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YIELD IMPROVEMENT OF *Solanum nigrum* L. (SOLANACEAE) THROUGH *Apis mellifera* L. (HYMENOPTERA: APIDAE) POLLINATION EFFICIENCY IN DANG (NGAOUNDERE, CAMEROON)

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ABSTRACT

Bees are vital for crop pollination, increasing both the quantity and quality of fruits, nuts, seeds, and vegetables. This research highlights the effect of *Apis mellifera* pollination efficiency on *Solanum nigrum* yields during the 2020 and 2021 cropping seasons. Four treatments were applied during pollination. They consisted of self-pollinated flowers, open-pollinated flowers, and flowers that received just a single visit from *A. mellifera* or no visitors at all after a delay in their exposure. Floral activity parameters of *A. mellifera* were assessed, and the relevant fruit and seed yields were compared between treatments. This study found that *A. mellifera* was the most common among the flower-visiting insects recorded on *S. nigrum*, with a mean relative visit frequency of 38.44%. The daily rhythm of floral activity among workers was shown to be from 6 a.m. to 3 p.m., with a peak in the 8-9 a.m. time frame. The mean density value found was 348 individuals/1000 flowers, the mean time of a floral visit was 31.31 sec, and the mean foraging speed was 8.7 flowers/minute. In addition, *A. mellifera* increased the fruiting rate and the rate of normal seeds in *S. nigrum* by 15.41% and 8.49%, respectively. This improvement of *S. nigrum* mainly depends on the effective presence of *A. mellifera* in the field of the Solanaceae.

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INTRODUCTION

Bee pollination enables the reproduction of about 87.5% of all angiosperms worldwide (Ollerton et al., 2011). It also contributes to yields of about 75% of all world crops, which otherwise could not be commercially grown or would not yield adequately (Toni et al., 2018; Lopez-Uribe, 2022). While some of the most important crops are wind-pollinated, it often goes unnoticed that most vegetables, fruits, nuts, fibres, and stimulants depend on biotic pollination, with *A. mellifera* as the most prominent and efficient pollinator (Klein et al., 2007). A recent survey across some African countries found that the cost of a diet is significantly lower in urban areas than in peri-urban and rural areas, especially in low-food-budget countries (FAO, 2023). This shows that agriculture, including extensive agriculture for local consumption of vegetables and fruits, remains an important source of nutritional security and individual income in many African countries (Toni et al., 2018).

Pollination of crops by insects, especially by honeybees, is an important tool in world agriculture (Gallai et al., 2009). In Afrotropical regions, particularly in Cameroon, for instance, despite their significant impact on the global economy, the relationships between pollinators and many crops remain understudied (Jordaens et al., 2024). To sustain fruit and seed production in such a country, ongoing research on insect pollination of crops is being conducted to expand the database for farmers and decision-makers (Azo'o et al., 2021). The present work highlights research on the relationship between *S. nigrum* and *A. mellifera* in a Cameroon agroecosystem.

Solanum nigrum, also called black nightshade, is a plant species belonging to the Solanaceae family and is widely cultivated in Africa (Särkinen et al., 2018). It is one of the components of diets due to its high content of crude protein, lipids, fibre, total sugars, minerals, and vitamins (Rani et al., 2017). This crop is among the most widely grown leafy vegetables in urban, peri-urban, and rural areas of Cameroon (Batchep, 2009). It has important nutritional qualities, economic value, and several therapeutic potentials, all of which are essential for human well-being (Iheanacho et al., 2009; Rani et al., 2017). A study by Mamoudou et al. (2021) conducted in the Far-North region of Cameroon showed that *A. mellifera* increased the fruiting rate and seed production of *S. nigrum* by 16.29% and 15.57%, respectively. A second study by Dongock et al. (2004), conducted in the western region of Cameroon, identified *S. nigrum* as an important pollen source for beekeeping. Apart from these two reports, research on the pollination efficiency of *S. nigrum* by honeybees investigated in the Adamawa ecoregion of Cameroon is scarce. Generally, the flower-visiting insects and their foraging parameters can vary across agroecological zones (AEZs), which justifies the rationale for this research. The specific objectives to attain the goal were (1) to rank honeybees in their flower-visiting entomofauna on the flower of *S. nigrum*, (2) to study the foraging behaviour of worker bees on the flower, and (3) to determine the impact of pollination by honeybees on the yields of *S. nigrum*.

MATERIALS AND METHODS

This research project was conducted in a field of about 450 m^2 (7°24'22.6''N; 13°32'52.3''E; 1085 m) located in Dang village (Ngaoundere city, Adamawa region, Cameroon) from April to September 2020, and from May to August 2021. The Adamawa region in Cameroon belongs to the high Guinean savannas AEZ, where a Sudano-Guinean climate prevails, with a rainy season from April to October and a dry season from November to March. The zone has an average annual temperature of 22°C and a mean annual relative humidity of 70% (Djoufack et al., 2011). The experimental field was set up not far from an apiary with about 36 colonised hives in 2020 and 42 colonised hives in 2021.

During the flowering period of *S. nigrum*, flowers were randomly tagged for the establishment of the following treatments (T): 1) a treatment with 120 open-pollinated flowers named T_1 and T'_1 (for 2020 and 2021 cropping seasons respectively) and classified in group X; 2) a treatment with 120 no visited-flowers in 2020 (T_0) and in 2021 (T'_0) which constituted the group Y; 3) a treatment with 120 flowers benefitted each with a single worker bee visit T_2 and T'_2 (group A) intended to the pollination efficiency of *A. mellifera*, and 4) a treatment with 120 isolated, opened and reclosed flowers without any insect visit T_3 and T'_3 (group Z).

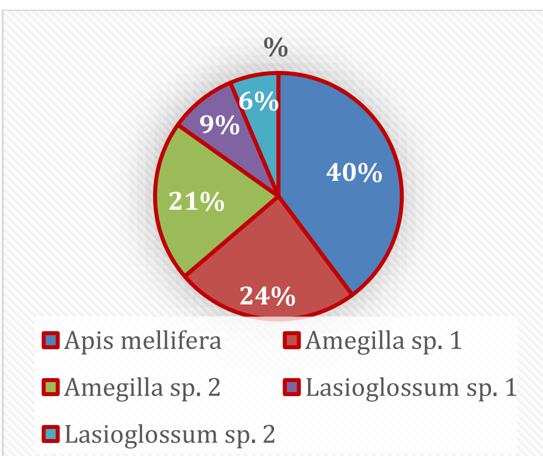
Observations were performed daily on the flowers of group X (treatments T_1 and T'_1) from September 1 to 5 in the 2020 cropping season, and from August 3 to 7 during the 2021 cropping season. The observations were carried out from sunrise to twilight following these time frames: 6 - 7 a.m., 8 - 9 a.m., 10 - 11 a.m., 12 - 1 p.m., 2 - 3 p.m., and 4 - 5 p.m. Anthophilous insect visits were registered on *S. nigrum* through direct count, helping to calculate each centesimal frequency, which helped to rank the different flower-visitors collected (Tchuenguem et al., 1997). Simultaneously, insects were captured using a hand net and preserved in boxes containing 70% ethanol for further identification.

The study of the floral activity of *A. mellifera* focused on the following parameters: 1) The daily rhythm of insect activity linked to the *S. nigrum* blossom was established using linear correlation between both parameters. 2) The fluctuation of the number of floral visits of foragers as a function of each daily time frame was elucidated. 3) The rate of floral products gathered by *A. mellifera* on *S. nigrum* was assessed from the behaviour of honeybees on flowers, together with the record of 4) the duration of a visit to collect floral products using a stopwatch. 5) The density of *A. mellifera* visits on 1000 flowers was estimated using the Tchuenguem et al. (2004) formula. 6) The foraging speed, which is the number of flowers visited per unit time, was assessed using Jacob-Remacle's (1989) formula. 7) The influence of some animate factors, such as the attractiveness of flowering plants around the vicinity of the experimental sites, and the action of other living organisms, such as competitors or predators, was studied. At the physiological maturity stage, fruits issued from different groups were harvested and compared according to the following production indicators: 1) the fruiting rate (%) or the ratio of the number of actual fruits/total number of flowers studied, 2) the average number of matured seeds per fruit, and 3) the percentage (%) of normal seeds per treatment.

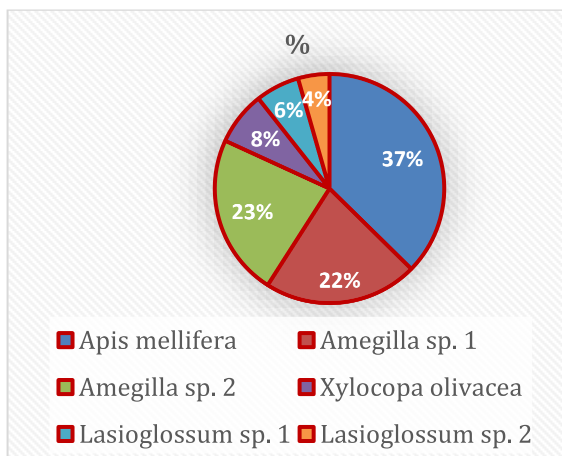
Data were analysed using R 2.13.0 software. Normal-theory statistical analysis was performed through standard analysis of variance (ANOVA). The Honestly Significant Difference (HSD) method was used to discriminate among pairwise treatment means. In addition, the Student's t-test was used to compare average values between two samples. Each average value is followed by the standard deviation (sd). Means are reported as significantly different if the probability p is less than or equal to 0.05. The Chi-square test (χ2) enabled us to compare the proportions between two samples. The Pearson coefficient (r) was used to establish linear correlations between two variables from samples of equal size. The contribution of the anthophilous insect activity on the production indicators studied was estimated using the modified equation reported by Diguir et al. (2020), which links treatments from each group following each year: $F = \{[(X - Z)/(X + Y - Z)] \times 100\}$. Likewise, the contributions of *A. mellifera* to the fruit set, the average number of grains/fruit, and the rate of normal seeds were simulated using the following modified equation reported in Djakbé et al. (2017): $Q = \{[(A - Z)/A] \times 100\}$.

RESULTS

In the 2020 and 2021 cropping seasons, 455 and 450 visits of 05 and 06 flower-visitors were recorded on *S. nigrum.* Figure 1 shows different foragers and their relative abundances of floral visits. All insects recorded belonged to the order Hymenoptera, with *A. mellifera* as the most frequent visitor, accounting for 40% of floral visits in 2020 and 37% in 2021. The difference between the two values of relative abundance of the honeybee was not significant in the two years ($\chi^2 = 0.20$; df = 1; $P > 0.05$). During the flowering period, foragers visited *S. nigrum* flowers and collected pollen exclusively. Yet, among the 300 visits selected for studying floral products harvested, 100% were dedicated solely to pollen collection, consistent with the proper foraging behaviour of individuals. No visit was observed for nectar gathering during both years.



2020



2021

Figure 1. Anthophilous insects of *Solanum nigrum* according to their frequency in both years.

Figure 2 is illustrative of the daily fluctuation of honeybee floral visits as a function of the variation in the number of flowers blossoming per observation day. Overall, the number of *A. mellifera* visits seems to be linked to the number of flowers opened on *S. nigrum*, apart from rain influence, as seen on August 4 2021. The correlation between these two parameters is positive in 2020 (r = 0.94; *df* = 4; $p < 0.05$) and 2021 (r = 0.72; *df* = 4; $p < 0.05$). Figure 3 shows the distribution of honeybee floral visits according to daily recording time frames on *S. nigrum*. It shows that *A. mellifera* floral activity occurs between 6 a.m. and 3 p.m., with a peak at 8-9 a.m.

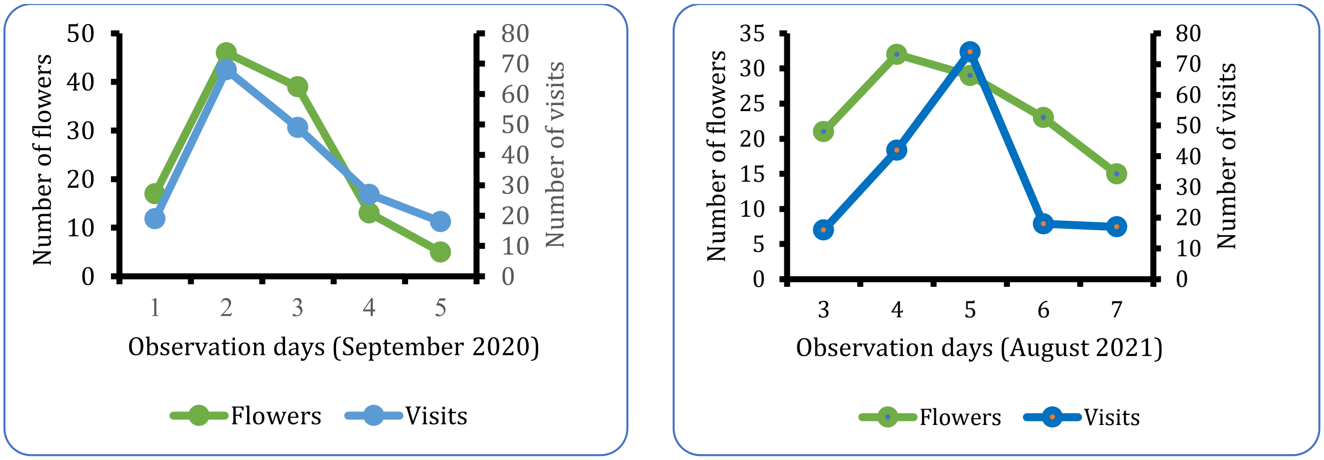


Figure 2. Variation of *Solanum nigrum* opened-flowers and the honeybee visits in 2020 and 2021.

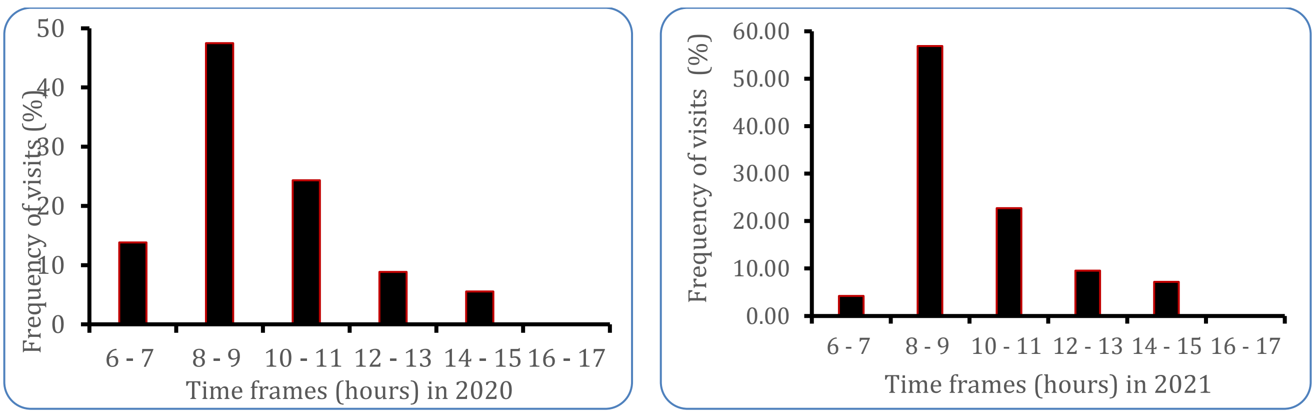


Figure 3. Fluctuation of honeybee frequency of visits according to the daily observation time.

Table 1 highlights data on the mean number of *A. mellifera* visitors per 1000 flowers on *S. nigrum*. The mean value ranged from 352.94 individuals/1000 flowers in 2020 to 343.15 in 2021, with no difference between the two years (t = 0.38; df = 118; p > 0.05).

From the observations on the flower of *S. nigrum*, data about the duration of honeybee visits were dedicated to pollen harvesting, as pollen was the only coveted floral product during the foraging activity of worker bees. From Table 2, it is revealed that the average time spent by an individual honeybee per flower was 31.70 sec. (n = 141; s = 29.63; *min* = 2; *max* = 112) in 2020 and 30.93 sec. (n = 149; s = 25.88; *min* = 2; *max* = 134) in 2021. The difference between the two values is not significant (t = 0.23; df = 288; p > 0.05). For both years combined, the average duration of a pollen collection visit was 31.31 sec (n = 290; s =27.75). From Table 3, the average speed of *A. mellifera* visiting *S. nigrum* flowers per time unit varies from 9.27 flowers/min. (n = 134; s = 6.83; *min* = 1.36; *max* = 52.94) in 2020 to 8.13 flowers/min (n = 127; s = 6.57; *min* = 1.07; *max* = 50) in 2021, with no difference between these means (t = 1.10; df = 259; P > 0.05). For both years, the average foraging speed was 8.7 flowers/min (n = 261; s = 7.97).

Table 1. Density of honeybees/1000 flowers on *Solanum nigrum* in 2020 and 2021

Years	Different values				
	n	*m*	*sd*	*Min*	*Max*
2020	60	352.94	167.92	100	700
2021	60	343.15	155.50	100	700
Mean/year	60	348.05	161.71	100	700

Table 2. Mean value of the time of floral visit in 2020 and 2021

Years	Different values				
	n	*m*	*sd*	*Min*	*Max*
2020	140	31.70	29.63	2	112
2021	140	30.93	25.88	2	134
Mean/year	60	31.31	27.75	2	123

n: number of data recorded; *m*: average number; *sd*: standard deviation

Table 3. Mean value of the speed of floral visitation in 2020 and 2021.

Years	Foraging speed values (flower/minute)				
	n	*m*	*sd*	*Min*	*Max*
2020	134	9.27	6.83	1.36	52.94
2021	127	8.13	6.57	1.07	50
Mean /year	130	8.70	7.97	2	51.47

n: number of data recorded; *m*: average number; *sd*: standard deviation

Table 4 shows that, during foraging, honeybee individuals were identified as proper interrupters of their congener visits during pollen collection. Other insect competitors disrupting *A. mellifera* visits to *S. nigrum* were *Amegilla* sp. 1, *Amegilla* sp. 2, and *Lasioglossum* sp. The interruption rate was 7.80% in 2020 and 10.06% in 2021, with no difference between the two ($p > 0.05$). Overall, intraspecific interruptions are more common among *A. mellifera* workers than interspecific floral visit interruptions. Moreover, *A. mellifera* workers were not subjected to predation in our field experiments in 2020 and 2021.

Table 4. Distribution of *Apis mellifera* disrupted visits and its visit-interrupters on *Solanum nigrum* flowers.

Years	TNV	TVI	P (%)	Frequency of interruption of foragers			
2020	141	11	7.80	Am1 = 2.13	- -	Am = 4.96	La =0.71
2021	149	15	10.06	Am1 = 2.01	Am2 = 1.34	Am = 5.37	La = 1.34

TNV: Total number of visits observed; TVI: Total number of visits interrupted; P: Interruption rate = (TVI/TNV) x 100; Am1: *Amegilla* sp. 1; Am2: *Amegilla* sp. 2; Am: *Apis mellifera*; La: *Lasioglossum* sp.

During investigations, several other plant species belonging to the Family Asteraceae, such as *Bidens Pilosa, Tithonia diversifolia*, and *Tridax procumbens*, were blooming near the field experiment and made their pollen and nectar available to *A. mellifera*. In all, *A. mellifera* foragers showed their loyalty towards *S. nigrum* flowers during each foraging trip.

Table 5 presents results for the targeted production parameters across different treatments. The fruiting rate (χ^2 = 39.24; *df* = 3; $p < 0.0001$), the mean number of seeds per fruit (F = 27.14; *df* = 3/476; $p < 0.0001$), and the percentage of normal seeds per treatment (χ^2 = 48.67; *df* = 3; $p < 0.0001$) show a significant difference between treatments T_0, T_1, T_2, and T_3 in 2020 as compared with treatments T'_0, T'_1, T'_2, and T'_3 in 2021. The pairwise comparison between treatments showed no difference between T_1 and T_2, T_0 and T_3 in 2020 ($p >$ 0,05), as well as between T'_1 and T'_2, T'_0 and T'_3 in 2021 ($p >$ 0,05). However, the difference was significant between the following treatments: T_0 vs T_1, T_1 vs T_3, T_2 vs T_3, T_0 vs T_2 ($p <$ 0,001) in 2020, and in 2021: T'_0 vs T'_1, T'_1 vs T'_3, T'_2 vs T'_3, T'_0 vs T'_2 ($p <$ 0,001).

For the three production parameters studied, the same causes produced similar effects across the different treatments. This is helpful for a better understanding of the important contribution made by the entomofauna of *S. nigrum*, in general, and honeybees in particular, to pollination, fruit, and seed yield of this crop. The fruit set rate, the average number of seeds per fruit, and the rate of normal seeds per treatment were higher in the treatments that benefitted from pollinator visits (T_1 and T_2 in 2020; T'_1 and T'_2 in 2021) than in the treatments protected from those visits (T_0 and T_3 in 2020; T'_0 and T'_3 in 2021).

The gaps observed between the different treatments allowed us to deduce the impact of pollinating insects, in general and of honeybees in particular, on the fruit and seed yields of *S. nigrum*. Indeed, the contribution of listed insects to the fruiting rate, the average number of seeds per fruit, and the rate of normal seed was, respectively, 17.43%, 24.24%, and 6.94% in 2020; and 26.61%, 21.29%, and 9.21% in 2021.The contribution of the floral activity of foragers to the average number of seeds per fruit (χ^2= 1.83; *df* = 1; $p > 0.05$), and the rate of normal seeds per treatment (χ^2 = 0.69; *df* = 1; $p > 0.05$) across both years were no significant; however, their contribution to the improvement of the fruiting rate is significant between 2020 and 2021 (χ^2 = 11.68; *df* = 1; $p < 0.05$). In the same vein, the contribution of *A. mellifera* to the increase in the fruiting rate, the mean number of seeds per fruit, and the percentage of normal seeds per treatment was 9.82%, 29.91%, and 8.28% in 2020;

21.01%, 28.08%, and 8.64% in 2021. Only a significant difference was found between proportions related to the influence of *A. mellifera* in the fruiting rate across years 2020 and 2021.

Table 5. Production of *Solanum nigrum* according to different groups and treatments in 2020 (T_0, T_1, T_2, T_3) and 2021 (T'_0, T'_1, T'_2, T'_3).

Groups	Treatments	TFS	TFF	F (%)	ASF		TS	NS	%NS
					m	*sd*			
Y	T_0	120	98	81.66	58.18	13.13	5644	5057	89.60
	T'_0	120	90	75.00	52.95	15.72	4766	4147	87.01
X	T_1	120	120	100	69.00	16.40	8280	7712	93.14
	T'_1	120	120	100	69.00	17.16	7680	7302	94.95
A	T_2	120	112	93.33	71.88	15.57	12076	11384	94.27
	T'_2	120	120	100	70.69	15.54	12160	11463	94.27
Z	T_3	120	101	84.17	55.38	11.93	5089	4400	86.46
	T'_3	120	94	78.33	57.00	11.76	5563	4791	86.12

TFS: Total number of flowers studied; TFF: Total number of fruits formed; F: Fruiting rate: TFF/TFS x 100; ASF: Average number of seeds/fruits; TS: Total number of seeds; NS: Number of normal seeds; %NS: Rate of normal seeds: NS/TS x 100; T_0 and T'_0: Protected flowers; T_1 and T'_1: Unprotected flowers; *m*: mean; *sd*: Standard Deviation. T_2 and T'_2: Flowers dedicated for the pollination efficiency of *Apis mellifera*; T_3 and T'_3: Flowers bagged, opened, and rebagged without any visitor; T_n : Treatements of year 2020; T'_n: Traitment of year 2021

DISCUSSION

The two-year investigations conducted in 2020 and 2021 in the Dang village (Ngaoundere, Adamawa region, Cameroon) on the insect pollination of *S. nigrum* highlighted the exclusivity of the order Hymenoptera and the prominence of the species *A. mellifera* in the entomofauna of this crop. These results are similar to the findings of Mamoudou et al. (2021). The latest authors found that honeybees ranked first among the flower-visiting insects captured and identified on Solanaceae species in Meskine village (Maroua, Far-North region, Cameroon). These findings are in line with earlier reports confirming that *A. mellifera* is the most important flower visitor for several plant species, including *S. nigrum* (Klein et al., 2007). In contrast to our results, which reported 06 anthophilous insect species from the order Hymenoptera in Dang village, about 21 insect species from five orders were identified in Meskine village, located in the Sudano-Sahelian AEZ, in 2019 and 2020. A comparative study of both findings shows that the flower-visiting entomofauna of *S. nigrum* varies across the high Guinean savanna and Sudano-Sahelian AEZs. Indeed, the number of taxa and the compositional diversity of the flower-visitors associated with *S. nigrum* are characteristic of the AEZ and fluctuate from year to year. The same observations were ascertained regarding the variability of the floral entomofauna associated with *Cucumeropsis mannii* (Azo'o and Messi, 2012) or *Sesamum indicum* (Azo'o et al., 2021). Overall, *S. nigrum* is considered one of the main food sources for *A. mellifera*.

On the flowers of *S. nigrum*, *A. mellifera* exhibited an exclusive pollen-collection behavior which is linked to the tiny nectar secretion by this plant species (Mein, 2021). This result confirms the findings of Dongock et al. (2004) conducted in the western Region of Cameroon. In the same vein, Mamoudou et al. (2021) showed that honeybees harvested more pollen than nectar from the same plant species in Meskine village (Maroua, Cameroon), with a significant difference in preference for both floral products. The foraging behaviour of *A. mellifera* depends on the colony's real food needs in the apiary environment and on the availability and accessibility of the floral product sought (Mbere et al., 2025). Moreover, *A. mellifera* workers tend to focus on *S. nigrum* flowers during foraging trips, ensuring efficient pollination of that crop.

In the absence of a pollen vector, the ova were fertilised by self-pollen to ensure seed and fruit sets of *S. nigrum*. Passive self-pollination is characteristic of Solanaceae (Kengni et al., 2022). However, *Apis mellifera* workers play a vital role in the pollination and productivity of *S. nigrum*. During its floral activity, a honeybee individual commonly landed on the stigma, moved to the anthers, and collected pollen grains with the mouthparts, with a relatively higher mean visit duration. Pollen transfer through the body of the honeybee forager is considered to be an effective or pollinating visit (Vaissière *et al*., 1996). This bee, mainly devoted to *S. nigrum* pollen, contributed directly and efficiently to the pollination of the crop studied. A floral visit of *A. mellifera* has appeared to have a significant additional supply of pollen grains on the stigma of the flower visited. A longer duration of *A. mellifera* visits during pollen harvesting increased the potential for self-pollination in *S. nigrum* visited flowers. Similar findings were mentioned by Azo'o et al. (2017) on the floral activity of *Eucara macrognatha* on *Abelmoschus esculentus*. In fact, *A. mellifera* foragers got dusted with the *S. nigrum* pollen grains, and frequently go forth and back between the anthers and the stigma of the same foraged flower. When not interrupted by a competitor or a predator, an individual could spend up to 30 seconds visiting a flower. During this time, it frequently contacted the anthers, picked up pollen grains on its body hair, and could thereby self-pollinate before flying off. Worker honeybees can load up on pollen grains through their fuzzy body, which promote self-pollination. That's why the yields from studying a single flower visit by *A. mellifera* are markedly better than those from treatments where flowers do not get visited by pollinating insects. This clearly explains the significant difference that results from comparing the production factors between the treatments from group Y (treatments T_0 and T'_0) and those from group A (treatments T_2 and T'_2). Our results are comparable with those of several other authors across a range of plant species, demonstrating the positive impact of efficient pollination by honeybees on crop productivity (Klein et al., 2007; Ollerton et al., 2011).

The insignificant difference was observed between treatments in which bisexual flowers were assigned to the study of the pollination efficiency of *A. mellifera* and those in which these flowers were freely left to the foraging and pollination activity of insects. This can be interpreted as follows: in group A, consisting of treatments T_2 and T'_2, each flower actually benefits from a pollinating visit by *A. mellifera*; on the other hand, in group X, consisting of treatments T_1 and T'_1, the relative density of *A. mellifera* workers, which is approximately 350 individuals/1000 flowers, does not allow all flowers to benefit from an effective visit by the honeybee. Furthermore, the native bees recorded as active on *S. nigrum* flowers are relatively scarce, which means that not every flower in group X is visited by a pollinator. Although kept in open-pollination, most of the flowers in group X may be subjected to passive self-pollination, which tends to balance the resulting yields with those obtained from flowers from group A. *S. nigrum*-related species are known to be predominantly self-pollinating (Mamoudou et al., 2021). It is also well documented that some outcrossing occurs in *S. nigrum* (Jacoby and Labuschagne, 2006; Mamoudou et al., 2021; Kengni et al., 2022). Owing to their relatively high abundance and characteristic interfloral activity, *A. mellifera* workers ensure cross-pollination of *S. nigrum* flowers. This foraging behavior manifests itself in the fertilisation of a flower by pollen from another flower on a genetically identical *S. nigrum* plant (geitonogamy), or visits from one flower on a given plant to another flower on another *S. nigrum* plant. Flowers from group X or open-pollinated treatments (T_1 in 2020 and T_1' in 2021) are concerned by this category of fertilisation with *A. mellifera* as the main pollen vector. The significant difference in fruiting rates due to insect floral activity across years is linked to pollination intensity, which was higher in 2021 than in 2020, depending on the number of bee colonies near the experimental plot. Furthermore, the lack of difference in the pollination efficiency of *A. mellifera* on the fruiting rate shows that the same level of pollination by *A. mellifera* promotes stable fruit production in *S. nigrum* across the years. Indeed, a flower that benefits from an effective visit by *A. mellifera* produces viable fruit and very good quality seeds. On the other hand, poor pollination undoubtedly leads to the fall of poorly pollinated flowers. Overall, the pollination activity of *A. mellifera* positively impacted the reproductive ability and yield improvement in *S. nigrum*. That is why the yields from treatments where the flowers benefited from visits by pollinating insects were higher than those where the flowers were free from such visits. The capacity of honeybees to optimise agricultural production through their pollination activity is known to apply to several other plant species (Klein et al., 2007). Therefore, the honeybee has great agroecological value that must be exploited to preserve and sustain agroecosystems for efficient agriculture.

CONCLUSION

In Dang, *A. mellifera* was the main pollen collector and pollen vector of *S. nigrum*. This bee species is mainly self-pollinated, with high pollination effectiveness, increasing the fruiting rate, the mean number of seeds per fruit, and the percentage of normal seeds per fruit of *S. nigrum* by 15.41%, 28.99%, and 8.49%, respectively. It is important to sanitise and preserve the immediate environment of *S. nigrum* farms to safeguard the effectiveness of *A. mellifera* pollination and maximise fruit and seed production for this crop, with a view to achieving high-performance agriculture in Cameroon.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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REFERENCES

Azo'o, E.M. and Messi, J. 2012. Yield responses of *Cucumeropsis mannii* (Cucurbitaceae) to the presence or the absence of the insect foraging activity at Nkolbisson in Cameroon. Journal of Animal and Plant Sciences, 13(3): 1791-1799.

Azo'o, E.M., Djenatou, P. and Messi, J., 2017. Repercussions of *Eucara macrognatha* (Hymenoptera: Apidae) duration of visit on the pollination rate and yields of *Abelmoschus esculentus*. Journal of Animal and Plant Sciences, 32 (3): 5203-5211.

Azo'o, E.M., Ndouwé, T., Firitawada, C., Kengni, B.S., Djackbe, J., Mbere, N. and Tchuenguem, F.F.N. 2021. Dynamics and Impact of Flowering Insects on *Sesamum indicum* L. (Pédaliaceae) Production in Maroua (Far-North, Cameroon). European Scientific Journal, 17 (25): 342-360.

Batchep, R. 2009. Analyse des filières légumes feuilles (amarante, morelle, corète potagère) dans la ville de Yaoundé. Mémoire de fin d'études. FASA. Université de Dschang, 109 p.

Diguir, B. B., Pando, J. B., Fameni, T. S. and Tchuenguem, F. F-N. 2020. Pollination Efficiency of *Dactylurina staudingeri* (Hymenoptera: Apidae) on *Vernonia amygdalina* (Asteraceae) Florets at Dang (Ngaoundéré, Cameroon). International Journal of Research Studies in Agricultural Sciences, 6(2): 22-33

Djakbé, D. D., Ngakou, A., Wékéré, C., Faibawa, E. and Tchuenguem, F. F-N. 2017. Pollination and yield components of *Physalis minima* (Solanaceae) as affected by the foraging activity of *Apis mellifera* (Hymenoptera: Apidae) and compost at Dang (Ngaoundere, Cameroon). International Journal of Agronomy and Agricultural Research, 11(3): 43-60.

Djoufack, V., Fontaine, B., Martiny, N. and Tsalefac, M. 2012. Climatic and demographic determinants of vegetation cover in northern Cameroon. International Journal of Remote Sensing, 21: 6904-6926.

Dongock, N. D., Foko, J., Pinta, J. Y., Ngouo, L. V., Tchoumboue, J. and Zango, P. 2004. Inventaire des plantes mellifères de la zone soudano-guinéenne d'altitude de l'Ouest Cameroun. Tropicultura, 22(3) : 139-145.

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.

Iheanacho, Kizito, M.E. and Udebuani, A.C. 2009. Nutritional Composition of Some Leafy Vegetables Consumed in Imo State, Nigeria. J.ournal of Applied Sciences and Environment Management, 13 (3): 35-38.

Jacob – Remacle, A., 1989. Comportement de butinage de l'abeille domestique et des Abeilles sauvages dans des vergers de pommiers en Belgique. Apidologie, 20 (4): 271-285.

Jacobi, A. and Labuschagne, M. 2006. Hybridization Studies of Five Species of the *Solanum nigrum* Complex Found in South Africa and two Coctail Tomato Cultivars. Euphitica, 149 (3): 303-307.

Jordaens, K., De Meyer, M., Van Nuffel, M., Kirk-Spriggs, A.H., Sabuni, C., Mwatawala, M., Mujabwa, R., Kabota, S., Belligam, T., Goergen, G., Mansell, M., Manrakhan, A., Sinzogan, A., Schutze, M.K., Thomas-Cabianca, A., Copeland, R., Muller, B., Virgilio, M., Bert, E., November, E. and Midgley, J. 2024. A best way to the organisation of the entomological training courses in the sub-Saharan Africa. International Journal of Educational Development, 107: 103026.

Kengni, B.S., Kodji, I.I., Azo'o, E.M. and Tchuenguem, F.F.-N. 2022. Influence of *Xylocopa* sp. (Hymenoptera: Apidae) on *Solanum aethiopicum* L., 1763 production in Far-North, Cameroon. Trends in Entomology, 18: 104-114.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C. and Tscharntke, T., 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society, London (B), 274: 303-313.

Lopez-Uribe, M.M., 2022. Crop pollination by bees, Volume 1: Evolution, Ecology, Conservation, and Management. American Entomologist, 68 (2): 61-62.

Mamoudou, J., Fameni, S.T., Basga, E. and Tchuenguem, F.F.-N. 2021. Pollination efficiency of *Apis mellifera* (Hymenoptera: Apidae) on *Solanum nigrum* (Solanaceae) at Miskine (Maroua, Cameroun). International Journal of Biological and Chemical Sciences, 15 (3): 1073-1089.

Mbere, N., Azo'o, E.M., Njoya, M.T.M., Tchobsala, and Tchuenguem, F.F-N. 2025. Screening of beekeeping potential on three wild plant species in Nyambaka (Adamawa region of Cameroon). International Journal of Agricultural Extension, 13 (01): 57-67.

Mein, H., Opoku, K.N., Bissah, N.A.B. and Su, T. 2021. *Solanum aethiopicum*: the nutrient-rich vegetable crop with great economic, genetic piodiversity and pharmaceutical potential. Horticulturae, 126(7): 1-7.

Ollerton, J., Winfree, R. and Tarrant, S. 2011. How many flowering plants are pollinated by animals? Oikos, 120: 321-326.

Rani, Y.S., Reddy, V. J., Basha, S. J., Koshma, M., Hanumanthu, G. and Swaroopa, P. 2017. A review on *Solanum nigrum*. World Journal of Pharmacy and Pharmaceutical Sciences, 6 (12): 293-303.

Särkinen, T., Poczai, P., Barboza, G.E., van der Weerden, G.M., Baden, M. and Knapp, S. 2018. A revision of the Old-World Black Nightshades (Morelloid clade of *Solanum* L., Solanaceae). PhytoKeys, 106: 1-22.

Tchuenguem, F. F.-N., Mapongmetsem, P. M., Hentchoya, H. J. and Messi, J. 1997. Activité d'*Apis mellifica* L. (Hymenoptera : Apidae) sur les fleurs de quelques plantes ligneuses à Dang (Adamaoua - Cameroun). Cameroon Journal of Biological and Biochemical Sciences, 7 (1): 86-91.

Tchuenguem, F.F.-N., Mapongmetsem, P. M., Hentchoya, H. J. and Messi, J. 2004. Exploitation des fleurs de quatre plantes oléagineuses par *Apis mellifera adansonii* à Ngaoundéré (Cameroun) : *Bombax pentandrum*, *Vitellaria paradoxa*, *Lophira lanceolata* et *Dacryodes edulis*. Procédés Biologiques et Alimentaires, 2: 27-36.

Toni, C.H., Djossa, B.A., Yédomonhan, H. Zannou, E.T. and Mensah, G.A. 2018. Werstern honeybee management for crop pollination. African crop Science Journal, 26(1): 1-17.

Vaissière, B.E., Rodet, G., Cousin, M., Botella, L. and Torré G.J.P. 1996. Pollination effectiveness of honey bees (Hymenoptera: Apidae) in a Kiwifruit orchard. Journal of Economic Entomology, 89(2): 453-461.