-	4	0.04	4	0.04
		<i>Philanthus tringulum</i> (ne, pr)	1	0.04	-	-	1	0.01
Lepidoptera	Nymphalidae	<i>Precis</i> sp. (ne)	1	0.04	25	0.28	26	0.23
		(sp.) (ne)	-	-	2	0.02	2	0.02
	Acraeidae	<i>Acraea</i> sp. (ne)	-	-	5	0.06	5	0.04
	Hesperiidae	(sp.) (ne)	1	0.04	2	0.02	3	0.03
Pladiodera	Chrysomelidae	(sp.) (ne)	9	0.33	3	0.03	12	0.10
Orthoptera	(Ensifera)*	(sp.) (ne)	5	0.18	2	0.02	7	0.06
Total	32 species		2744	100.00	8756	100.00	11500	100.00

*n*1: number of visits on 120 capitula in 17 days; *n*2: number of visits on 120 capitula in 21 days; *nt*: total number of visits; *sp.*: undetermined species; *P*1, *P*2, *P**t*: percentages of visits: $P1 = (n1/2744) * 100$; $P2 = (n2/8756) * 100$; $Pt = (nt/11500) * 100$; *ne*: collection of nectar; *po*: collection of pollen; *pr*: predator of *Apis mellifera*.

3.4. Rhythm of Visits According to the Flowering Stages

Ceratina cyanea visits were numerous on the *H. annuus* flowers when the number of opened florets was highest (Figure 4). The correlation between the number of *C. cyanea* visits and the number of *H. annuus* opened florets was not significant (r

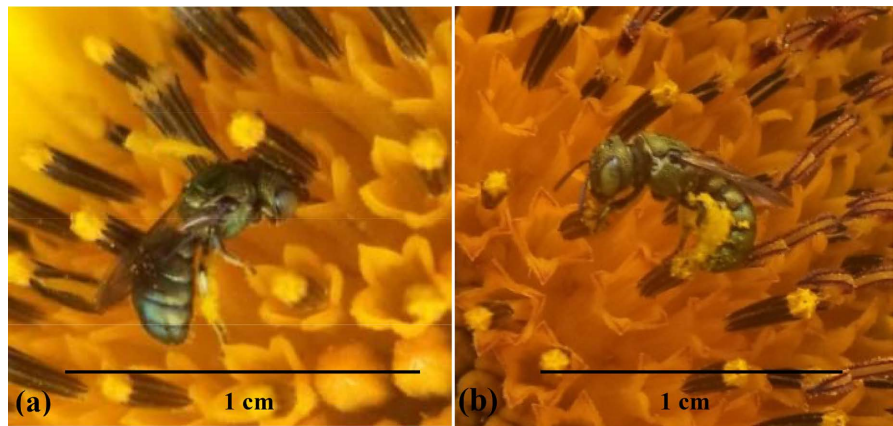


Figure 1. *Ceratina cyanea* collecting nectar (a) and pollen (b) on *Helianthus annuus* florets.

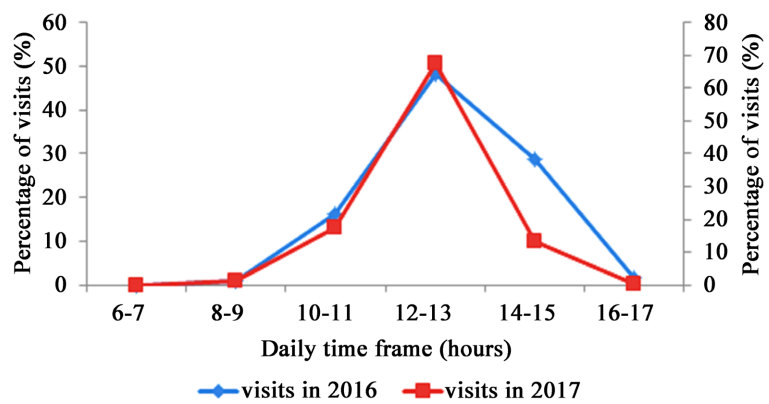
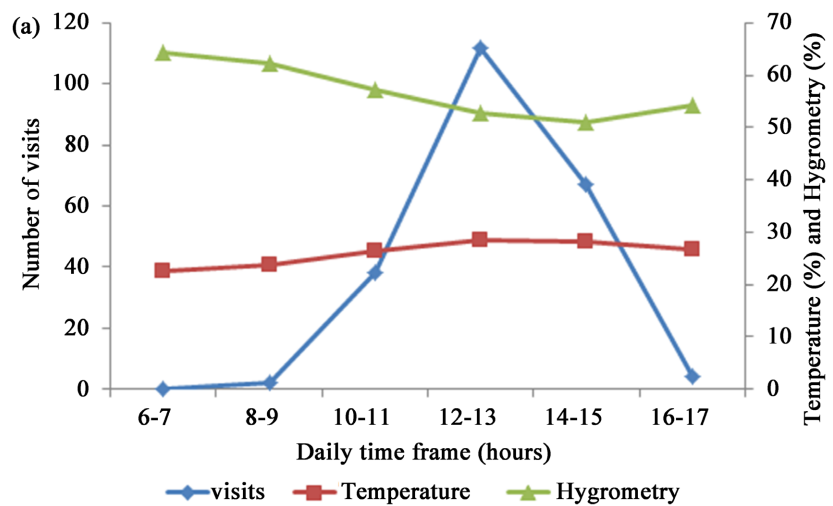


Figure 2. Variation of number of *Ceratina cyanea* visits on *Helianthus annuus* florets according to daily time frames in 2016 and 2017 at Dang.



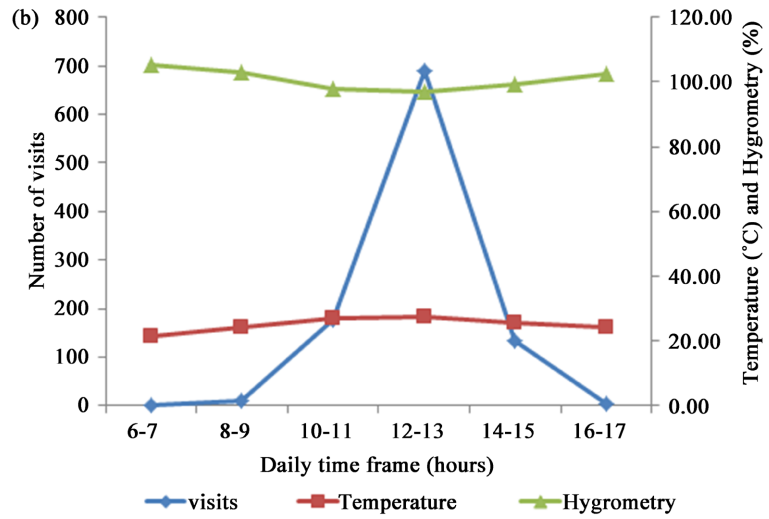


Figure 3. Daily variation of *Ceratina cyanea* visits on *Helianthus annuus* florets in 21 and 16 days, mean temperature and mean hygrometry of the study site in 2016 (a) and 2017 (b) at Dang.

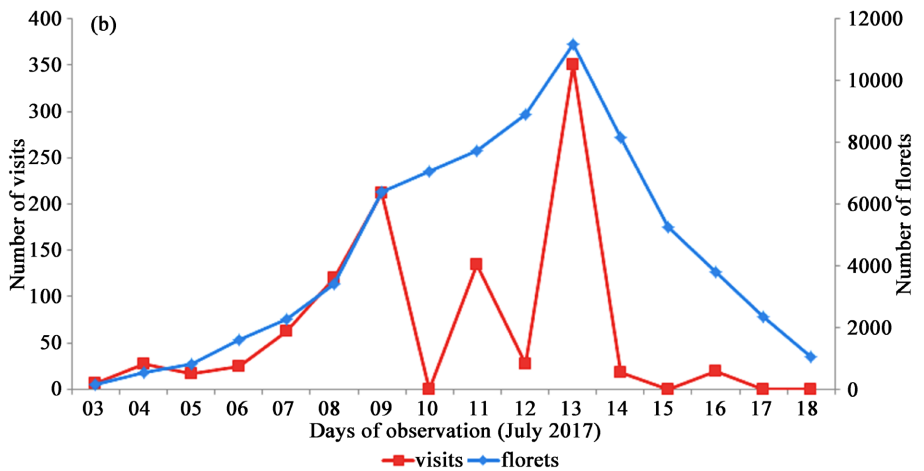
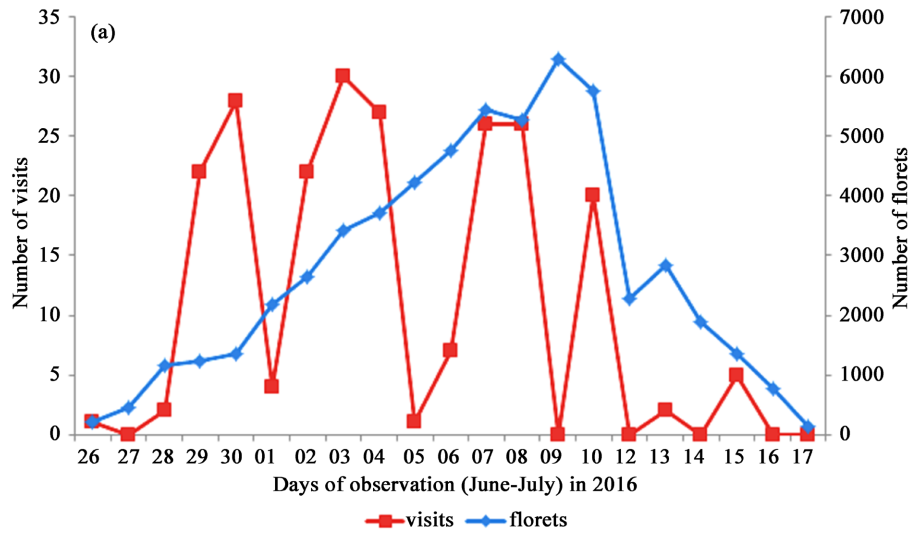


Figure 4. Seasonal variation of the number of *Helianthus annuus*' opened florets and the number of *Ceratina cyanea* visits in 2016 (a) and 2017 (b) at Dang.

= 0.37; $df=19$; $P > 0.05$) in 2016. However, this correlation was significant ($r = 0.58$; $df=14$; $P < 0.05$) in 2017.

The positive and significant correlation between the number of *H. annuus* flowers and the number of *C. cyanea* visits in 2017, underscores the good attractiveness of *H. annuus* nectar and/or pollen for *Ceratina cyanea*.

3.5. Abundance of *Ceratina cyanea*

In 2016, the highest mean number of *Ceratina cyanea* individuals simultaneous in activity was 1 per floret, 1.54 per capitula and 14.55 per 1000 florets (Table 2). In 2017, the corresponding figures were 1 per floret, 1.55 per capitula and 12.70 per 1000 florets (Table 2). For the two cumulative years the mean number of *C. cyanea* individuals was 13.86 per 1000 florets. The difference between the mean number of this bee per capitula was not significant ($t = 0.22$; $df = 394$; $P > 0.05$) and 1000 florets ($t = 1.84$; $df = 254$; $P > 0.05$) in 2016 and 2017.

The high abundance of *C. cyanea* individuals per 1000 florets proves the good attractiveness of *H. annuus* nectar and/or pollen for *C. cyanea*. The attractiveness for sunflower nectar and pollen could be partially explained by the highest availability and the accessibility of these products.

3.6. Duration of Visits per Floret

The mean duration of a *Ceratina cyanea* visit per *H. annuus* floret varied significantly according to floral product harvested (Table 3).

In 2016, the mean duration of a floret visit for nectar harvest was 3.68 sec ($n = 545$; $s = 2.20$) and for pollen collection it was 9.63 sec ($n = 94$; $s = 8.16$). In 2017, the corresponding figures were 3.55 sec ($n = 411$; $s = 1.82$) for nectar and 9.53 sec ($n = 115$; $s = 3.92$) for pollen. For the two cumulative years, the mean duration of visit on a floret was 3.62 sec ($n = 956$; $s = 2.01$) for nectar collection and 9.58 sec ($n = 209$; $s = 6.04$) for pollen harvest. The difference between these two means was highly significant ($t = 14.06$; $df = 1163$; $P < 0.001$).

The significant difference observed between the mean duration of a pollen harvest and that of nectar harvest could be explained by the accessibility of each

Table 2. Abundance of *Ceratina cyanea* on *Helianthus annuus* florets in 2016 and 2017 at Dang.

Years	Abundance									
	Per capitulum					Per 1000 florets (A_{1000})				
	<i>n</i>	<i>m</i>	<i>s</i>	<i>mini</i>	<i>maxi</i>	<i>n</i>	<i>m</i>	<i>s</i>	<i>min</i>	<i>max</i>
2016	235	1.54	0.73	1	5	161	14.55	8.17	4.76	50
2017	121	1.55	0.68	1	4	95	12.70	7.50	4.31	49.18
Total _{2016/2017}	356	1.54	0.74	1	5	256	13.86	7.96	4.31	50

n: number of recorded of visit; *m*: mean; *s*: standard deviation; *max*: maximum; *min*: minimum.

Table 3. Duration of visits of *Ceratina cyanea* on *Helianthus annuus* florets in 2016 and 2017 at Dang.

Years	Harvested products	Duration visits per floret (sec)					Comparison of means		
		<i>n</i>	<i>m</i>	<i>s</i>	<i>mini</i>	<i>maxi</i>	<i>t</i> -value	<i>df</i>	<i>p</i> -value
2016	Nectar	545	3.68	2.20	1	15	6.99	637	<0.001 ^{VHS}
	Pollen	94	9.63	8.16	1	38			
2017	Nectar	411	3.55	1.82	1	9	15.82	524	<0.001 ^{VHS}
	Pollen	115	9.53	3.92	3	22			
Total _{2016/2017}	Nectar	956	3.62	2.01	1	15	14.06	1163	<0.001 ^{VHS}
	Pollen	209	9.58	6.04	1	38			

n: number of recorded visits; *m*: mean; *s*: standard deviation; *max*: maximum; *min*: minimum.

of these floral products. Pollen is produced by the anthers, which are on the top of the stamens, whereas nectar is between the base of the style and stamens. Under these conditions, an individual bee must spend much more time on a floret to obtain its nectar load, compared to the time needed for the collection of pollen.

3.7. Foraging Speed of *Ceratina cyanea* on *Helianthus annuus* Florets

In *H. annuus* field an individual of *Ceratina cyanea* visited between 3 and 61 florets per minute in 2016 and 2017. The mean foraging speed was 13.27 florets/min ($n = 323$; $s = 8.51$) in 2016 and 14.06 florets per minute ($n = 255$; $s = 6.29$) in 2017. The difference between these two means is not significant ($t = 1.49$; $df = 576$; $P > 0.05$).

3.8. Influence of Fauna

Individuals of *Ceratina cyanea* were disturbed in their foraging activity by other individuals of the same bee species or those from other species, which were the competitor for *H. annuus* nectar and/or pollen. In 2016, of 838 visits, 10 (1.19%) were interrupted by *A. mellifera* and 2 (0.24%) by individuals of *C. cyanea* whereas in 2017, of 619 visits, 7 (1.13%) were interrupted by *A. mellifera* and 1 (0.16%) by individuals of *C. cyanea*. In order to obtain their nectar or pollen load, individuals of *C. cyanea* who suffered such disturbances were forced to visit more florets and/or capitula during the corresponding foraging trip. For the pollen foragers, these disturbances resulted in partial loss of carried pollen.

3.9. Pollination Efficiency of *Ceratina cyanea* on *Helianthus annuus*

During pollen and/or nectar harvest in sunflower's florets, individuals of *C. cyanea* were regularly in contact with anthers and stigma, increasing there by possibility of *H. annuus* pollination.

The comparison of the fruiting rate (**Table 4**) showed that the differences observed were highly significant between treatments 1 and 2 ($\chi^2 = 8432.36$; $df = 1$; $P < 0.0001$) and treatments 3 and 4 ($\chi^2 = 7352.85$; $df = 1$; $P < 0.0001$).

The comparison of the percentage of fruits with seed (**Table 2**) showed that the difference observed was highly significant between treatments 1 and 2 ($\chi^2 = 1981.71$; $df = 1$; $P < 0.0001$) and treatments 3 and 4 ($\chi^2 = 3587.37$; $df = 1$; $P < 0.0001$).

The comparison of the percentage of normal seeds (**Table 2**) showed that the difference observed was highly significant between treatments 1 and 2 ($\chi^2 = 741.28$; $df = 1$; $P < 0.0001$) and treatments 3 and 4 ($\chi^2 = 173.93$; $df = 1$; $P < 0.0001$).

Hence, in 2016 and 2017, the fruiting rate, the percentage of fruits with seed and the percentage of normal seeds of capitula protected and visited exclusively by *C. cyanea* were higher than that of capitula protected, opened and closed without a single visit.

In 2016, the numeric contribution of *C. cyanea* on the fruiting rate, the percentage of fruits with seed and the percentage of normal seeds via a single capitula visit were 69.75%, 63.94% and 87.17% respectively. In 2017, the corresponding figures were 29.04%, 57.18% and 64.70% respectively. For the two cumulated years, the corresponding figures were 49.40%, 60.56% and 75.87% respectively.

On the same plant, regarding *A. mellifera*, [8] in India and [20] in Cameroon have revealed that the percentage of seed setting (86.9% and 62.21% respectively) due this Apidae through its pollination efficiency was significantly higher over the pollination without insects.

Thus in Dang, in view of the published works, *H. annuus* appears to be a plant species which benefits enormously from pollination by insects among which *Ceratina cyanea* is the most important and harvested nectar and pollen.

Table 4. Fruiting rate, percentage of fruits with seed and percentage of normal seeds according to different treatments of *Helianthus annuus* in 2015 and 2016 at Dang.

Treatments	Years	NCS	NFS	TNFr	Fr (%)	NFrS	% FrS	NNS	% NS
1 (BCCe)	2016	42	29,808	11,530	38.68	6146	53.30	2941	47.85
2 (BCN)		72	55,014	6435	11.70	1237	19.22	76	6.14
3 (BCC)	2017	171	91,196	26,932	29.53	18,370	68.21	3180	17.31
4 (BCN)		103	63,922	7168	11.21	2094	29.21	128	6.11

BCCe: bagged capitula and exclusively visited by *Ceratina cyanea*; BCN: bagged capitula, without the visit of insects or any other organism; NCS: number of capitula studies; NFS: number of florets studies; TNFr: total number of fruits; Fr: fruiting rate; NFrS: number of fruits with seed; NNS: number of normal seeds; % FrS: percentage of fruits with seed; % NS: percentage of normal seeds.

4. Recommendation

The protection of *Ceratina cyanea* nests at the vicinity of sunflower fields to in-

crease fruit and seed yields is recommended in Adamaoua Region of Cameroon.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Eardley, C.D., Kuhlmann, M. and Pauly, A. (2010) The Genus and Subgenus of Bees in Sub-Saharan Africa. ABC Taxa, 152 p.
- [2] Hussain, A., Abdulaziz, S.A., Mohamed, S. and Michael, S.E. (2016) Notes on the Nesting Biology of the Small Carpenter Bee *Ceratina smaragdula* (Hymenoptera: Apidae) in Northwestern Pakistan. *Florida Entomologist*, **99**, 89-93. <https://doi.org/10.1653/024.099.0116>
- [3] Michener, C.D. (2007) The Bees of the World. 2nd Edition, The John Hopkins University Press, Baltimore and London, 953 p.
- [4] Rehan, S.M., Richards, M.H. and Schwarz, M.P. (2009) Evidence of Social Nesting in the Ceratina of Borneo (Hymenoptera: Apidae). *Journal of the Kansas Entomological Society*, **82**, 194-209. <https://doi.org/10.2317/JKES809.22.1>
- [5] Al-Snafi, A.E. (2018) The Pharmacological Effects of *Helianthus annuus*. *Indo American, Journal of Pharmaceutical Sciences*, **5**, 1745-1756. <http://doi.org/10.5281/zenodo.1210521>
- [6] Contreras, R.A.L. and Maxted, N. (2016) *Helianthus annuus*. The IUCN Red List of Threatened Species, 9 p.
- [7] Boucly, M. (2007) The Sunflower: A European Speciality. Press Conference, 17 p.
- [8] Krishna, V.K., Prashanth, Y., Yogeewarudu, B. and Maurya, K.K. (2014) Pollination Efficiency of Honeybees in Sunflower (*Helianthus annuus* L.). *Journal of Agriculture and Life Sciences*, **1**, 92-95. <https://hal.archives-ouvertes.fr/hal-01356116>
- [9] Laporte, M.A. (2013) Contribution to the Modeling of the Absorption of Cadmium by the Roots of Sunflower (*Helianthus annuus* L.) in Relation to Root Architecture. Doctorate Thesis/PhD, University of Bordeaux 1, Bordeaux, 193 p.
- [10] Terres Univia (2016) Statistics of Oil Seed and Protein-Rich Plants, from Production to Consumption. The Interpretation of Vegetable Oils and Proteins, 44 p.
- [11] Pham-delègue, M.H., Caroline, F., Claudine, M. and Douault, P. (1985) Comparative Study of the Foraging Behavior of Insects (Honey Bees, *Apis mellifera* L. et Bumblebees *Bombus terrestris* L.) on Parental Sunflower Lines (*Helianthus annuus* L.). *Acta Ecologica Ecologica Applicata*, **6**, 47-67. <https://hal.inrae.fr/hal-02719460>
- [12] Ahmed, H.M.H., Siddig, M.A. and El-Sarrag, M.S.A. (1989) Honey Bee Pollination of Some Cultivated Crops in Sudan. *Proceeding of 4th International Conference on Apiculture in Tropical Climates*, Cairo, 100-108.
- [13] Osman, A.E. and Siham, K.A.N. (2015) Efficacy of Honeybees (*Apis mellifera*) on

- the Production of Sunflower (*Helianthus annuus* L.) Seeds in Sudan. *Journal of Experimental Biology and Agricultural Sciences*, **3**, 191-195.
[https://doi.org/10.18006/2015.3\(2\).191.195](https://doi.org/10.18006/2015.3(2).191.195)
- [14] Philippe, J.M. (1991) The Pollination by Bees: Installation of Colonies in the Field during Flowering for Yield Increase of Crops. EDISUD, La calade, Aix-en-Provence, 179 p.
- [15] Roubik, D.W. (2000) Pollination System Stability in Tropical America. *Conservation Biology*, **5**, 1235-1236. <https://doi.org/10.1046/j.1523-1739.2000.00016.x>
- [16] Mehmood, K., Naeem, M., Ahmad, M. and Butt, J.S. (2018) Diversity of Sunflower Insect Pollinators and Their Foraging Behavior under Field Conditions. *Uludag Bee Journal*, **18**, 14-27. <https://dergipark.org.tr/tr/download/article%20file/478820>
- [17] Kasina, M., Nderitu, J. and Nyamasyo, G. (2007) Sunflower Pollinators in Kenya: Does Diversity Influence Seed Yield? *African Crop Science Conference Proceedings*, **8**, 1149-1153. <https://www.researchgate.net/publication/285381215>
- [18] Oz, M., Abdullah, K., Ibrahim, C., Abdurrahim, T.G. and Zeki, M. (2009) Effects of honey Bee (*Apis mellifera*) Pollination on Seed Set in Hybrid Sunflower (*Helianthus annuus* L.). *African Journal of Biotechnology*, **8**, 1037-1043.
- [19] Mahmut, M.A. and Cicek, Y. (2010) Effect of Honey Bee (*Apis mellifera* L.) and Bumblebee (*Bombus terrestris* L.) Pollinators on Yield and Yield Factors in Sunflower (*Helianthus annuus* L.) Production Areas. *Journal of Animal and Veterinary Advances*, **9**, 332-335. <https://doi.org/10.3923/javaa.2010.332.335>
- [20] Tchuenguem, F.F.-N., Djonwangwé, D., Messi, J. and Bruckner, D. (2009) Foraging and Pollination Activity of *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae, Apinae) on the Flowers of *Helianthus annuus* (Asteraceae) in Ngaoundere (Cameroon). *Cameroun Journal of Experimental Biology*, **5**, 1-9.
<https://doi.org/10.4314/cajeb.v5i1.44442>
- [21] Vimla, G., Khan, M.S. and Usha (2013) Studies on Pollinator and Their Relative Abundance of Sunflower (*Helianthus annuus* L.) at Pantnagar (Uttarkhand, India). *Journal of Applied and Natural Science*, **5**, 294-296.
<https://doi.org/10.31018/jans.v5i2.319>
- [22] Pisanty, G., Klein, A.M. and Mandelik, Y. (2013) Do Wild Bees Complement Honey Bee Pollination of Confection Sunflowers in Israel. *Apidologie*, **45**, 235-247.
<https://doi.org/10.1007/s13592-013-0242-5>
- [23] Fougereux, A., Leylavergne, S., Guillemard, V., Geist, O., Gary, P., Cenier, C., Caumes-Sudre, E., Senechal, C. and Vaissière, B. (2017) Effect of Pollinating Insect Activity on Pollination and Yield of Food Sunflower. *Oilseeds, Fats Crops and Lipids*, **24**, 8 p. <https://doi.org/10.1051/ocl/2017050>
- [24] Gallai, N., Salles, J.M., Settele J. and Vaissière, B.E. (2009) Economic Valuation of the Vulnerability of World Agriculture Confronted with Pollinator Decline. *Ecological Economics*, **68**, 810-821. <https://doi.org/10.1016/j.ecolecon.2008.06.014>
- [25] Djoufack, M.V., Fontaine, B., Martiny, N. and Tsalefac, M. (2012) Climatic and Demographic Determinants of Vegetation Cover in Northern Cameroon. *International Journal of Remote Sensing*, **33**, 6904-6926.
<https://doi.org/10.1080/01431161.2012.693968>
- [26] Amougou, J.A., Abossolo, S.A. and Tchindjang, M. (2015) Variability of Precipitations at Koundja and Ngaoundere Based on Temperature Changes of Atlantic Ocean and El NINO. *Ivory Coast Review of Science and Technology*, **25**, 110-124.
http://REVIST_25_9/

- [27] Tchuenguem, F.F.-N., Messi, J. and Pauly, A. (2001) Activity of *Meliponula erythra* on *Dacryodes edulis* Flowers and Its Impact on Fructification. *Fruits*, **56**, 179-188. <https://doi.org/10.1051/fruits:2001121>
- [28] Tchuenguem, F.F.-N. (2005) Foraging and Pollination Activity of *Apis mellifera adansonii* Latreille (Hymenoptera: Apidae, Apinae) on the Flowers of Three Plants in Ngaoundere (Cameroun): *Callistemon rigidus* (Myrtaceae), *Syzygium guineense* var. *macrocarpum* (Myrtaceae) and *Voacanga africana* (Apocynaceae). State Thesis Doctorate, University of Yaoundé I, Yaoundé, 10 p.
- [29] Borror, D.J. and White, R.E. (1991) North American Insects (North Mexico). Broquet, the Prairie, 408 p.
- [30] Jean-Prost, P. (1987) Apiculture: Knowing the Bees-Taking Care of the Apiary. 6th Edition, Lavoisier, Paris, 579 p.
- [31] Jacob-Remacle, A. (1989) Foraging Behavior of Domestic and Wild Bees within the Apple Orchards in Belgium. *Apidologie*, **20**, 217-285. <https://hal.archives-ouvertes.fr/hal-00890783>
<https://doi.org/10.1051/apido:19890401>
- [32] Kajobe, R. (2006) Pollen Foraging by *Apis mellifera* and Stingless Bees *Meliponula nebulata* in Bwindi Impenetrable National Park, Uganda. *African Journal of Ecology*, **45**, 265-274. <https://doi.org/10.1111/j.1365-2028.2006.00701.x>