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Pollination efficiency of *Chalicodoma cincta* (Fabricius) (Hymenoptera: Megachilidae) on *Cajanus cajan* (L.) Millsp. (Fabaceae) flowers at Doyaba (Sarh, Chad)

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Abstract

To evaluate *Chalicodoma cincta* impact on pod and seed yields of *Cajanus cajan*, its foraging and pollinating activities were studied in Doyaba, during the rainy season of 2015 and 2016. Each year, treatments included flowers accessible to all visitors, bagged flowers to avoid insect visitors, bagged flowers using gauze bags destined to be visited exclusively by *C. cincta* and bagged flowers destined to opening and closing without the visit of insects or any other organism. For each year of study, observations were made on 1028 ± 90 flowers per treatment. *Chalicodoma cincta* daily rhythm of activity, its foraging behaviour on flowers and its pollination efficiency were evaluated. On flowers, individual bees intensely harvested exclusively nectar. The fruiting rate, the number of seeds per pod and the percentage of normal seeds of unprotected flowers were significantly higher than those of flowers protected from insects. Through its pollination efficiency, *C. cincta* provoked a significant increment of the fruiting rate by 21.40% and 7.55%, the number of seeds per pod by 16.69% and 14.96% and the percentage of normal seeds by 32.95% in 2015 and 36.30% in 2016 respectively. The Conservation of *C. cincta* nests close to *C. cajan* fields is recommended to improve pod and seed productions in the region.

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Introduction

Several plant species depend on insect pollinators for their reproduction; in agro ecosystems, these pollinators have a great ecological and economic importance because they influence positively the plant production (McGregor, 1976; Philippe, 1991; Tchuenguem, 2005). *Cajanus cajan* is an ideal pulse crop of rainfed tropics and subtropics (Saxena *et al.,* 2002). Its grows up right to 4 m (Niyonkuru, 2002).

The leaves are generally trifoliate; flower is pink, but can vary from white to red (ICRISAT, 1981) and produces nectar and pollen which attract insects (Grewal *et al.,* 1990; Saxena *et al.*, 1990; Reddy *et al.*, 2004; Sarah *et al.,* 2010).

Indian is the largest producers of pigeon pea in the world (Kimani, 2000). The fruit is a pod containing four raw of seven seeds (Pando *et al.*, 2011b). Seeds contain 21 to 30% proteins important for human's diets (Sharma and Green, 1980; Gupta *et al.,* 2001; Saxena *et al.,* 2002). *Cajanus cajan* flowers were reported to produce fewer seeds per pod in the absence of insect pollinators in Great Britain (Kendall and Smith, 1976) and in Cameroon (Pando *et al.*, 2011b).

The research conducted in the United Stated of America (Grewal *et al.*, 1990; Ibarra-Perez *et al.*, 1999) and in Cameroon (Pando, 2012; Mazi*,* 2015) has revealed that bees of the genus *Chalicodoma* and *Megachile* visits *C. cajan* flowers and collect nectar and pollen. In Chad, the quantity of *Ca. cajan* available to consumers is very low, the demand for pigeon pea seeds is high, and its pod and seed yields are weak because notably of the insufficiency of knowledge on its relationships with anthophilous insects in general and *C. cincta* in particular. Therefore, it is important to investigate how the production of this plant could be increased in Chad.
Prior to these studies, no previous research has been reported on the interactions between *Ca. cajan* and insects in Chad. The main objective of this work is to contribute to the understanding of the relationships between *C. cajan* and *C. cincta*, for their optimal management in this country. Specific objectives are to: (a) study the activity of this Megachilidae on *C. cajan* flowers, (b) evaluate the impact of flowering insects including *Ch. cincta* on pollination and fruit and seed yields of this Fabaceae, (c) estimate the pollination efficiency of *C. cincta* on this plant species.

Materials and methods

Site and biological materials

The studies were conducted twice, June to November in 2015 and 2016 in a field located at Doyaba, Moyen-Chari Region of Chad. This Region belongs to the Sudanian agro-ecological zone (Cabot and Bouquet, 1972). The climate is tropical type with two seasons: a dry season (November to April) and a rainy season (May to October).

The mean annual temperature is 28°C; the mean rainfall is 1100 mm (Madjimbé, 2013). The experimental plot was an area of 437 m^2 (Latitude: 09° 04.875' N, Longitude: 018° 25.721' E, Altitude 363.3 m.a.s.l.). The animal material was represented by insects naturally present in the environment.

The vegetation was represented by wild and cultivated species. The plant material was represented by the seeds of *C. cajan* variety ICPL 9145, provided by the Agronomic Institute of the University of Sarh.

Sowing and weeding

On June 14^{th}, 2015 and 2016 the experimental plot was divided into eight subplots (8*4.5 m^2). Seeds were sown on 16 lines per subplot; each line had nine holes and each hole received three seeds.

The spacing was 50 cm between rows and 50 cm on rows. Each hole was 5 cm depth. Two weeks after germination, the plants were thinned and only two were left per hole (Pando *et al.*, 2011b). Weeding was performed manually as necessary to maintain subplots weeds-free (Tchuenguem *et al*, 2009a; Pando *et al.,* 2013).

Determining the reproduction mode

In October 12th, 2015, 2282 flowers of *Ca. cajan* at the bud stage were labeled, among which 1136 were allowed for treatment 1 (open pollination) and 1146 for treatment 2 (bagged with gauze bags to prevent visitors) (Tchuenguem, 2005; Delaplane *et al.*, 2013) (Fig. 1). In October 11th, 2016, 2039 flowers at the bud stage were labeled, among which 992 were provided for treatment 3 (open pollination) and 1047 flowers for treatment 4 (bagged with gauze bags). For each year, ten days after the wilting of the last flower, the number of pods formed in each treatment was counted. For each treatment, the fruiting index (*Ifr*) was then calculated using the following formula: $Ifr = (F_1/F_2)$, where F_1 is the number of pods formed and F_2 the number of flowers initially labeled (Tchuenguem *et al.*, 2001). For each year, the out crossing rate (*TC*) was calculated using the formula: $TC = \{[(Ifr_a - Ifr_b /fr_a]*100\}$, where Ifr_a and Ifr_b are the mean fruiting indexes in treatment *a* (flowers in open pollination) and treatment *b* (bagged flowers) respectively (Demarly, 1977). The rate of self-pollination in the broad sense (*TA*) was calculated using the formula: $TA = (100 - TC)$ (Tchuenguem, 2005; Népidé and Tchuenguem, 2016).

Study of the activity of Chalicodoma cincta on Cajanus cajan flowers

Observations were conducted on individually opened flowers of treatments 1 and 3, each day, from October 13th to November 03th 2015 and from October 12th to November 04th 2016, at one hour interval, from 6 am to 15 pm (6-7 am, 8-9 am, 10-11 am, 12-13 pm and 14-15 pm). In a slow walk along all labeled flowers of treatments 1 and 3, the identity of each insect that visited *Ca. cajan* flowers was noted. All insects encountered on flowers were recorded and the cumulated results expressed in number of visits to determine the relative frequency of *C. cincta* in the anthophilous entomofauna of *C. cajan* (Pando *et al.*, 2011b). Direct observations of the foraging activity of this bee on flowers were made. The floral products (nectar and/or pollen) collected by *Ch. cincta* were recorded during the same dates and time slots as that of the insect counts (Pando *et al.*, 2011b). The duration of visits per flower was recorded (using stopwatch) according to five time frames (7-8 am, 9-10 am, 11-12 am, 13-14 pm and 15-16 pm). The foraging speed (number of flowers visited by individual bee per minute (Jacob-Remacle, 1989) was recorded during the same date and daily periods as the registration of the duration of visits. Abundances (highest number of individuals simultaneously active) per flower and per 1000 flowers (A_{1000}) were recorded during the same dates and time slots as that of the registration of the duration of visits per flower. The first parameter was recorded as a result of direct counts. For the abundance per 1000 flowers, bees were counted on a known number of open flowers at the moment *t*. The abundance per 1000 flowers is calculated using formula: $A_{1000} = [(A_a/F_b)*1000]$, where F_b and A_b are respectively the number of flowers and the number of *C. cincta* effectively counted on these flowers at time *t* (Tchuenguem *et al.*, 2004; Tchuenguem, 2005; Douka *et al.*, 2017). The disruption of the activity of individual bee by competitors or predators and the attractiveness of other plant species with respect to *C. cincta* were assessed. During the days of investigation, the temperature and humidity of the study site were recorded every 30 min, from 6 am to 17 pm, using a thermo hygrometer installed in the shade (Tchuenguem *et al.*, 2004; Farda and Tchuenguem, 2018).

Evaluation of the impact of flowering insects including Chalicodama cincta on Cajanus cajan yield

For each investigation year, this evaluation was based on the impact of flowering insects on pollination, the impact of pollination on fruiting and the comparison of yields (fruiting rate, mean number of seeds per pod and percentage of normal *i.e.* well-developed seeds) of treatment *a* (unprotected flowers) and treatment *b* (bagged flowers).

The fruiting rate due to the influence of foraging insects (Fr_i) was calculated using the formula: $Fr_i = \{[(Fr_a - Fr_b)/Fr_a]*100\}$, where Fr_a and Fr_b are the fruiting rate in treatments *a* and *b* respectively. The fruiting rate of a treatment (*Fr*) is $Fr = [(F_2/F_1)*100]$, where, F_2 is the number of pods formed and F_1 the number of viable flowers initially set (Tchuenguem *et al.*, 2001). At maturity, pods were harvested from all treatments.

The mean number of seeds per pod and the percentage of normal seeds were then calculated for each treatment.

Assessment of the pollination efficiency of Chalicodoma cincta on Cajanus cajan

In 2015, along with the development of treatments 1 and 2, 1976 flowers at bud stage were protect and two treatments was formed: treatments 5, with 1052 flowers protected using gauze bags to prevent insect visitors and destined exclusively to be visited by *Ch. cincta*; treatment 6, with 924 flowers protected from insects using gauze bags.

In 2016, along with the realization of treatments 3 and 4, 1940 flowers at the bud stage were labeled and two treatments was formed: treatment 7 with, 893 flowers protected from insects using gauze bags and destined exclusively to be visited by *C. cincta*; treatment 8 with 1047 flowers protected from insects using gauze bags.

As soon as the first flowers were opened, in treatments 5 and 7, the gauze bag was delicately removed and flowers were observed for up to 10 min. Flowers visited by *C. cincta* was marked and then protected once more. For treatment 6 and 8, as soon as the firsts flower was opened, the gauze bag was delicately removed and flowers were observed for up to 10 min while avoiding the visits by any other organism.

At the maturity, pods were harvested and the contribution of *Ch. cincta* in fruiting, number of seeds per pod and percentage of normal seeds was then calculated using data of treatments 3 or 8 (flowers visited exclusively by *C. cincta*) and those of treatments 2 or 7 (bagged flowers).

Data analysis

Data were subjected to descriptive statistics, student's *t*-test for the comparison of means of the two samples, ANOVA for the comparison of means of more than two samples, correlation coefficient (*r*) for the study of the association between two variables, and chi-square ($\chi 2$) for the comparison of percentages, using Microsoft Excel 2010 software.

Results

Reproduction mode of Cajanus cajan

The podding indexes were 0.92, 0.73, 0.84 and 0.74, in treatments 1, 2, 3 and 4 respectively. Consequently, in 2015, the allogamy rate was 20.85% and the autogamy rate was 79.15%; for 2016, the corresponding data were 11.90% and 88.10%. It appears that the *Ca. cajan* variety used in our experiment has a mix reproduction mode, autogamous-allogamous with the predominance of autogamy over allogamy.

Activity of Chalicodoma cinta on Cajanus cajan flowers

Seasonal frequency of visits: Among the 2317 and 2373 visits of 16 and 14 insect species recorded on *C. cajan* flowers in 2015 and 2016 respectively, *C. cincta* was the most represented insect with 371 visits (15.35%) in 2015 and 383 visits (16.14%) in 2016 (Table 1). The difference between these two percentages is not significant ($\chi 2 = 0.87$; $df = 1$; $P > 0.05$).

Flower substances harvested: From our field observations of the years 2015 and 2016 *C. cincta* were found to collect regularly and exclusively nectar in the flowers of *C. cajan* (Fig. 2).

Abundance of *Chalicodoma cincta***:** In 2015, the highest mean number of *Ch. cincta* simultaneous in activity was one per flower ($n = 230$; $s = 0$) and 188.08 per 1000 flowers ($n = 230$; $s = 154.84$). In 2016, the corresponding results were one per flower ($n = 198$; $s = 0$) and 189.65 ($n = 198$; $s = 198.65$) per 1000 flowers.

The difference between the mean number of *C. cincta* per 1000 flowers of the two years was not significant ($t = 1.08$; $df = 426$; $P > 0.05$).

Duration of visits per flower: In 2015, the mean duration of individual *Ch. cincta* visit per *Ca. cajan* *flower* was 9.00 sec ($n = 1168$; $s = 8.9$). The corresponding index was 8.36 sec ($n = 704$; $s = 8.27$) in 2016. The difference between these two means is higher significant ($t = 20.56$; $df = 292$; $P < 0.001$).

Table 1. Diversity of floral insects on *Cajanus cajan* in 2015 and 2016 at Doyaba, number and percentage of visits of different insects.

		Insects	2015		2016		2015/2016	
Order	Family	Genus, species	n_1	p_1 (%)	n_2	p_2 (%)	n_T	p_T (%)
Hymenoptera	Apidae	*Apis mellifera* (ne)	195	8.07	189	7.96	384	8.19
		Amegilla acraensis (ne)	125	5.17	125	5.27	250	5.33
		Amegilla sp. 1 (ne)	115	4.76	126	5.31	241	5.14
		Amegilla sp. 2 (ne)	68	2.81	71	2.99	139	2.96
		Xylocopa inconstans (ne)	91	3.76	93	3.92	184	3.92
		Xylocopa olivacea (ne)	276	11.42	292	12.31	568	12.11
		Euapsis abdominalis (ne)	91	3.76	96	4.05	187	3.99
	Megachilidae	*Chalicodoma rufipes* (ne)	259	10.72	273	11.50	532	11.34
		Chalicodoma cinta (ne)	371	15.35	383	16.14	754	16.08
		Megachile sp. 1 (ne)	189	7.82	196	8.26	385	8.21
		Megachile sp. 2 (ne)	59	2.44	56	2.36	115	2,45
	Vespidae	*Belonogaster juncea* (ne)	58	2.40	58	2.44	116	2.47
		Coelioxys sp (ne)	63	2.61	-	-	63	1.34
	Formicidae	*Camponotus flavomarginatus* (ne)	200	8.27	225	9.48	425	9.06
		Myrmicaria sp. (ne)	182	7.53	190	8.01	372	7.93
Lepidoptera	Pieridae	*Eurema sp.* (ne)	75	3.10	-	-	75	1.60
Total		16 species	2317	100,00	2373	100	4584	100

*n*1: number of visits on 1136 flowers in 23 days; *n*2: number of visits on 1146 flowers in 23 days; *p1* and *p2*: percentages of visits; $p1 = (n1/2317)*100$; $p2 = (n2/2373)*100$; n_T: total number of visit; p_T (%):total percentages; sp.: undetermined species; ne: visitor collected nectar.

Comparison of percentages of *Chalicodoma cincta* visits for two years: $\chi 2 = 0.01$ ($df = 1$; $P > 0.05$).

Foraging speed of *Chalicodoma cincta* in *Cajanus cajan* field: In *Ca. cajan* field, *Ch. cincta* visited between 3 and 25 flowers per minute in 2015 and between 2 and 26 flowers per minute in 2016. The mean foraging speed was 12.38 flowers/min ($n = 316$; $s = 0.55$) in 2015 and 11.09 flowers per minute ($n = 260$; $s = 1.12$) in 2016.

The difference between these two means is highly significant ($t = 157.36$; $df = 574$; $P < 0.001$).

Table 2. Fruiting rate, number of seeds per pod and percentage of normal seeds according to different treatments of *Cajanus cajan* in 2015 and 2016 at Doyaba.

Years	T	NF	NFP	FrR (%)	Seeds/pod		TNS	NS	% NS
					m	*sd*			
2015	1 (Uf)	1136	1048	92.25	5.88	0.38	635	598	94.17
	2 (Bf)	992	725	73.08	4.90	0.70	500	327	65.40
	5 Bfvch)	1052	971	92.30	5.87	0.42	587	531	90.45
	6 (Biwv)	924	670	72.54	4.89	0.30	465	282	60.64
2016	3 (Uf)	1146	967	84.38	5.64	0.52	609	572	93.92
	4 (Bf)	1036	792	76.44	4.91	0.53	496	321	64.71
	7(Bfvch)	893	739	82.75	5,68	0.68	568	515	90.66
	8 (Bfwv)	1047	801	76.50	4.83	0.40	464	268	57.75

NF: Number of flowers; NFP: Number of formed pod; FrR: Fruiting rate; TNS: Total number of seeds; NS: Normal seeds; %NS: Percentage of normal seeds; *m*: mean; *sd*: standard deviation; T: traitments Uf: unprotected flowers; Bf: flowers bagged; Bfvch: flowers bagged and exclusively visited by *Chalicodoma cincta*; Bfwv: flower bagged and not visit by insects or any other organism.

Daily rhythm of visits: *Chalicodoma cincta* were active on the flowers of *C. cajan* from 7 am to 16 pm, with a peak of visits between 9 and 10 am in 2015 as well as in 2016 (Fig. 3). Ambiant temperature and humidity conditions have not influenced the activity of *C. cincta* on *C. cajan* flowers in the field conditions.

Fig. 1. Plant of *Cajanus cajan* showing a flower protected from insects.

The correlation was not significant between the number of *C. cincta* visits on *Ca. cajan* flowers and the temperature in 2015 (r = -0.82; df = 3; P > 0.05) and in 2016 (r = -0.86; df = 3; P > 0.05). The correlation between the number of visits and the humidity was not significant in 2015 (r = 0.50; df = 3; P > 0.05) as well as in 2016 (r = 0.67; df = 3; P > 0.05) (Fig. 3).

Impact of flower-feeding insects on the pollination and yields of Cajanus cajan

During nectar harvest, flowering insects of *Ca. cajan* were in regular contact (100% respectively in 2015 and 2016) with the anthers and stigma. Thus, these insects increased the pollination possibilities of this plant species. Table 2 present the results on the fruiting rate, the number of seeds per pod and the percentage of normal seeds in different treatments. From this table, we documented the following:

(a) The comparison of the fruiting rate showed that the difference was highly significant between treatment 1 (unprotected flowers) and treatment 2 (bagged flowers) in the first year (χ^2 = 11.83; df = 1; P< 0.001) and significant between treatment 3 (unprotected flowers) and treatment 4 (bagged flowers) in the second year (χ^2 = 4 .68; df = 1; P < 0.05). Consequently, in 2015 and 2016, the fruiting rate of unprotected flowers was higher than that of bagged flowers;

Fig. 2. *Chalicodoma cincta* collecting nectar in a flower of *Cajanus cajan*.

(b) The comparison of the mean number of seeds per pod showed that the difference was highly significant between treatments 1 and 2 (t = 785.23; df = 1771; P < 0.001) in 2015 and between treatment 3 and 4 (t = 605.61; df = 1757; P < 0.001) in 2016. Consequently, in 2015 as in 2016, the mean number of seeds per pod of the unprotected flowers was higher than that of protected flowers;

(c) The comparison of the percentage of normal seeds showed that the difference was highly significant between treatments 1 and 2 (χ^2 = 1 5 3 .59; df = 1; P < 0.001) as well between treatments 3 and bagged (χ^2 = 150.40; df = 1; P < 0.001). Thus, in 2015 as in 2016, the percentage of normal seeds produced by unprotected flowers was higher than that produced by of protected flowers.

The numeric contribution of flowering insects to the fruiting rate, the mean number of seeds per pod and the percentage of normal seeds were respectively

20.78%, 16.66% and 30.55% in 2015. The corresponding figures were 9.40%, 12.94% and 31.10% in 2016. For the two cumulate years, the numeric contributions of flowering insects were 15.09%, 14.37% and 30.82% in the fruiting rate, the mean number of seeds per pod and the percentage of normal seeds respectively.

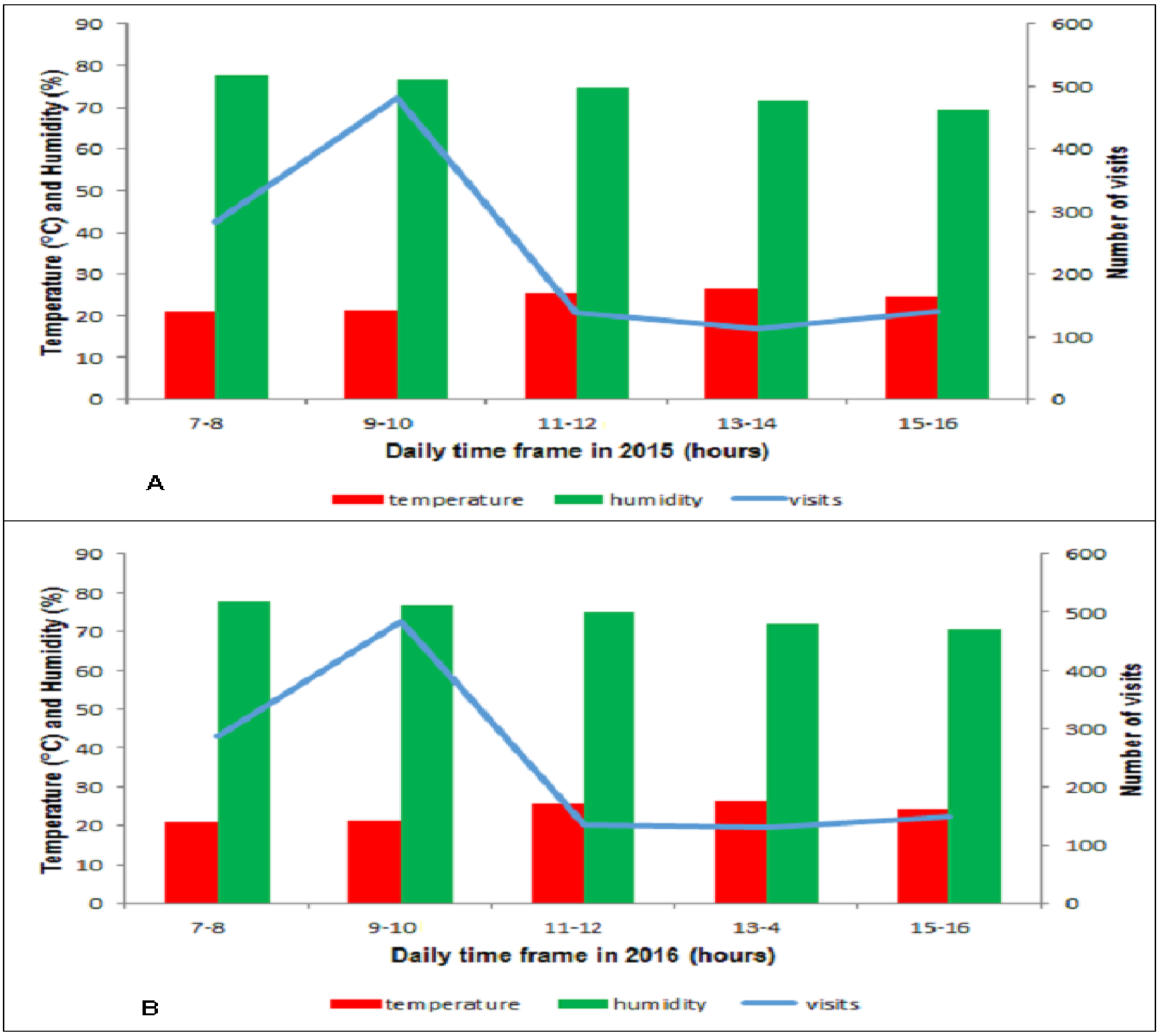

Fig. 3. Mean daily temperature and humidity and number of *Chalicodoma cincta* visits on *Cajanus cajan* flowers in 2015 (A) and 2016 (B) at Doyaba.

Pollination efficiency of Chalicodoma cincta on Cajanus cajan

From Table 2, it appears that:

(a) The comparison of the fruiting rate showed that the difference were higher significant between treatment 5 (flowers protected and visited exclusively by *Ch. cincta*) and treatment 6 (bagged flowers to prevent insect visitors) ($\chi 2$ = 136.83; *df* = 1; $P < 0.001$) as well as between treatment 7 (flowers protected and visited exclusively by *Ch. cincta*) and treatment 8 (bagged flowers to prevent insect visitors) ($\chi 2$ = 11.50; *df* = 1; $P < 0.001$). Consequently, in 2015 as in 2016, the fruiting rate of flowers protected and visited exclusively by *C. cincta* was higher than that of flowers bagged to prevent insect visitors;

(b) The comparison of the mean number of seeds per pod showed that the difference were highly significant between treatments 5 and 6 (t = 1033.58; *df* = 1639; $P < 0.001$) and between treatments 7 and 8 (t = 591.10; *df* = 1538; $P < 0.001$). Consequently, in 2015 as in 2016, the pods produce by flowers bagged and visited exclusively by *C. cincta* were higher than those of flowers protected to prevent insect visitors;

(c) The comparison of the percentage of normal seeds showed that the difference were highly significant between treatment 5 and 6 ($\chi 2$ = 131.37; *df* = 1; $P <$ 0.001) and between treatments 7 and 8 ($\chi 2$ = 151.10; *df* = 1; $P <$ 0.001) respectively. For the two years, the pods produced by flowers bagged and visited exclusively by *C. cincta* had more normal seeds than those of flowers protected to prevent insect visitors.

The numeric contribution of *Ch. cincta* in the fruiting rate, the mean of number of seed per pod and the percentage of normal seeds were respectively 21.40%, 16.69% and 32.95% in 2015. The corresponding results were 7.55%, 14.96% and 36.30% in 2016. For the two cumulated years, the numeric contributions of *Ch. cincta* in the fruiting rate, the mean number of seeds per pods and the percentage of normal seeds of *Ca. cajan* were 14.47%, 15.82% and 34.62% respectively.

Discussion

Reproduction mode of Cajanus cajan

Our results show that *C. cajan* has an allogamy-autogamy reproduction mode with the predominance of autogamy. The same result was reported by Pando *et al.* (2011b) in Yaoundé and Mazi *et al.* (2014) in Ngaoundéré.

Activity of Chalicodoma cinta on Cajanus cajan flowers

Results obtained from our experiments indicated that *C. cincta* was the main floral insect visitor of *Ca. cajan*. The same result was reported by Pando *et al.* (2011b) for the same bee on the same plant species in Yaoundé. The significant difference between the percentages of *C. cincta* visit for the two years of study could be explained by the variation of the number of *C. cincta* nests (17 in 2015 and 28 in 2016) and the needs of this bee for one year to another. The activity of *C. cincta* on the flowers of *C. cajan* was highest in the morning, which correspondent to the daily moment of highest availability of nectar on *Ca. cajan* flowers. The same result has been reported by Saxena and Kumar (2010) in India and Pando *et al.* (2011b) in Cameroon. The high abundance of *C. cincta* per 1000 flowers indicated a good attractiveness of *C. cajan* nectar vis-à-vis of *C. cincta*. The positive and significant contribution of *C. cincta* in the pod and seeds yields of *C. cajan* is justified by the action of this leat cutter bee on pollination.

Pollination efficiency of Chalicodoma cincta on Cajanus cajan

During the collection of nectar on each flower, *C. cincta* regularly come into contact with the stigma. They were also able to carry pollen with their hairs, abdomen, legs and mouth accessories from a flower of one plant to stigma of another flower of the same plant (geitonogamy), to the same flower (autogamy) or to that of another plant (xenogamy) (Saxena and Kumar, 2010). The significant contribution of *C. Cincta* on pod and seed production of *C. cajan* is in agreement with the similar findings in Yaoundé (Pando *et al.*, 2011b) on the same Fabaceae. The contribution of *C. cincta* to *C. cajan* production through its pollination efficiency was significantly higher than that of all insects on the exposed flowers. The weight of *C. cincta* played a positive role. During nectar collection, *C. cincta* shook flowers and could facilitate the liberation of pollen by anthers for the optimal occupation of the stigma. This phenomenon was also reported by Pando *et al.* (2011b) in Yaoundé (Cameroon) on this same plant species.

The higher production of seeds per pod and that of normal seeds in the treatment with flowers visited exclusively by *C. cincta* compared to that of the treatment with protected flowers showed that *C. cincta* visit was effective in increasing pollination. Our results confirmed those of Pando *et al.*, 2011 and Mazi (2015) who revealed that *C. cajan* flowers set little pods in the absence of insect pollinators.

Conclusion

From our observations, the variety of *Cajanus cajan* studied is a plant species that highly benefits from pollination by insects among which *C. cincta* is of great importance. The comparison of pod and seed set of unprotected flowers to those of flowers visited exclusively by *C. Cincta* underscores the value of this bee in increasing podding rate, the number of seeds per pod and the percentage of normal seeds of *Ca. cajan*. The installation and/or the kept of *Ch. cincta* nest at the vicinity of pigeon pea fields is recommended to Chadian farmers to increase pot and seed productions.

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