Effect of a single *Xylocopa olivacea* Fabricius, 1778 (Hymenoptera: Apidae) flower visit on *Solanum lycopersicum* L., 1753 (Solanaceae) Rudina variety at Meskine (Maroua, Cameroon)

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***Keywords:** Carpenter bee, tomato, pollination effectiveness, production.*

Submitted 19/08/2024, Published online on 30th September 2024 in the *Journal of Animal and Plant Sciences (J. Anim. Plant Sci.) ISSN 2071 – 7024*

1 ABSTRACT
To evaluate the effect of *Xylocopa olivacea* on *Solanum lycopersicum* productions, foraging and pollinating activities of the individuals of this carpenter bee were examined at Meskine in Maroua (Far North, Cameroon) in January 2019 and February 2020. Every year, the trials were done on 540 flowers separated into four treatments: two treatments distinguished by the presence or absence of protection of flowers; the third with flowers preserved and revealed when they were bloomed, to permit a single *X. olivacea* visit; the fourth with flowers preserved then uncovered and reprotected without the visit of some life forms. Foraging activity and pollination effectiveness of *X. olivacea* on flowers were assessed. Outcomes demonstrate that 21 insect species recorded on tomato flowers, *X. olivacea* ranked second representing for 21.39 % of visits. This bee consistently and intensively gathered pollen, though nectar was marginally harvested. All through the pollination effectiveness of a single flower insect visit, *X. olivacea* expanded the fruiting rate, the mean number of seeds per fruit, and the percentage of typical seeds by 39.45 %, 35.19 % and 8.51 %, respectively. Thus, the installation of the nests of this carpenter bee near or within tomato fields is recommended to enhance fruit production as well as seed quality.

2 INTRODUCTION
Solanum lycopersicum regularly called tomato is native to South America (Shankara, 2005). The plant is yearly in cultivation (Ranc, 2010). It is pubescent, has flowers, and requires pollination to reproduce (Reeves, 1973) It is cultivated and utilized as food (Shankara, 2005) and therapeutic (Jouzier, 2005). It is the principal vegetable on the planet, ahead of watermelon and cabbage (FAOSTAT, 2018). In Cameroon, fruits are broadly cultivated; however the yield stays low (889 800 tons/year) (FAOSTAT, 2018). The yearly need in this nation was assessed at 1 159 195 tons/year (MINADER, 2015). Consequently, investigating the possibilities of increasing the production of *S. lycopersicum* in Cameroon is important. To expect significant yields, farmers ought to consider all factors that can enhance the production of tomatoes, for example, pollinating insects. Without a doubt, more than 70 % of the world's crop species rely upon anthophilous pollination for their survival or

evolution (Klein *et al*., 2007; Abrol, 2012). Xylocopes are the best pollinators of vegetables since they had better trigger the flower pollination system than different bees (Pauly *et al*., 2015). Very little distributed information exists on the relationships between insect and *S. lycopersicum* flowers. Silva-Neto *et al*. (2017) in Bazil found that *Exomalopsis analis* was the primary bee visitor; Toni *et al*. (2018) in Kétou (Benin) observed that *X. olivacea*, *Amegilla* sp., *Halictus* sp. and *Hylaeus* sp. enhance the fruiting percentage from 6 to 29 % and the number of seeds per fruit from 39 to 61 %; Kingha *et al*. (2021) in Ngaoundéré (Cameroon) discovered that the pollinating efficiency of *X. olivacea* caused an important increase in the fruiting percentage by 25.40 % and the percentage of typical seeds by 12.92 %. Following the deficiency of complete information on the relationship between *S. lycopersicum* and its anthophilous insects, it is important to do extra research on tomatoes to fulfill the beneficial accessible information. Consequently, concentrating on the *X. olivacea* proficiency in *S. lycopersicum* flowers in the Far North Region of Cameroon is necessary. The fundamental objective of this work was to add to the understanding of the relationships between *S. lycopersicum* and *X. olivacea* for their ideal management. In particular, it was to: (a) deternine the place of *X. olivacea* in *S. lycopersicum* floral entomofauna; (b) study of the activity of this carpenter bee on tomato flowers; (c) evaluate the effect of flowering insects including *X. olivacea* on fruit and seed productions of the Salanaceae; (d) assess the pollination efficiency of a single flower visit of this carpenter bee on *S. lycopersicum*.

3 MATERIAL AND METHODS

3.1 Material

3.1.1 Study site: The trials were done from fifth January to eighth February 2019 and from fourth February to eighth March 2020 at Meskine (scope: 10° 32' 26" N; longitude: 14° 14' 53" E; height: 410 m), a Western suburb of Maroua in the Far North Region of Cameroon. This Region has a place in the environmental zone with three phytogeographical areas (Sudano-Sahelian, Sahelian and Sudanian elevations) occasionally flooded, with unimodal precipitation (Letouzey, 1968). The climate is portrayed by two seasons: a dry season (November to May) and a wet season (June to October); August is the wettest month of the year (Bouba, 2009). Yearly precipitation fluctuates from 310 to 1100 mm; the yearly average temperature changes somewhere in the range between 29°C and 38°C; the day-to-day temperature range somewhere in the range between 6°C and 7°C (Wanie and Ndi, 2018). The trial plot was a cleared field of 437 m^2. The animal material included *X. olivacea* and other insect species normally present in the environment. The vegetation was represented by wild and cultivated species.

3.1.2 Biological materials: The plant material was *S. lycopersicum* Rudina variety whose seeds (Figure 1) were given by the SEMAGRI of Maroua. The animal material was principally represented by insects normally present in the environment of the investigation site.

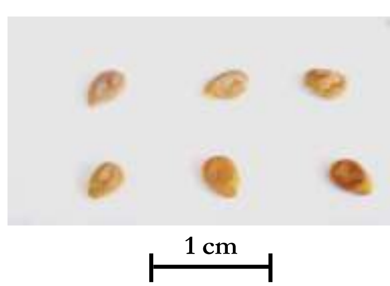


Figure 1: Seeds of *Solanum lycopersicum* variety Rudina.

3.2 Methods

3.2.1 Sowing and weeding: From October twelfth to eighteenth 2019 and from October twenty-second to thirtieth 2020, the experimental plot was separated into 8 subplots of 8*4.5 m^2 each. Three seeds were planted per opening on six lines per subplot. There were 16 openings for every line. Openings were isolated 70 cm from each other, while lines were 70 cm separated. Weeding was performed manually as important to keep plot weed-free (Mamoudou *et al*., 2021).

3.2.2 Determination of the reproduction mode of *Solanum lycopersicum:* On January thirteenth, 2019, 240 flowers of *S. lycopersicum* at bud stage were marked and isolated into two treatments: 120 flowers available to all visitors (treatment 1) and 120 flowers bagged utilizing gauze bags sacks net to stay away from insect visits (treatment 2) (Tchuenguem *et al*., 2001). In addition, on February thirteenth, 2020, 240 flowers at the budding stage were named of which 120 flowers were left unprotected (treatment 5), while 120 were stowed (treatment 6). For every year, after the flowering period, the number of fruits formed in every treatment was counted. For every treatment, the fruiting index (Fr_i) was then determined as portrayed by (Tchuenguem *et al*., 2001):

$$Fri = Fb/Fa \quad (1)$$

where *Fa* was the number of flowers and *Fb* the number of formed fruits. For every year, the allogamy rate (*Alr*) from which determines the autogamy rate (*Atr*) was communicated as the variation in fruiting indices between treatment *X* (unprotected flowers) and treatment *Y* (sacked flowers) (Tchuenguem *et al*., 2004):

$$Atr = (FriX - FriY/FriX) \times 100 \quad (2)$$

where *FriX* and *FriY* were the fruiting indices in treatments *X* and *Y* respectively;

$$Alr = 100 - Atr \quad (3)$$

3.2.3 Determination of the place of *Xylocopa olivacea* in *Solanum lycopersicum* entomofauna: Perceptions were directed on 120 individual opened pollinated flowers of treatments 1 and 5, every day, from seventeenth to twenty-seven January 2019 and from seventeenth to twenty-eight February 2020, as indicated by six daily time frames: 6 - 7 am, 8 - 9 am, 10 - 11 am, 12 - 13 pm, 14 - 15 pm and 16 - 17 pm. In a sluggish stroll alongside all-named flowers of treatments 1 and 5, the identity of all insects that visited *S. lycopersicum* flowers was recorded. Samples of every insect taxon were captured utilizing an insect net on unlabelled flowers and conserved in 70% ethanol, barring butterflies that were preserved dry (Borror and White, 1991), for additional taxonomic ID. All insects come across on flowers were enrolled and the cumulated results were communicated as the number of visits (Tchuenguem *et al*., 2009a; Fameni *et al*., 2022). The recurrence of visits of every insect species (Fv_i) on *S. lycopersicum* flowers was resolved utilizing information got. For each study period:

$$Fvi = (Nvi/Nvt) \times 100 \quad (4)$$

where *Nvi* was the number of visits of insect *i* on treatment with unprotected flowers and *Nvt*, the total number of insect visits recorded on these flowers.

3.2.4 Study of the foraging activity of *Xylocopa olivacea* on *Solanum lycopersicum* flowers

3.2.4.1 Floral product harvested: The floral products (nectar or pollen) collected by *X. olivacea* during each floral visit were documented in view of its foraging behaviour. Nectar foragers were supposed to expand their proboscis within the corolla, while pollen finders should scratch anthers utilizing mandibles and legs (Jean-Prost, 1987). During the similar time that *X. olivacea* visits on flowers were enlisted, the sort of floral product gathered by this carpenter bee was noted (Tchuenguem, 2005).

3.2.4.2 Duration of visits and foraging speed: During the same days concerning the recurrence of visits, the span of individual flower visits was recorded (utilizing a stopwatch) as indicated by six time frames: 7 - 8 am, 9 - 10 am, 11 - 12 am, 13 - 14 pm, 15 - 16 pm and 17 - 18 pm. Also, the number of visits during which the carpenter bee body came into contact with the stigma (Jacob-Remacle, 1989) was enlisted. As to foraging speed (*Fs*) which is the number of flowers visited by an individual carpenter bee per minute (Jacob-Remacle, 1989), information was enlisted during the similar dates and per similar time frames and day-to-day lengths concerning the span of visits. The stopwatch, recently set to zero was turned on when an individual arrived at a flower and the number of visited flowers was correspondingly counted. The stopwatch was halted when the visitor was lost to sight or when it left *S. lycopersicum* flowers for another plant species. The foraging speed was determined utilizing the accompanying equation:

$$Fs = (Nf/dv) \times 100 \quad (5)$$

where d_v was the time (sec) given by a stopwatch and *Nf* the number of flowers visited during d_v. During the perception, when a forager gets back to a formerly visited flower, counting was performed as two distinct flowers (Tchuenguem, 2005).

3.2.4.3 Abundances per flower and per 1000 flowers: The abundance of foragers (highest quantities of individuals foraging simultaneously) per flower and per 1000 flowers (A_{1000}) were recorded on similar dates and day-to-day time frames concerning the enrolment of length of visits. Abundance per flower was recorded because of direct counting. For deciding the abundance per 1000 flowers, foragers were counted on a known number of opened flowers, and A_{1000} was determined utilizing the accompanying equation:

$$A_{1000} = (Nfx/Nbx) \times 100 \quad (6)$$

where *Nfx* and *Nbx* were respectively, the number of flowers and the number of individual bees effectively counted on these flowers at time *x* (Tchuenguem*et al.*, 2004).

3.2.4.4 Foraging ecology: The disturbance of the activity of foragers by contenders or predators and the attractiveness applied by flowers of other plant species on *X. olivacea* was evaluated by direct perceptions (Fameni *et al.*, 2012). For the second parameter, the times that the carpenter bee left *S. lycopersicum* flowers to those of other plant species, as well as the other way around, was noted through the examination periods (Tchuenguem, 2005) During every day-to-day time of examination, ambient temperature and relative humidity in the review station were enrolled every 30 minutes utilizing a mobile thermo-hygrometer (Technoline WS9119) installed in the shade (Tchuenguem, 2005).

3.2.4.5 Evaluation of the impact of the flowering insects including *Xylocopa olivacea* on *Solanum lycopersicum* production: Lined up with the constitution of treatments 1, 2, 5 and 6, 600 flowers at bud stage were named in 2019 and 2020 to form two treatments:

- treatments 3 in 2019 or 7 in 2020: 200 flowers preserved utilizing gauze sack nets to forestall insect visits and bound to get one visit of *X. olivacea*. When the flowers were opened, each flower of treatments 3 and 7 was reviewed. Subsequently, the gauze sack was gently taken out and this flower was observed for as long as 10 minutes; the flowers visited by *X. olivacea* were marked and afterward reprotected. Unvisited flowers by this carpenter bee were involved in treatment 4 or 8 (Tchuenguem and Népidé, 2018); the flowers visited by different insects are rejected from treatments 3 or 7;
- treatments 4 in 2019 or 8 in 2020: 100 flowers protected utilizing gauze sack nets and bound to be uncovered then rebagged without the visit of insects or some other organisms (Diguir *et al.*, 2020); when each flower of these treatments was opened, the gauze sack was taken out and this flower was observed for as long as 10 minutes keeping away from visits by insects or some other life forms (Diguir *et al.*, 2020). At maturity, fruits were reaped and counted from every treatment. The mean number of seeds per fruit, the percentage of typical (matured) seeds (Tchuenguem *et al.*, 2009b) were then assessed. The assessment of the impact of insects including *X. olivacea* on *S.*

lycopersicum production depended on the effect of flowering insects on pollination, the effect of pollination on *S. lycopersicum* fruiting, and the correlation of production (fruiting percentage, number of seeds per fruit, and percentage of

$$Frri = ([(FrrU - FrrW)) / ((FrrU + FrrP - FrrW)] \times 100) \quad (7)$$

where *FrrU*, *FrrP*, and *FrrW* were the fruiting percentages in treatment *U* (unprotected flowers), treatment *P* (flowers preserved from all insect visits), and treatment *W* (flowers stowed then uncovered and rebagged without insect or some other life form visit). The fruiting percentage of a treatment (*Frr*) was determined utilizing the accompanying equation:

$$Frr = (Nfr/Nfl) \times 100 \quad (8)$$

where *Nfl* was the number of flowers and *Nfr* the number of formed fruits (Tchuenguem *et al*., 2009b). The effect of flower visiting insects including *X. olivacea* on the number of seeds per fruit and the percentage of typical seeds were assessed utilizing a similar technique as referenced above for the fruiting percentage.

3.2.4.6 Assessment of the pollination efficiency of a single flower visit by *Xylocopa olivacea* on *Solanum lycopersicum*: The contribution of *X. olivacea* on the fruiting percentage, the number of seeds per fruit and the percentage of typical seeds typical seeds) of treatments 1, 2, 4, 5, 6 and 8. For every perceptions year, the fruiting percentage because of the flowering insects including *X. olivacea* (*Frri*) was determined utilizing the accompanying equation:

through a single flower visit was determined utilizing the information of treatments 3 and 4 for 2019 and those of treatments 7 and 8 for 2020. For every study year, the contribution of *X. olivacea* on the fruiting percentage (*FrrX*) was determined utilizing the accompanying equation:

$$FrX = (FrrX - FrrW/FrrX) \times 100 (9)$$

(9)

where *FrrX* is the fruiting percentage in treatment *X* (flowers bagged then revealed, visited solely by *X. olivacea* and rebagged) (Tchuenguem *et al*., 2009a).The effect of *X. olivacea* on the fruiting percentage, the number of seeds per fruit, and the percentage of typical seeds were assessed utilizing a similar technique as referenced above for the fruiting percentage.

3.3 Data analysis: Information was analyzed utilizing descriptive statistics, ANOVA (*F*) for the overall comparison of means for multiple samples, Student's *t*-test for the comparison of means of two samples, Pearson correlation coefficient (*r*) for the trial of the relationship between two factors, and chi-square (χ^2) for the comparison of percentages utilizing R commander (version i386 3.2.0.) and Microsoft Excel 2010.

4. RESULTS AND DISCUSSION

4. 1 Reproduction mode of *Solanum lycopersicum*: The fruiting indexes of *S. lycopersicum* were 0.92, 0.89, 0.93 and 0.82 for treatments 1, 2, 5 and 6 respectively. Consequently, in 2019, the allogamy rate was 4.30 % though the autogamy rate was 95.70 %. In 2020, the comparing figures were 11.82 % and 88.18 %; for the two cumulated years, the allogamy rate was 8.06 % and the autogamy rate was 91.94 %. Apparently, *S. lycopersicum* Rudina variety has a mixed reproduction mode with the transcendence of autogamy over allogamy. Our outcome is in accordance with those got by Kingha *et al.* (2021) at Dang (Ngaoundéré) on *S. lycopersicum* var. Rio Grande who found that the allogamy rate was 15.06 % and the autogamy rate was 84.94 %.

4.2. Place of *Xylocopa olivacea* in *Solanum lycopersicum* floral entomofauna: Among 983 and 1130 visits of 10 and 21 insect species recorded on *S. lycopersicum* flowers in 2019 and 2020 respectively, *X. olivacea* positioned second with 230 visits (23.40 %) after *Xylocopa* sp. 1 in 2019 and first with 222 visits (19.6 %) in 2020 (Table 1). The contrast between the rates of *X. olivacea* visits for the two years is exceptionally significant ($\chi^2 = 4.40$; $df = 1$; $P < 0.001$). This contrast could be the result of climatic variables and seasonal variations in flower resources availability. *Exomalopsis analis* was the fundamental pollinator on the flowers of *S. lycopersicum* (Silva-Neto *et al.*, 2017) in the Minas Gerais State (Southeast Bazil). Toni *et al.* (2018) in the Kétou community (South Benin) viewed that *X. olivacea* and *Amegilla* sp. were the most frequent insect guests of *S. lycopersicum* flowers. Kingha *et al.* (2021) in Ngaoundéré (Cameroon) have shown that *Pachynomia* sp. was the most regular guest on *S. lycopersicum* flowers followed by *X. olivacea*. This contrast could be credited to a combination of climatic variables and seasonal variation in flower resources availability (Roubik, 1995).

Table 1: List of insects collected on *Solanum lycopersicum* flowers in 2019 and 2020 at Meskine, number and percentage of visits of different insects.

Insects			**2019**		**2020**		**Total**	
Order	**Family**	**Genus and species**	n_1	P_1 (%)	n_2	P_2 (%)	n_t	P_t (%)
Coleoptera		(sp. 1) (ne, po)	-	-	8	0.70	8	0.38
	Meloidae	*Mylabris* sp. (ne)	-	4	0.35	4	0.19	
Diptera	Muscidae	*Chrysomia chloropyga* (ne)	21	2.14	12	1.06	33	1.56
Hemiptera	Coreidae	*Anoplocnemis curvipes* (ne, po)	-	-	6	0.53	6	0.28
Hymenoptera	Apidae	*Apis mellifera* (ne, po)	121	12.30	112	9.91	233	11.03
		Amegilla calens (ne, po)	86	08.75	88	7.78	174	8.23
		Amegilla sp. 1 (ne, po)	-	-	32	2.83	32	1.51
		Amegilla sp. 2 (ne, po)	-	-	28	2.48	28	1.33
		Amegilla sp. 3 (ne, po)	25	2.54	16	1.42	41	1.94
		Ceratina sp. (po)	48	4.88	44	3.89	92	4.35
		Xylocopa olivacea (ne, po)	230	23.40	222	19.65	452	21.39
		Xylocopa sp. 1 (ne, po)	271	27.57	280	24.78	551	26.08
		Xylocopa sp. 2 (ne, po)	-	-	64	5.66	64	3.03
	Formicidae	*Componotus brutus* (ne)	-	-	6	0.53	6	0.28
	Halictidae	*Lipotriches azarensis* (ne, po)	124	12.61	82	7.26	206	9.75
		Lasioglossum sp. 1 (ne, po)	29	2.95	22	1.94	51	2.41
		Lasioglossum sp. 2 (ne, po)	-	-	18	1.59	18	0.85
	Megachilidae	(1. sp.) (ne, po)	-	-	22	1.94	22	1.04
	Vespidae	(1. sp.) (ne, po)	-	-	10	0.88	10	0.47
		(2. sp.) (ne)	-	-	12	1.06	12	0.57
Lepidoptera	Pieridae	*Eurema* sp. (ne)	28	2.84	42	3.72	70	3.31
TOTAL			**983**		**1130**		**2113**	
			10 species		**21 species**		**21 species**	

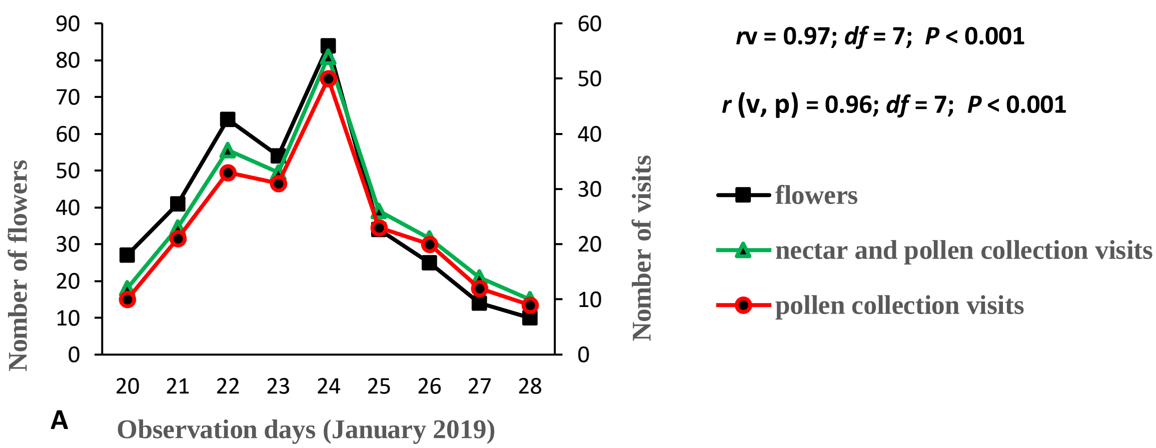
n_1 and n_2: number of visits on 120 flowers in 2019 and 2020 respectively; P_1 and P_2: percentages of visits in 2019 and 2020 respectively; sp.: undetermined species; $P_1 = (n_1 / 983) \times 100$; $P_2 = (n_2 / 1130) \times 100$; ne: nectar collection; po: pollen collection

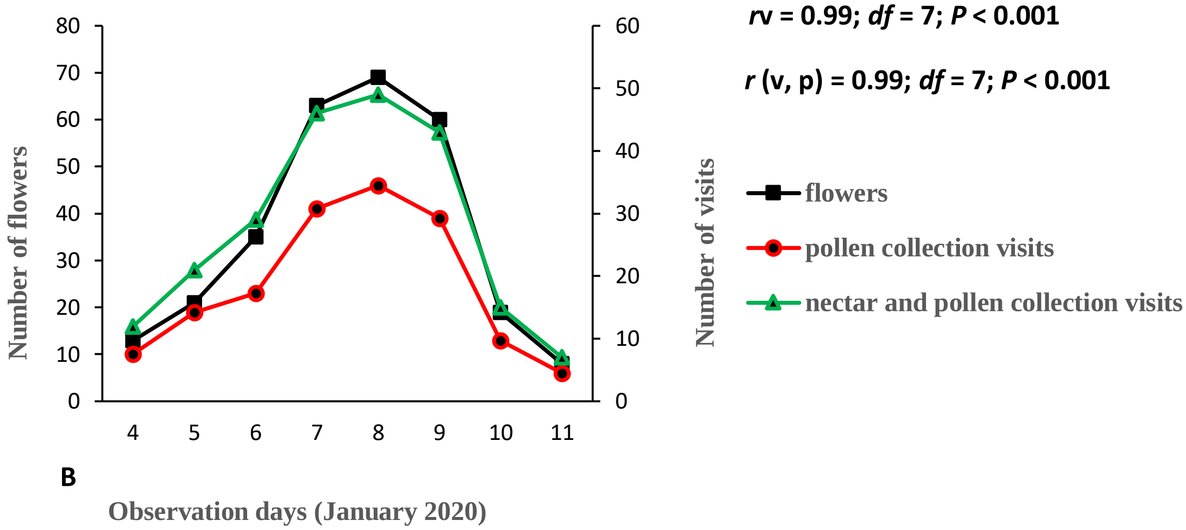
4.3 Activity of *Xylocopa olivacea* on *Solanum lycopersicum* flowers

4.3.1 Floral product harvested: During each flowering period, individuals of *X. olivacea* were found to gather pollen (Figure 2) routinely and intensively while nectar was marginally reaped in *S. lycopersicum* flowers. For 516 and 321 visits enrolled in 2019 and 2020 respectively, 467 (90.50%) and 280 (87.23%) were for pollen collection while 49 (9.50%) and 41 (12.77%) were for nectar harvest. For the total of 837 visits recorded during the two seasons, the percentage of the number of visits apportioned to pollen reap was 89.25% and that for nectar collection was 10.75%. These outcomes could be clarified by the fact that *S. lycopersicum* flowers give a lot of pollen (2-6 mg/flower) and very little amount of nectar, as demonstrated by Buchmann (1983).

Figure 2: *Xylocopa olivacea* collecting pollen in a *Solanum lycopersicum* flower at Meskine in 2019.

4.3.2 Rhythm of visits according to the flowering stages: *Xylocopa olivacea* visits were more in treatments 1 and 5 when their number of opened flowers was highest (Figure 3). We tracked down a positive and exceptionally important relationship between the number of *X. olivacea* visits and the number of *S. lycopersicum* opened flowers in 2019 ($r = 0.97$; $df = 7$; $P < 0.001$) (Figure 3A) as well as in 2020 ($r = 0.99$; $df = 7$; $P < 0.001$) (Figure 3B). These positive and important relationship demonstrate the generally excellent attraction of *S. lycopersicum* nectar and pollen regarding *X. olivacea*. At Dang, Kingha *et al.* (2021) have likewise tracked down a positive and exceptionally important relationship between the number of *X. olivacea* visits and the number of *S. lycopersicum* var. Rio Grande opened flowers. There was an exceptionally important relationship in 2019 [r (v, p) = 0.96; $df = 7$; $P < 0.001$] (Figure 3A) as well as in 2020 [r (v, p) = 0.99; $df = 7$; $P < 0.001$] (Figure 3B) between the number of visits committed solely to the collection of pollen and the number of blossoming flowers. Comparative discoveries on *S. lycopersicum* in Brazil (Silva-Neto *et al.*, 2017) have shown that *Exomalopsis analis* (Apidae) exceptionally foraged the pollen of the Solanaceae.

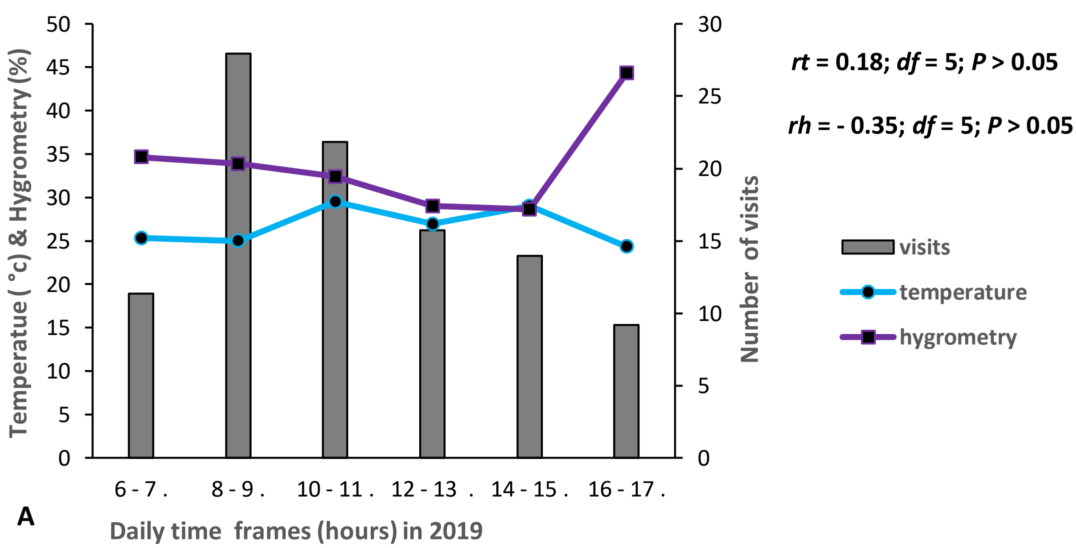


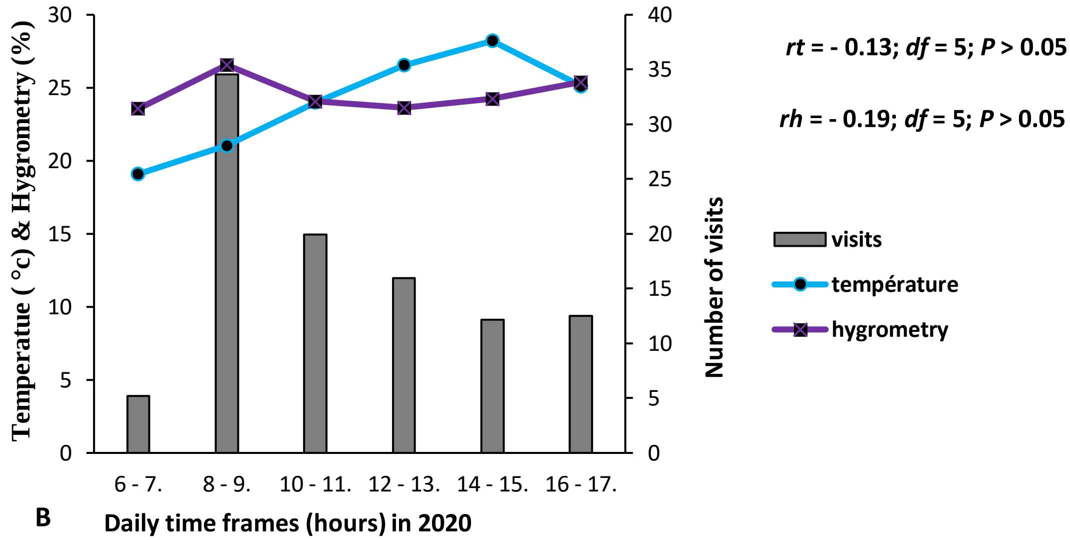


rv*:** correlation coefficient between the nectar and pollen collection visits and blooming flowers; ***r* (v, p):** correlation coefficient between the pollen collection visits and blooming flowers; ***p: p-value; ***df***: degree of freedom

Figure 3: Seasonal variations of the number of *Solanum lycopersicum* opened flowers and the number of *Xylocopa olivacea* for pollen collection visits, then nectar and pollen collection visits in 2019 (**A**) and 2020 (**B**) at Meskine.

4.3.3 Daily rhythms of visits: The carpenter bee was dynamic on *S. lycopersicum* flowers from 6 am to 6 pm in 2019 and in 2020. The pinnacle of activity was arranged somewhere in the range of 8 and 9 am in both years (Figure 4). Ambient temperature and relative hygrometry did not impact the activities of *X. olivacea* on *S. lycopersicum* (Figure 4). In 2019, the relationship was not important between the number of *X. olivacea* visits and the temperature (r = 0.18; *df* = 5; $P > 0.05$), and between the similar number of visits and the relative humidity (r = - 0.35; *df* = 5; $P > 0.05$). In 2020, the relationship was not important between the number of *X. olivacea* visits and the temperature (r = - 0.13; *df* = 5; $P > 0.05$), and between the similar number of visits and the relative hygrometry (r = - 0.19; *df* = 5; $P > 0.05$).





rt: correlation coefficient between visits and temperature**,** ***rh***: correlation coefficient between visits and hygrometry; ***p***: p-value, ***df***: degree of freedom

Figure 4: Variation of the ambient temperature, the air hygrometry and the number of *Xylocopa olivacea* visits on *Solanum lycopersicum* flowers according to the daily time frames in 2019 (**A**) and 2020 (**B**) at Meskine.

4.3.4 Abundance of *Xylocopa olivacea*: In 2019, the highest mean number of *X. olivacea* individuals concurrently in activity was 1 per flower (n = 213; s = 0) and 525.83 per 1000 flowers (n = 283; s = 289.41; *maxi* = 1000). In 2020, the relating figures were 1 per flower (n = 189; s = 0) and 536.78 per 1000 flowers (n = 555; s = 290.04; *maxi* = 1000). There is no contrast between these two means (t = 0.52; df = 836; P > 0.05). For the two cumulated years, the most noteworthy mean number of *X. olivacea* individuals concurrently in activity per 1000 flowers was 531.30. The abundance of *X. olivacea* individuals per 1000 flowers demonstrates the engaging quality of *S. lycopersicum* pollen for this carpenter bee. This could be because of the necessities of individual carpenter bees during the flowering time of the Solanaceae. This figure is higher than that brought up at Dang by Kingha *et al.* (2021) who stated that the abundance of *X. olivacea* individuals was 114.94 per 1000 flowers on *S. lycopersicum* var. Rio Grande. This contrast could be made sense of by the variety utilized.

4.3.5 Duration of visits per flower: In 2019, the mean length of a visit was 7.55 sec (n = 71; s = 6.40; *maxi* = 21) for nectar collection, against 8.47 sec (n = 721; s = 3.94; *maxi* = 49) for pollen reap. The contrast between these two means is not important (t = 1.18; df = 790; P > 0.05). In 2020, the relating figures were 6.97 sec (n = 110; s = 1.83; *maxi* = 21) for nectar, against 8.30 sec (n = 620; s = 2.74; *maxi* = 68) for pollen. The contrast between these later two means is exceptionally important (t = 6.42; df = 728; P < 0.001). The contrast between the length of a visit for nectar reap in 2019 and 2020 is not important (t = 0.74; df = 179; P > 0.05). The contrast between the span of a visit for pollen collection in 2019 and 2020 is not important (t = 0.93; df = 1339; P > 0.05). For the two cumulated years, the mean length of a flower visit was 7.26 sec (n = 181; s = 4.11) for nectar collection and 8.30 sec (n = 1341; s = 3.34) for pollen reap. The contrast between these two later means is exceptionally important (t = 3.50; df = 1520; P < 0.001). The important contrast observed between the span of pollen reap visits and that of nectar collection visits could be explained by the accessibility of every one of these floral products. Flowers of *S. lycopersicum* have tubular anthers that open just at their apical pores, stated by Michener (1962). In this condition, the pollen does not appear to escape easily from the anthers and requires vibration by *X. olivacea* to deliver it (Vinícius-Silva, 2017). This could explain the greatest length of pollen reap visits contrasted with that of nectar.

4.3.6 Foraging speed: In *S. lycopersicum* field, the mean foraging speed of *X. olivacea* was 9.08 flowers per minute (n = 249; s = 2.88; *maxi* = 25) in 2019 and 9.07 flowers per minute (n = 255; s = 8.27; *maxi* =25) in 2020. The contrast between these two means is not important (t = 0.02; df = 502; P > 0.05). For the two cumulated years, the mean foraging speed was 9.07 flowers per minute. This foraging speed is smaller than that recorded at Dang by Kingha *et al.* (2021). These authors referenced that the mean foraging speed was 21.59 flowers per minute. The contrast could be explained by the unsettling influence of individuals of *X. olivacea* during their foraging trip, by contenders for *S. lycopersicum* nectar and pollen.

4.3.7 Influence of the fauna: Individuals of *X. olivacea* were upset in their foraging activity by others of similar species or those from different species, which were contenders for *S. lycopersicum* nectar or pollen. In 2019, for 792 visits, 12 (1.51 %) were intruded on by *A. mellifera* and 10 (1.26 %) by *Xylocopa* sp. In 2020, for 730 visits, 14 (1.92 %) were intruded on by *X. olivacea*, 13 (1.78 %) by *Xylocopa* sp. and five (0.68 %) by *A. mellifera*. Kingha *et al.* (2021) have additionally observed the perturbation of individuals of *X. olivacea* in their foraging activity by other *X. olivacea* (0.27 % of 109 visits) and *Pachynomia* sp. 1 (0.27 % of visits) on flowers of *S. lycopersicum* var. Rio Grande in Dang. To get their ideal nectar load, individuals of *X. olivacea* who experienced such disturbances had to visit more flowers during the relating foraging trip.

4.3.8 Influence of neighbouring flora: During the flowering time of *S. lycopersicum,* flowers of numerous other plant species ambient the field of this Solanaceae were visited by *X. olivacea*, for nectar (ne) as well as pollen (po). Among these plants were *Solanum nigrum* (Solanaceae: ne and po), *Solanum aethiopicum* (ne and po), *Mangifera indica* (Anacardiaceae: ne and po), *Cosmos sulphureus* (Asteraceae: ne and po), *Luffa aegyptiaca* (Cucurbitaceae: ne and po), *Gossypium hirsutum* (Malvaceae: ne and po), *Hibiscus sabdariffa* (Malvaceae: ne and po) and *Phaseolus vulgaris* Black seed variety (Fabaceae: ne). During the two years of study, we observed no entry of *X. olivacea* from *S. lycopersicum* flowers to flowers of another plant species as well as the other way around. Consequently, during foraging trips on *S. lycopersicum*, individuals of *X. olivacea* were devoted to this Solanaceae. The loyalty of individuals of *X. olivacea* to *S. lycopersicum* was additionally stated at Dang (Ngaounéré, Cameroon) by Kingha *et al.* (2021).

4.4 Impact of anthophilous insects including *Xylocopa olivacea* on S*olanum lycopersicum* production: The production in the different treatments of *S. lycopersicum* are shown in Table 2.

Table 2: Fruiting rate, mean number of seeds per fruit and percentage of typical seeds in the different treatments of *Solanum lycopersicum* in 2019 and 2020 at Meskine.

Years	Treatments	NFS	NFF	FR (%)	Seeds/fruit		TNS	NNS	%NS
					mean	*sd*			
2019	**1 (Uf)**	120	111	92.50	56.51	7.11	6335	5985	94.47
	2 (Pf)	120	107	89.17	42.47	8.48	4545	3941	86.71
	3 (Fpvx)	100	95	95.00	58.00	8.18	5516	5229	94.79
	4 (Fpwv)	122	71	58.20	43.32	7.89	3076	2660	86.47
	5 (Uf)	120	112	93.33	54.17	6.28	6068	5706	94.03

2020	**6 (Pf)**	120	99	82.50	42.27	8.31	4185	3435	82.07
	7 (Fpvx)	90	82	91.11	58.92	5.28	4832	4554	94.24
	8 (Fpwv)	118	71	60.17	43.78	7.29	3109	2741	88.16

Uf: uncovered flowers; **Pf**: preserved flowers; **Fpvx**: flowers sacked then revealed, visited once by *Xylocopa olivacea* and reprotected; **Fpwv**: flowers sacked then revealed and rebagged without visited by insect or some other life forms; **NFS**: number of flowers studies; **NFF**: number of fruits formed; **FR**: Fruiting percentage; **TNS**: total number of seeds; **NNS**: number of typical seeds; **%NS**: percentage of typical seeds; ***sd***: standard deviation

This table shows that:

a) The fruiting percentages were 92.50 %, 89.17 %, 95.00 %, 58.20 %, 93.33 %, 82.50 %, 91.11 % and 60.17 % in treatments 1 to 8 respectively. The contrasts between these eight percentages are globally exceptionally important (χ^2= 155.76; *df* = 7; *P* < 0.001). The two to two comparisons showed that the contrast observed is exceptionally important between treatments 1 and 2 (χ^2 = 13.91; *df* = 1; *P* < 0.001), as well as between treatments 5 and 6 (χ^2 = 11.59; *ddl* = 1; *P* < 0,001). Consequently, in 2019 and 2020, the fruiting percentage of uncovered flowers (treatments 1 and 5) was higher than that of preserved flowers (treatments 2 and 6).

b) The mean numbers of seeds per fruit were 56.51, 42.47, 58.00, 43.32, 54.17, 42.27, 58.92 and 43.78 in treatments 1 to 8 respectively. The contrasts between these eight means are globally exceptionally important (*F* = 37191; df_1 = 7; df_2 = 95.88; *P* < 0,001). The two to two comparisons showed that the contrast observed is exceptionally important between treatments 1 and 2 (*t* = 13.16; *df* = 216; *P* < 0,001), as well as between treatments 5 and 6 (*t* = 11.56; *df* = 209; *P* < 0.001). Consequently, in 2019, as well as in 2020, the mean number of seeds per fruit of uncovered flowers (treatments 1 and 5) was higher than that of sacked flowers (treatments 2 and 6).

c) The percentages of typical seeds were 94.47 %, 86.71 %, 94.79 %, 86.47 %, 94.03 %, 82.07 %, 94.24 % and 88.16 % in treatments 1 to 8 respectively. The contrasts between these eight percentages are globally exceptionally important (χ^2 = 970.89; *df* = 7; *P* < 0.001). The two to two comparisons showed that the contrast observed is exceptionally important between treatments 1 and 2 (χ^2 = 17.92; *df* = 1; *P* < 0.001), as well as between treatments 5 and 6 (χ^2 = 17.26; *df* = 1; *P* < 0,001). Hence, in 2019 as well as in 2020, the percentage of typical seeds of exposed flowers (treatments 1 and 5) was higher than that of sacked flowers (treatments 2 and 4).

In 2019, the numeric contribution of anthophilous insects in the fruiting percentage, the mean number of seeds per fruit and the percentage of typical seeds of *S. lycopersicum* were 3.75 %, 33.05 % and 8.95 % respectively. In 2020, the comparing figures were 13.47 %, 28.15 % and 14.57 %. For the two cumulated years, the numeric contribution of anthophilous insects including *X. olivacea* was 8.61 %, 30.6 % and 11.76 % for the fruiting percentage, the mean number of seeds per fruit and the rate of typical seeds of *S. lycopersicum* respectively.

4.5 Pollination efficiency of *Xylocopa olivacea* on *Solanum lycopersicum*: During a single flower visit of *X. olivacea* for nectar or pollen, reap on *S. lycopersicum* flowers, this carpenter bee generally came into contact with anthers and stigma, expanding the chance of this Solanaceae pollination.

The examination of fruiting rates (Table 2) shows that the contrast observed was exceptionally important between treatments 3 and 4 (χ^2 = 11.63; *df* = 1; *P* < 0.001), as well as between treatments 7 and 8 (χ^2 = 9.96; *df* = 1; *P* < 0.001).

The examination of the mean quantities of seeds per fruit (Table 5) shows that the contrast observed was important between treatments 3 and 4 (*t* = 2.02; *df* = 195; *P* < 0.05), as well as between treatments 7 and 8 (*t* = 2.05; *df* = 193; *P* < 0.05).

The examination of the percentage of typical seeds (Table 5) shows that the contrast observed was exceptionally important between treatments 3 and 4 ($\chi^2 = 25.10$; $df = 1$; $P < 0.001$), as well as between treatments 7 and 8 ($\chi^2 = 29.36$; $df = 1$; $P < 0.001$).
Subsequently, in 2019 and 2020, the fruiting percentage, the mean number of seeds per fruit and the percentage of typical seeds of flowers visited once by *X. olivacea* was higher than that of flowers sacked then uncovered and rebagged without insect or some other organism visits. In 2019, the numeric contribution of *X. olivacea* on the fruiting percentage, the percentage of the number of seeds per fruit and the percentage of typical seeds were 41.28 %, 34.56 % and 9.60 %, respectively. In 2020, the relating figures were 37.63 %, 35.82 % and 7.41 %. For the two cumulated years, the comparing figures were 39.45 %, 35.19 % and 8.51 %. By laying on *S. lycopersicum* flowers, the individuals of *X. olivacea* could aid the release of pollen grains for the ideal control of their stigma. A negligible portion of this pollen likely lands on the stigma of the similar flower, prompting self-pollination and resulting in fruit development as referenced by Silva-Neto *et al.* (2017) on *S. lycopersicum* flowers. This carpenter bee could give allogamous pollination via conveying pollen on their hairs, legs, and mouth accessories from a flower of one plant, which is subsequently deposited on another flower having a place with various plant species (Tchuenguem *et al*., 2001; Fameni *et al*., 2023).

5 CONCLUSION

The outcomes got from this study uncover that *S. lycopersicum* is a plant that benefits from the pollination by insects, among which *Xylocopa olivacea* is one of the main reaper of pollen (89.25%) and nectar (10.75%). The correlation of fruit and seed sets of flowers visited once by *X. olivacea* with those of flowers sacked then revealed and rebagged without the visit of this carpenter bee or some other life forms highlights the worth of this carpenter bee in increasing the fruiting percentage, the mean number of seeds per pod and the percentage of typical seeds of *S. lycopersicum* Rudina variety. Hence, preservation or installation of *X. olivacea* nests near or within *S. lycopersicum* fields is prescribed to further develop its fruit production as well as seed quality and to incline toward the populaces of this carpenter bee in Maroua.

6 ACKNOWLEDGEMENTS

The authors thank the Agricultural Research Institute for Development of Maroua, which provided the plot for the experiment.
Competing interests: Authors have declared that no competing interests exist.
Authors' contributions: MJ was the main investigator. He collected data in the field and contributed to bibliographic research, preliminary insect determination and data analysis. FTS designed the project and TFFN supervised it. FTS and TFFN contributed to bibliographic research, insect identification and data analysis. All authors contributed to the writing of the manuscript.

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