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Effects of Botanical Extracts on Foraging and Pollination Activity of *Apis Mellifera* (Hymenoptera: Apidae) on *Glycine Max* (Fabaceae) Flowers at Bini (Ngaoundere, Cameroon)

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ABSTRACT

The impact of aqueous extracts from the leaves of *Callistemon rigidus, Lippia multiflora* and *Plectranthus glandulosus* on the foraging behavior of *Apis mellifera* on *Glycine max* flowers were evaluated in Ngaoundéré Cameroon, during two successive agricultural seasons. The search was conducted in 1064 m^2 experimental field with treatments arranged in a completely randomized blocks design 4 times replicated: 1 control x 3 plants x 3 extracts x 3 concentrations (5%, 10% and 15%) x 1 standard synthesis insecticide (Decis) x four groups of flower buds (group 1: flowers free to insect visits; group 2: flowers protected from insects using gauze bags; group 3: protected flowers and opened exclusively to *A. mellifera* and group 4: protected flowers opened from time to time without any visit of insects or other organisms). This Fabaceae was visited by nine species of insects of which the honeybee, *A. mellifera* was the most numerous (> 90%) and exclusively collected nectar. The different insecticides tested were attractive to this pollinating insect, specially at the concentration of 15%. The mean duration visit of this bee varied from 1.9 sec on the plots treated with Decis to 4.4 sec on the plots treated with 15% *C. rigidus*. The fruiting indices were 0.96, 0.69, 0.94 and 0.67 respectively for flowers of group 1, 2, 3 and 4. *Callistemon rigidus* at the content of 15% significantly improved the fruiting rate compared to the other treatments. According to this study, it would be wise to use aqueous extracts at 15% concentrations to improve the pollinating activity of *A. mellifera* in order to improve seed yield.

INTRODUCTION

Glycine max is an annual herb that can reach 110 cm in height at maturity. The alternate leaves are compound and generally formed of three leaflets (Gallais & Bannerot, 1992). The inflorescence is a cluster bearing 5 to 35 white, yellow or red flowers. The nectar and pollen produced by these flowers attract insects (Milfont *et al.*, 2013). The seeds are widely used in human food and play a beneficial role in human and animal health (Sherif, 2013). It consists of over 33% protein and carbohydrates, and excellent amounts of dietary fiber, vitamins and minerals. It also consists of 18% oil, making it an important crop for the production of edible oil (Inoussa *et al.*, 2020).

In Cameroon, the demand for *G. max* seeds was quick to take off ; however, this dynamics is scientifically poorly documented apart from sparse statistics (Nzossié & Bring, 2020).The decline in productivity would be linked particularly to the physico-chemical and biological degradation of the soil (FAO, 2018) and especially to the pressure exerted by pests on crops. To deal with this situation, stakeholders need to adopt sound management of insect pests and pollinators (Adamou *et al.*, 2022; Mohammadou *et al.*, 2023). Unfortunately, pollinator management is ignored by most African farmers (Eardley *et al.*, 2010); because the management of these arthropods is not generally included in the agricultural programs of several countries on this continent, despite their positive role in food security (Fontaine *et al.*, 2006a, 2006b; Vamosi *et al.*, 2006). In effect, to increase yields and meet ever-increasing market demand, farmers resort to synthetic pesticides that have caused more damage than they have resolved (Bambara & Tiemtoré, 2008). In Cameroon, farmers use pesticides on crops without consideration for their effects on bees who are exposed to them through direct contact with spray residues on plants, through ingestion of contaminated pollen and nectar, or through exposure to nesting sites or contaminated materials. These pesticides affect the physiology, behavior and reproductive potential of the bee (Baskar *et al.*, 2017), which results in sub-optimal agricultural production.

Many plants through their extracts provide natural insecticides and can therefore be used as a substitute for synthetic chemical insecticides (Tembo *et al.*, 2018; Kosini *et al.*, 2021; Adamou *et al.*, 2022; Mohamadou *et al.*, 2023). In fact, insecticides of plant origin are more biodegradable (Bakkali *et al.*, 2008; Suthisut *et al.*, 2011a,b) and present, with a few exceptions for certain pure compounds, low toxicity for mammals (Regnault- Roger *et al.*, 2012, El-Wakeil, 2013) and beneficial arthropods (Tembo *et al.*, 2018). Aqueous extracts of *Callistemon rigidus, Lippia multiflora* and *Plectranthus glandulosus* have been tested effective in the field against cowpea pests, with a yield improvement varying between 120 and 260% (Kapeuhag *et al.*, 2021). Organic extracts from the leaves

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of these plants have also been successfully tested against post-harvest pests (Danga *et al*., 2015; Dessenbe *et al*., 2022). Since these plants are available in rural areas, they constitute an effective, accessible and inexpensive means of combating legume pests. Although some research has been conducted on the impact of the use of pesticidal plants on non-target arthropods (Mkenda *et al*., 2015; Tembo *et al*., 2018; Adamou *et al*., 2022; Mohamadou *et al*., 2023), this remains a neglected area of research that requires further investigation to understand possible trade-offs of using more plant-based pesticide products.
The present investigation made it possible to evaluate the impact of certain biopesticides (aqueous extracts of three cosmopolitan plants *Callistemon rigidus, Lippia multiflora* and *Plectranthus glandulosus*) on beneficial soybean arthropods, including *Apis mellifera*.

MATERIAL AND METHODS

Study Site and Biological Material

The works were carried out from May to August 2019 and from May to September 2020, in Bini (Ngaoundéré) in the Adamawa Region, Cameroon. *Cosmos sulphureus, Helianthus annuus, Tithonia diversifolia, Phaseolus vulgaris, Zea mays, Ipomea batatas, Arachis hypogea* and *Abelmoschus esculentus* were the most frequently observed plants. According to Djoufack *et al*. (2012), the climate of this region is of the Sudano-Guinean type, mild and cool, characterized by two seasons: a rainy season (April to October) and a dry season (November to March). The average annual temperature is 22°C and the average annual humidity is 70% (Amougou *et al*., 2015).
The experimental field was an area of 1064 m2 centered on a point of latitude: 07°24'33.9"N; longitude: 013°32'53.6"E; altitude: 1087m. The seeds of *G. max* (variety HOULA 1, 120 days) sown were purchased at the station of the Institute of Agricultural Research for Development (IRAD) in Garoua. The biopesticides were produced from the fresh leaves of *Callistemon rigidus, Lippia multiflora* and *Plectranthus glandulosus*, harvested in the Adamaoua region, respectively at Bini, on the cliff and at Nyanbaka. The latter were identified at the National Herbarium of Cameroon by comparison with the samples registered under the numbers 18564/SRFCam, 9051/SRFCam, 60652/HNC, respectively for *C. rigidus, L. multiflora and P. glandulosus.*

Experimental Device, Sowing and Maintenance of the Culture

The experimental plots were cleared, plowed and landscaped according to the procedure of the completely randomized block device with four repetitions for each experimental unit. Each experimental plot consisted of 44 experimental units of 4 x 3.5 m spaced from each other by one meter furrows. On May 1, 2019 and May 22, 2020, sowing was done in rows, with 6 rows of 10 pockets each and three seeds per pocket. The spacings were 36.36 cm on the lines and 50 cm between the lines.
From germination (May 7, 2019 and May 29, 2020) to the appearance of the first flowers (June 27, 2019 and July 19, 2020), weeding was regularly carried out with a hoe, every two weeks. From flowering to pod maturation, weeding was done by hand.

Process for Obtaining Biopesticides

The middle fresh leaves of *C. rigidus, L. multiflora* and *P. glandulosus* harvested in the morning, were cleaned and dried separately in the shade. After drying, they were pounded separately using a wooden mortar, then sieved with a 0.2mm mesh sieve and stored in dry plastic bags tightly closed in a refrigerator at 4°C until use for extractions. For each of the powders derived from plants, 75, 150 and 225g were weighed using a CAMRY brand electronic scale (accuracy 0.01g) and introduced separately into a container containing 1.5 L of water to obtain the concentrations 5, 10 and 15% respectively. After stirring and maceration for 24 hours, the mixtures were sieved using a 0.2 mm mesh sieve.

Insecticide Treatment

The experimental units were treated with two types of insecticides: synthetic pyrethroid, Decis (Deltamethrin 15g/L) used as reference and three concentrations (5%, 10% and 15%) of aqueous extracts of the three species of plants (*C. rigidus, L. multiflora* and *P. glandulosus*) tested in this study. The experimental units were distributed in a completely randomized design with four repetitions: 1 control x 3 plants x 3 extracts x 3 concentrations x 1 reference insecticide (Decis) x four groups of flowers (group 1:120flower buds whose open flowers have been left free to pollinate, group 2: 120 flower buds whose open flowers have been protected from insects using gauze bags, group 3: 200 flower buds whose open flowers have been protected, then uncovered for 10 minutes for an exclusive visit by *A. mellifera* before being protected again, and group 4: 100 flower buds with open flowers protected, then uncovered for 10 minutes and protected again, without visit insects or any other organism). The spraying of insecticides was done using a manual sprayer at sunset, five weeks after sowing, and repeated every 7 days until the last flower faded. The extracts and the reference insecticide (recommended dilution is 3mL/15L of water) were applied at the rate of 268L/ha and 2.1L/ha respectively.

Data collection

At the flower bud stage, the flowers were grouped as described above and labeled. The observations for the determination of the biological diversity of the anthophile insects of *G. max* were made on the flowers left in free pollination. Observations were made every day, during five time slots: 8 - 9 a.m., 10 - 11 a.m., 12 - 1 p.m., 2 - 3 p.m. and 4 - 5 p.m. The number of morphologically identical insects was recorded. A recognition code was assigned to each visiting species. Two to five insects of each species, depending on their abundance, were captured using a sweep net and preserved in 70% ethanol, except for Lepidoptera, which were preserved in foil for later identification (Borror and White, 1991).

Insects not having been marked, the cumulative results of these counts were expressed by the number of visits (Tchuenguem *et al.*, 1997). At the end of the investigations, the insects were identified using insect keys (Delvare and Arbelenc, 1989; Borror and White, 1991; Eardley *et al.*, 2010; Gourmel, 2014).

At the same time, the durations of the pollen collection visits and those of the nectar collection were recorded separately according to the different insecticide treatments, using a stopwatch. The density of foragers (Tchuenguem & Népidé, 2018) and browsing speed (Jacob Remacle, 1989) were recorded for the different treatments. The number of blooming flowers, the temperature and the ambient humidity were recorded during each time slot. The last two parameters were recorded using a portable thermo-hygrometer, installed in the shade. At maturity, the pods were harvested and counted.

Impact of the Insect's Pollination Including *Apis Mellifera* and the Single Visit of *Apis Mellifera* on the Podding Rate of *Glycine Max*

The evaluation of the effect of insects including *A. mellifera* on the podding rate of *G. max* was based on the impact of flowering insects on pollination and the impact of pollination on *G. max* fruiting of treatments 1 and 2 (2019) and 3 and 4 (2020). For each year, the podding index (Pi) was then calculated according to the formula of Tchuenguem *et al.* (2001):

$Pi = Fb/Fa$,

Where Fa is the number of viable flowers initially set and Fb the number of pods formed.

For each year of investigation, the podding rate due to flower insects (Pi) is calculated using the formula of Diguir *et al.* (2020) :

$Pi = \{[(FX – FZ)/(FX + FY – FZ)] * 100\}$

Where FX, FY and FZ are respectively the podding rates in treatments X (flowers left free to pollinate), Y (flowers protected from insects) and Z (flowers protected, uncovered then protected again, without visiting insects).

For one treatment, the podding rate (P) is :

$Pr = (Fb/Fa)*100$, (Tchuenguem *et al.*, 2001).

The podding rate due to *A. mellifera* (Pr) was calculated using the formula of Diguir *et al.* (2020) :

$Pr = \{[(FP – FZ)/FP]*100\}$,

Where FP and FZ are the podding rates in treatment P (flowers protected, then uncovered, visited exclusively by *A. mellifera* and again protected) and Z.

Data Analysis

Data were analysed using descriptive statistics, student's t-test for the comparison of means of the two samples, Pearson correlation coefficient (r) for the study of the association between two variables and chi-square ($\chi 2$) for the comparison of percentages. The transformed data was subjected to the ANOVA procedure of SPSS 16.0. Tukey's range test (DSH) was applied for the separation of means at the 5% probability threshold. Microsoft Excel software, version 2021 was also used.

RESULTS

Frequency of Visits

Amongst the 1084 and 721 visits of 9 and 5 insect species recorded on its flowers in 2019 and 2020 respectively, *A. mellifera* ranked first insect with 1007 visits (92.39%) and 695 visits (96.39%) in 2019 and 2020 respectively (Table 1). The difference between these two percentages is not significant ($\chi 2 = 2.64$; df = 10; $P > 0.05$).

Table 1: Number and percentage of insects recorded on *Glycine max* flowers in 2019 and 2020

Insects			**2019**		**2020**		**Total**	
Order	**Family**	**Genus and species**	**n1**	**p1 (%)**	**n1**	**p1 (%)**	**nT**	**TP (%)**
Hymenoptera	Apidae	*Apis mellifera*	1007	92.9	695	96.39	1702	94.65
		Xylocopa olivacea	8	0.74	7	0.97	15	0.85
	Halictidae	*Lasioglossum sp.*	5	0.46	3	0.42	8	0.44
	Formicidae	(1 sp.)	12	1.10	11	1.52	23	1.31
	Vespidae	(sp.1)	10	0.92	-	-	10	0.46
		(sp.2)	7	0.65	5	0.7	12	0.67
Diptera	Syrphidae	(1 sp.)	7	0.65	-	-	7	0.33
Lepidoptera	Pieridae	*Eurema* sp. 1	18	1.66	-	-	18	0.83
		Eurema sp. 2	10	0.92	-	-	10	0.46
Total		**9 species**	**1084**	**100**	**721**	**100**	**1805**	**100**

Floral Products Harvested

During each flowering period, *A. mellifera* was seen harvesting intensively and exclusively nectar on *G. max* flowers.

Figure 1: *Apis mellifera* harvesting nectar on *Glycine max* flower

Relationship between Visits and Flowering Stages

The visits of *A. mellifera* were more numerous on treatment 1 and 3 when the number of opened flowers was high (Fig. 2A and B). The correlation was highly significant between the number of *G. max* opened flowers and the number of *A. mellifera* visits in 2019 (r = 0.75; 0.88; 0.88; 0.79; 0.89; 0.72; 0.82; 0.70; 0 .91; 0.70; 0.87; df = 10; p < 0.01) as in 2020 (r = 0.69; 0.89; 0.85; 0.85; 0.85; 0, 65; 0.68; 0.62; 0.86; 0.59; 0.88; df = 10; p < 0.01), respectively for the control and the extracts of *C. rigidus* (5%), *C. rigidus* (10%), *C. rigidus* (15%), *L. multiflora* (5%), *L. multiflora* (10%), *L. multiflora* (15%), *P. glandulosus* (5%), *P. glandulosus* (10%), *P. glandulosus* (15%) and Decis.

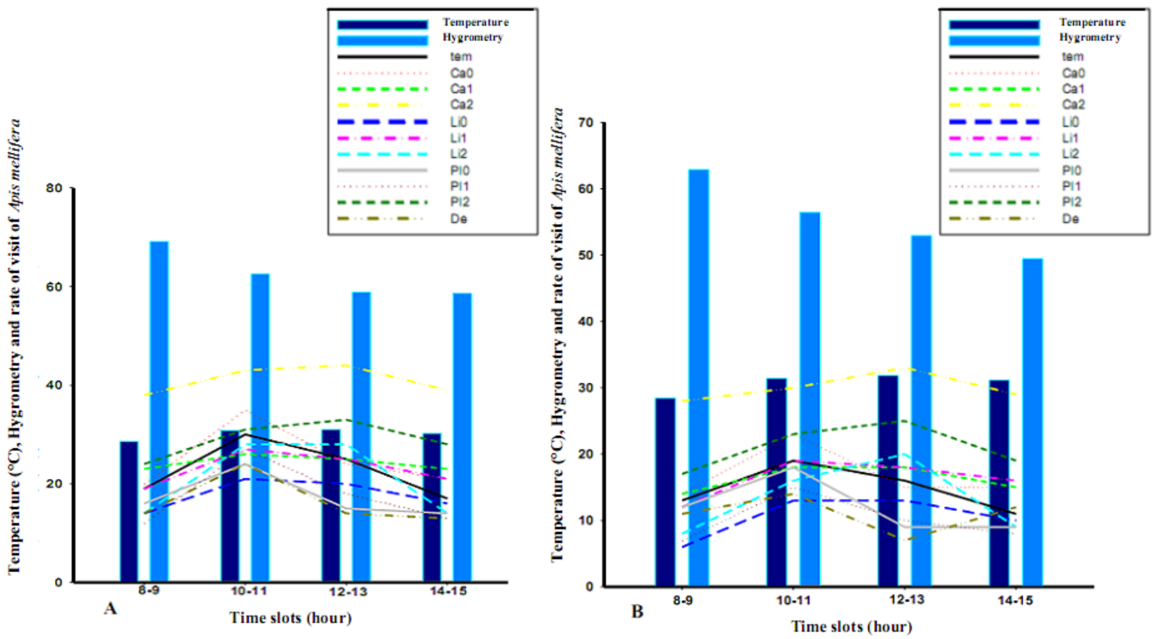

Figure 2: Seasonal variation of the number of *Glycine max* opened flowers and the number of *Apis mellifera* visits according to the different treatments

Tem = control, Ca0 = *C. rigidus* (5%), Ca1 = *C. rigidus* (10%), Ca2 = *C. rigidus* (15%), Li0 = *L. multiflora* (5%), Li1 = *L. multiflora* (10%), Li2 = *L. multiflora* (15%), Pl0 = *P. glandulosus* (5%), Pl1 = *P. glandulosus* (10%), Pl2 = *P. glandulosus* (15%) and De = *Decis.*

Daily Visits

The honey bee were registered on G. max flowers between 8 a.m. and 3 p.m. with a peak in visits between 10 a.m. and 11 a.m., except for the sub-plots with aqueous extracts of *C. Rigidus* (15%), *L. multiflora* (15%) and *P. glandulosus* (15%) whose peak visits were between 12 p.m. and 1 p.m.. The bee activity period coincided with the opening flowers of this Fabaceae. The correlation was :

a) Positive and highly significant between the number of insect visits and temperature in 2019 (r = 0.63 ; 0.58 ; 0.75 ; 0.88 ; 0.90 ; 0.87 ; 0.80 ; 0.28 ; 0.66 ; 0.97 and 0.37) respectively for control, *C. rigidus* (5%), *C. rigidus* (10%), *C. rigidus* (15%), *L. multiflora* (5%), *L. multiflora* (10%), *L. multiflora* (15%), *P. glandulosus* (5%), *P. glandulosus* (10%), *P. glandulosus* (15%) and Decis (df = 10 ; P < 0.01);

b) Negative (r = - 0.12 ; - 0.13 ; - 0.27 ; - 0.53 ; - 0.54 ; - 0.48 ; - 0.37 ; - 0.20 and – 0.76) respectively for control, *C. rigidus* (5%), *C. rigidus* (10%), *C. rigidus* (15%), *L. multiflora* (5%), *L. multiflora* (10%), *L. multiflora* (15%), *P. glandulosus* (5%), *P. glandulosus* (10%), *P. glandulosus* (15%)), positive (r = 0.19 and 0.08) respectively for *P. glandulosus* (5 %) and Decis. And significant between the relative humidity and number of visits in 2019 (df = 10 ; P < 0.01) ;

c) Positive (r = 0.41 ; 0.41 ; 0.81 ; 0.75 ; 0.95 ; 0.94 ; 0.74 ; 0.58 and 0.83) respectively for control, *C. rigidus* (5%), *C. rigidus* (10%), *C. rigidus* (15%), *L. multiflora* (5%), *L. multiflora* (10%), *L. multiflora* (15%), *P. glandulosus* (5%), *P. glandulosus* (10%), *P. glandulosus* (15%)), negative (r = -0.02 and – 0.14) respectively for *P. glandulosus* (5 %) and Decis. And significant between between the number of insect visits and temperature in 2020 (df = 10 ; P < 0.01) ;

d) Negative (r = - 0.34 ; - 0.44 ; - 0.60 ; - 0.60 ; - 0.28 ; - 0.09 and – 0.41) respectively for *C. rigidus* (10%), *C. rigidus* (15%), *L. multiflora* (5%), *L. multiflora* (10%), *L. multiflora* (15%), *P. glandulosus* (5%), *P. glandulosus* (10%), *P. glandulosus* (15%)), positive (r = 0.18 ; 0.01 ; 0.43 and 0.41) respectively for control, *C. rigidus* (5%), *P. glandulosus* (5 %), and Decis. And significant between the relative humidity and number of visits in 2020 (df = 10 ; P < 0.01) ;

Figure 3: Daily distribution of *Apis mellifera* visits on *Glycine max* flowers in 2019 (A) and 2020 (B), mean temperature and mean humidity of the study site
Tem = control, Ca0 = *C. rigidus* (5%), Ca1 = *C. rigidus* (10%), Ca2 = *C. rigidus* (15%), Li0 = *L. multiflora* (5%), Li1 = *L. multiflora* (10%), Li2 = *L. multiflora* (15%), Pl0 = *P. glandulosus* (5%), Pl1 = *P. glandulosus* (10%), Pl2 = *P. glandulosus* (15%) and De = *Decis*.

Duration of Visit

In 2019, at *A. mellifera*, the average duration of a visit per G. max flower for the nectar harvest varied from 1.93 sec (n = 43 ; s = 0.96) on the plots treated with Decis to 4.4 sec (n = 40 ; s = 0.26) on the plots treated with *C. rigidus* 15 %. In 2020, the average duration of a visit varied from 1.92 sec (n = 26 ; s = 0.12) on the plots treated with Decis to 4.39 sec (n = 38 ; s = 0.28) on the plots treated with *C. rigidus* 15 %.

Foraging Speed of *Apis Mellifera* on *Glycine Max* Flowers

The average foraging speed was 13 flowers per minute (n = 50 ; s = 1.73) in 2019 and 14 flowers per minute (n = 32 ; s = 2.68) in 2020. Then, 12 flowers per minute (n = 26 ; s = 0.64) in 2019 and 12 flowers per minute (n = 20 ; s = 0.75) in 2020 respectively for the plots treated with aqueous plant extracts of *C. rigidus* (15%) and *L. multiflora* (5%).

Influence of Neighboring Floral

During each observation periods, flowers of many other plant species surrounding the study area were visited by *A. mellifera*, for nectar and / or for pollen. Among these plants were : *Zea mays* (Po), *Vigna unguiculata* (Ne), *Phaseolus vulgaris* (Ne), *Ipomea batatas* (Ne, Po), *Solanum nigrum* (Ne, Po), *Arachis hypogea* (Ne) and *Richardia brasiliensis* (Po).

Influence of Wildlife

The foragers of *A. mellifera* were disturbed in their foraging activity by biotic factors such as other arthropods that were either by competitors for nectar and/or pollen and abiotic factors like wind, rain and temperature. These disturbances resulted in the interruption of some visits. In 2019, for 1084 visits, 21 (63.64%) were interrupted by *A. mellifera*, 9 (27.27%) by *Eurema* sp. and 3 (9.09%) by *Formicidae* (1 sp.). While in 2020 for 721 visits, 19 (70.37%) were interrupted by *A. mellifera*, 7 (25.93%) by *Xylocopa olivacea* and 1 (3.70%) by *Formicidae* (1 sp.). For their load of floral products, some individuals of *A. mellifera* who suffered such disturbances were forced to visit more flowers during the corresponding foraging trip.

Table 2: Interruptions of *Apis mellifera* visits on *Glycine max* flowers by competing insects

Years	Number of visits	Visits interrupted by insects		Insects responsible for interruption
		Number	Percentage (%)	
2019	1084	21	63.64	*Apis mellifera*
		9	27.27	*Eurema* sp.
		3	9.09	*Formicidae* (1 sp.)
2020	721	19	70.37	*Apis mellifera*
		7	25.93	*Xylocopa olivacea*
		1	3.70	*Formicidae* (1 sp.)

Impact of the Insect's Pollination Including *Apis Mellifera* and the Single Visit of *Apis Mellifera* on the Podding Rate of *Glycine Max*

During nectar harvest on soybean flowers, honey bees and the other flowering insects always contacted anthers and stigma, thereby increased the pollination possibilities of *Glycine max* as they frequently flew from flowers to flowers on the same plants and / or on other flowers of the neighboring plants of soybean. Table 3 reveals that:

The podding rates (treatments 1, 2, 3 and 4) due to the flowering insects were 2.81 %, 2.67 % for *C. rigidus* 15 % and *P. glandulosus* 5 % then, 1.29 % for *C. rigidus* 15 % in 2019 and 2.80 %, 2.63 % for *C. rigidus* 15 % and Décis then, 1.28 % ; for *C. rigidus* 15 % in 2020.

By its positive action on the pollination of the flowers visited (treatments 5 and 7), *A. mellifera* increased in the podding rate of 2 % and 2.12 % for *C. rigidus* and 15 %

Table 3: Fruiting rate according to the different *Glycine max* treatments in 2019 and 2020

Parameters	Treatments											F
	Ca0	Ca1	Ca2	Li0	Li1	Li2	Pl0	Pl1	Pl2	ST	De	
2019												
1 (FL)	1.75 ± 0.46^{abAB}	2.00 ± 0.00^{aA}	2.81 ± 0.40^{aA}	1.75 ± 0.50^{aAB}	2.17 ± 0.41^{aA}	2.12 ± 0.83^{aA}	2.67 ± 0.33^{aA}	2.33 ± 0.33^{aA}	1.92 ± 0.23^{aAB}	0.00 ± 0.00^{cB}	0.62 ± 0.18^{cB}	9.08^{*}
2 (FP)	0.50 ± 0.28^{bC}	1.00 ± 0.00^{cB}	1.29 ± 0.18^{bA}	0.00 ± 0.00^{cC}	0.00 ± 0.00^{cC}	1.00 ± 0.00^{bB}	0.00 ± 0.00^{cC}	1.00 ± 0.00^{bB}	1.00 ± 0.00^{abB}	0.00 ± 0.00^{cC}	1.00 ± 0.00^{abB}	39.14^{***}
5 (FPD)	2.00 ± 0.00^{aA}	1.14 ± 0.14^{bcAB}	2.00 ± 0.00^{abA}	0.50 ± 0.29^{bB}	$1.25 \pm 0.25b^{AB}$	1.83 ± 0.31^{abAB}	1.60 ± 0.25^{abA}	1.71 ± 0.18^{abAB}	2.12 ± 0.12^{aA}	1.56 ± 0.18^{aAB}	0.50 ± 0.22^{cB}	8.46^{*}

6 (FPS)	-	$1.00±0.00^{cB}$	$1.80±0.20^{abA}$	-	-	-	$0.00±0.00^{cC}$	$0.50±0.00^{cC}$	$0.00±0.00^{bC}$	$1.50 ± 0.50^{abA}$	$1.43±0.29^{aA}$	5.30^{*}
F	16.06^{**}	57.00^{***}	29.06^{**}	20.05^{**}	58.15^{***}	4.13*	20.63^{**}	8.49^{*}	14.16^{**}	37.49^{**}	4.41^{*}	-
2020												
3 (FL)	$2.29±0.29^{aA}$	$2.00±0.00^{aB}$	$2.80±0.11^{aA}$	$2.00±0.40^{aB}$	$2.33±0.33^{aA}$	$2.21±0.3^{aA}$	$2.00±0.26^{aB}$	$2.33±0.33^{aA}$	$2.00 ± 0.26^{abB}$	$2.10 ± 0.17^{abA}$	$2.63±0.26^{aA}$	8.39*
4 (FP)	$0.50±0.29^{bcC}$	$1.00±0.00^{cB}$	$1.28±0.18^{bA}$	$0.00±0.00^{cC}$	$0.00±0.00^{cC}$	$1.00 ± 0.00^{abB}$	$0.00±0.00^{cC}$	$1.00±0.00^{cB}$	$1.00±0.00^{cB}$	$0.00±0.00^{cC}$	$0.89±0.11^{bB}$	25.30^{***}
7 (FPD)	$2.00 ± 0.00^{abA}$	$1.17 ± 0.16^{bcB}$	$1.87±0.12^{abA}$	$0.50±0.28^{bB}$	$1.25±0.25^{abcB}$	$1.67 ± 0.21^{abAB}$	$1.60±0.25^{abA}$	$1.72±0.19^{bAB}$	$2.13±0.13^{aA}$	$1.55±0.17^{bB}$	$0.60±0.25^{bC}$	7.14^{*}
8 (FPS)	$2.00 ± 0.00^{abAB}$	$2.00 ± 0.00^{aAB}$	$2.00±0.32^{aAB}$	-	$1.00±0.00^{bC}$	$2.00 ± 0.00^{aAB}$	$2.00 ± 0.00^{aAB}$	$2.00 ± 0.00^{abAB}$	$1.67±0.33^{bB}$	$2.50±0.50^{aA}$	$2.50±0.22^{aA}$	6.34^{*}
F	21.28^{**}	49.87^{***}	23.87^{**}	20.05^{**}	58.16^{***}	5.94^{*}	17.18^{**}	7.37^{*}	15.21^{**}	30.51^{**}	6.87^{*}	-

*ST = control, Ca0 = C. rigidus (5%), Ca1 = C. rigidus (10%), Ca2 = C. rigidus (15%), Li0 = L. multiflora (5%), Li1 = L. multiflora (10%), Li2 = L. multiflora (15%), Pl0 = P. glandulosus (5%), Pl1 = P. glandulosus (10%), Pl2 = P. glandulosus (15%) and De = Decis. FL: flowers left free to pollinate; FP: flowers protected from insects; FPD: flowers protected from insects and visited exclusively by Apis mellifera ; FPS: flowers protected from insects then uncovered, and again protected without visits from insects or any other organism. The means of the same column and of the same row, followed respectively by the same lowercase and uppercase letter, do not differ significantly ($p < 0.05$; Tukey's test). Each value represents the mean ± SE. *$p<0.05$; **$p<0.01$; ***$p<0.001$; – estimating the value of F is not possible due to equal variance.*

for *P. glandulosus* in 2019. Then, 2.13 % for *P. glandulosus* 15 % in 2020.

DISCUSSION

Among insect species recorded on soybean flowers, *Apis mellifera* was the majority with a cumulative frequency of visits of 94.65% for the two years of investigation. Thus, the main anthophilic insects of *G. max* in Ngaoundéré belong to the order Hymenoptera, with the dominance of the family Apidae. This result corroborates that obtained by Milfont *et al.* (2013) that *A. mellifera* is the most abundant anthophilous insect of *G. max*. However, the diversity and abundance of anthophilous insects of this Fabaceae may vary with regions. Because, contrary to our results and those obtained by other researchers, the Halictidae family was more abundant on the flowers of *G. max* in the Far North of Cameroon (Tchuenguem & Dounia, 2014) and in the Littoral Cameroon (Taïmanga & Tchuenguem, 2018).

From our observations in the field, during each flowering period and in all sub-plots treated with aqueous plant extracts or not, *A. mellifera* visited the flowers of *G. max* and intensely and exclusively collected nectar. The number of visits from *A. mellifera* for this harvest was proportional to the number of blooming flowers. This result highlights the good attractiveness of the floral nectar of *G. max* vis-à-vis *A. mellifera*, independently of the treatment. Attractiveness is also linked to the abundance of floral products, which can vary depending on the number of blooming flowers. The various insecticide treatments were not repellent against *A. mellifera*, including the reference insecticide Decis which acts by contact and ingestion.

Indeed, the plants tested in this study are aromatic whose essential oils can be used as an alternative to acaricides and synthetic antimicrobials for an overall improvement in the state of health of honey bee colonies (Eguaras *et al*., 2005; Al-Ghamdi *et al*., 2021).

The peak in *A. mellifera* activity was likely related to daily periods of greater nectar availability due to optimal temperature for flower development and nectar production. According to the work of Manrique & Thimann (2002), an increase in temperature stimulates the production of nectar, the availability of which is characterized by the yellow color of the flowers (Carrión-Tacuri *et al*., 2012). *A. mellifera* would therefore have associated the color (yellow) with the availability of the reward, which would have allowed it to maximize its energy gain. This illustrates the theory of optimal foraging which indicates that foragers tend to move towards abundant food resources to reduce energy losses (Baude *et al*., 2011). Other factors such as the spraying of insecticides had an impact on the foraging activity of the honey bee. This impact was concentration dependent, with the highest concentration (15%) being more attractive to *A. mellifera*. *Callistemon rigidus* was more active. In a similar study, Adamou *et al*. (2022) found that botanical extracts have an attractive effect against *A. mellifera*. Further studies are needed to identify the active compounds in these extracts.

According to previous studies, foragers take longer to obtain their maximum nectar load on flowers where this resource is available in large quantities. Botanical extracts would therefore increase nectar production in *G. max* or prevent insect competitors of *A. mellifera* from harvesting this floral product. The extracts therefore had no significant impact on the accessibility of the nectar collected by the foragers.

During the flowering period, and in all the sub-plots treated with aqueous plant extracts, including the positive and negative controls, the foraging activity of *A. mellifera* was interrupted by individuals of the same species or by other insects that were competitors for nectar collection. Strong competition for nectar harvesting was observed in *A. mellifera* during the two years of observation. *Eurema* sp. and *Xylocopa olivacea* were major competitors of *A. mellifera* in 2019 and 2020, respectively. These interruptions occurred as a result of collisions between visitors. One of the consequences of these disturbances was the reduction in the duration of certain visits; this forced some individuals of *A. mellifera* to visit more flowers on a foraging trip to obtain their optimal nectar load, as reported by Djakbé *et al*. (2017) on *Physalis minima*, then Tchuenguem *et al*. (2018) on *Ceratotheca sesamoides*.

In 2019, unlike the control treatments and the reference insecticide Décis, the various botanical extracts generally significantly improved the fruiting rate of flowers left open to pollination (FL) and that of flowers pollinated exclusively by *A. mellifera* (FPD). In 2020, the fruiting rate of the sub-plots left in free pollination and those visited exclusively by *A. mellifera* and treated with synthetic insecticide (Decis) was significantly low compared to the other treatments including the control. Fruiting rates from protected flowers were significantly low for both years. These results show a potentiation of the pollinating action of *A. mellifera* and botanical extracts for improving the fruiting rate of *G. max*. Indeed, during the nectar harvest, the workers of *Apis mellifera* were frequently in contact with the anthers and the stigma. They could therefore intervene directly in self-pollination, by putting the pollen of a flower on its stigma. They could also intervene in cross-pollination, by putting the pollen of one flower on the stigma of another flower of the same plant or by putting the pollen of one plant on the stigma of a flower of another plant. Therefore, *A. mellifera* strongly increased the pollination possibilities of *G. max*. Similar results were found in *Vigna unguiculata* (Adamou *et al*., 2020). The impact of extracts with biopesticide effects would be linked on the one hand to their attractive property vis-à-vis this pollinating insect and on the other hand to their pesticidal property against the pests of *G. max*. The aqueous extracts of *C. rigidus, L. multiflora* and *P. glandulosus* were therefore more selective for *A. mellifera* than the synthetic insecticide Decis as reported by Pereira *et al*. (2020).

CONCLUSION

Botanical extracts increased the foraging ability of pollinators. In this locality of Bini, the number of insect species visiting this Fabaceae varies from year to year. It is highly visited by *A. mellifera* for the exclusive collection of nectar. This study demonstrated that the aqueous extracts of *C. rigidus, L. multiflora* and *P. glandulosus* with the highest concentration (15%) are attractive to this honeybee and contribute synergistically to a significant improvement in the index and fruiting rate of *G. max*. This means that the botanical extracts with the highest concentration (15%) were selective for *A. mellifera* and could be used as alternative to synthetic insecticides. The preservation of honey bee hives near soybean plantations is necessary to improve the fruiting rate.

REFERENCES

Adamou M., Kosini D., Tchoubou-Sale A., Massah O. D., Tchocgnia T. F. C., Mohammadou M. & yousoufa O. (2022). Impact of aqueous extracts of Cassia occidentalis, Eucalyptus camaldulensis and Hyptis suaveolens on the entomofauna and the seed yield of Gossypium hirsutum at Bokle (Garoua, Cameroon). *Heliyon, 8*(10), e10937.

Adamou M., Nepide N. C., Mazi S. & Yatahaï C. M. (2020). Impact of the pollinating activity of *Apis mellifera* (Hymenoptera: Apidae) on the fruit and seed yields of Vigna unguiculata (Fabaceae) variety BR1 in Djoumassi (North, Cameroon). *Cameroon Journal of Biological and Biochemical Sciences, 28*(2), 146-159.

Al-Ghamdi A. A., Abou-Shaara H. F. & Ansari M. J. (2021). Effects of sugar feeding supplemented with three plant extracts on some parameters of honey bee colonies.

Saudi Journal of Biological Sciences, 28, 2076-2082.

Amougou J. A., Abossolo S. A. & Tchindjang M. (2015). Variability of precipitation in Koundja and Ngaoundéré in relation to temperature anomalies of the Atlantic Ocean and el nino. *Ivory Coast Review of Science and Technology, 25*, 110-124.

Bakkali F., Averbeck S., Averbeck D. & Idaomar M. (2008). Biological effects of essential oils - A review. *Food and Chemical Toxicology, 46*, 446-475.

Bambara D. & Tiemtoré J. (2008). Biopesticide efficacy of Hyptis spicigera Lam., Azadirachta indica A. Juss. and Euphorbia balsamifera Ait. on cowpea Vigna unguculata L. Walp. *Tropicultura, 26*, 53-55.

Baskar K., Sudha V. & Jayakumar M. (2017). Effect of pesticides on pollinators. *Ecology & Environmental Science, 2*(8), 299. https://doi.org/10.15406/mojes.2017.02.00052.

Baude M., Muratet A., Fontaine C. & Pellaton M. (2011). Plants and pollinators. Departmental Observatory of Urban Biodiversity (ODBU), Seine - Saint - Denis, 66

Borror D. J. & White R. E. (1991). *Insects of North America* (north of Mexico). Broquet (ed.). Laprairie, Quebec, 408 p.

Carrión-Tacuri J., Berjano R., Guerrero G., Figueroa M.E., Tye A. & Castillo J. M. (2012). Nectar production by invasive Lantana camara and endemic Lantana peduncularis in the Galápagos Islands. *Pacific Science, 66*(4), 435-445.

Danga Y. S. P., Nukenine E. N., Younoussa L., Adler C. & Esimone C. O. (2015). Efficacy of *Plectranthus glandulosus* (Lamiaceae) and *Callistemon rigidus* (Myrtaceae) leaf extract fractions to Callosobruchus maculatus (Coleoptera: Bruchidae). *Journal of Insect Science, 15*(1), 139.

Delvare G. & Arbelenc H. P. (1989). *Insects of Africa and tropical America: keys to family recognition*. CIRAD (ed.), Montpellier, 297.

Diguir B. B., Pando J. B., Fameni T. S. & 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), 22-31.

Djakbe D. J., Ngakou A., Wékéré C., Faibawa E. & 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 (Ngaoundéré-Cameroon). *International Journal of Agronomy and Agriculture Research, 11*(3), 43-60.

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

Eardley C. D., Kuhlmann M. & Pauly A. (2010). The bee genera and subgenera of sub-Saharan Africa. ABC Taxa 9, 152.

Eguaras M. J., Fuselli S., Gende L., Fritz R., Ruffinengo S.R. & Clemente G. (2005). An in vitro evaluation of Tagetes minuta essential oil for the control of the honeybee pathogens Paeni bacillus larvae and Ascosphaera apis, and the parasitic mite Varroa destructor. *Journal of Essential Oil Research, 17*, 336-340.

El-Wakeil N. E. (2013). Botanical pesticides and their mode of action. *Gesunde Pflanzen, 65*, 125-149.

FAO. (2018). The state of food security and nutrition in the world: building resilience to climate change for food security and nutrition food security and nutrition in the world. Roma, 218.

Fontaine C., Dajoz I., Meriguet J. & Loreau M. (2006a). Functional diversity of plant-pollinator interaction webs enhance the persistence of plant communities. *Plos Biology, 4*, 129-135.

Fontaine C., Meriguet J., Loreau M. & Dajoz I. (2006b). The diversity of plant-pollinator interactions: an essential prerequisite for the stability of ecosystems. *Magazine, 10*(22), 817 - 821.

Gallais A. & Bannerot H. (1992). Improvement of cultivated plant species. Objectives and selection criteria. *Editions Quae*. 768.

Gourmel C. (2014). Illustrated catalog of the main insect pests and beneficials of crops in French Guiana. BioSavane Cooperative, *French Guiana*.73.

Inoussa K. Y., Charles P., Marius K. S., Brehima D. & Mamoudou H. D. (2020). Physicochemical characteristics of some raw materials used in the formulation of poultry feed. *Journal of Applied Biosciences, 151*, 15598-15604.

Jacob-Remacle A. (1989). Foraging behavior of honey bees and wild bees in apple orchards in Belgium. *Apidology, 20*, 271-285.

Kapeuhag L. C., Barry B. R., Wini G. J., Dabolé M. O., Ngakou A. & Nukenine E. N. (2021). The use of plant extracts in the improvement of cowpea yield at Dang (Ngaoundere, Cameroon). *International Journal of Agronomy and Agricultural Research, 18*, 41-45.

Kosini D., Nukenine E. N., Agbor G. A., Tchinda A. T., Abdou J. P., Yaya J. A. G. & Kowa T. K. (202)1. Fractionated extracts from Gnidia kraussiana (Malvales: Thymeleaceae) as bioactive phytochemicals for effective management of Callosobruchus maculatus (Coleoptera: Chrysomelidae) in stored Vigna unguiculata (Fabales: Fabaceae) seeds. *Journal of Insect Science, 21*(1), 1-8.

Manrique A. J. & Thimann R. E. (2002). Coffee (Coffea arabica) pollination with africanized honeybees in Venezuela. *Interciencia Caracas, 27*(8), 414-416.

Milfont T. L., Richter I., Sibley C. G., Wilson M. S. & Fischer R. (2013). Environmental consequences of the desire to dominate and be superior. *Personality and Social Psychology Bulletin, 39*(9), 1127-1138.

Mkenda P., Mwanauta R., Stevenson P. C., Ndakidemi P., Mtei K. & Belmain S. R. (2015). Extracts from field margin weeds provide economically viable and environmentally benign pest control compared to synthetic pesticides. *PLoS ONE, 10*, e0143530.

Mohammadou M., Adamou M., Taïmanga, Kosini D. & Kenne M. (2023). Seed yield improvement in Vigna unguiculata (L.) (Fabaceae): efficiency of pollinators and impact of aqueous leaf extract ofthree plant species in north Cameroon. *Asian Journal of Research in Crop Science, 8*(3), 146-172.

Nzossié F. E. J. & Bring C. (2020). Soybean (*Glycine max* (L.) Merr.) production in the Cameroonian cotton basin between the dynamics of structuring an agricultural value chain and sustainability issues, 72.

Pereira R. C., Barbosa W. F., Pereira Lima M. A. &Vieira J. J. O. L. (2020). Toxicity of botanical extracts and their main constituents on the bees Partamona helleri and *Apis mellifera*. *Ecotoxicology*. 12.

Regnault-Roger C., Vincent C. & Arnason J. T. (2012). Essential oils in insect control: low-risk products in a high-stakes world. *Annual Review of Entomology, 57*, 405-424.

Sheriff M. H. (2013). *Soybeans, nutrition and health*. In: El-Shemy H (ed.), Soybean Bio-Active Compounds, InTech, Rijeka, 453-473.

Suthisut D., Fields P. G. & Chandrapatya A. (2011a). Fumigant toxicity of essential oils from three Thai plants (Zingiberaceae) and their major compounds against Sitophilus zeamais, Tribolium castaneum and two parasitoids. *Journal of Stored Products Research, 47*, 222-230.

Suthisut D., Fields P. G. & Chandrapatya A. (2011b.) Contact toxicity, feeding reduction, and repellency of essential oils from three plants from the ginger family (Zingiberaceae) and their major components against Sitophilus zeamais and Tribolium castaneum. *Journal of Economic Entomology, 104*, 1445-454.

Taimanga & Tchuenguem F. F.-N. (2018). Diversity of flower insects and its impact on fruit and seed yields of *Glycine max* (Fabaceae) in Yassa (Douala, Cameroon). *International Journal of Biological and Chemical Sciences, 12*(1), 141-156.

Tchuenguem F. F.-N. & Dounia, (2014). Foraging and pollination behavior of *Apis mellifera* adansonii Latreille (Hymenoptera: Apidae) on *Glycine max* L. (Fabaceae) flowers at Maroua. *Journal of Research in Biology, 4*(1), 1209-1219.

Tchuenguem F. F.-N., Djakbé J. D., Ngakou A., Wékéré C., Louabé S. & Faïbawa E. (2018). Impact of foraging activity of *Apis mellifera* Linné (Hymenoptera: Apidae) on pollination and yields of Ceratotheca sesamoides Endl. (Pedaliaceae) in Dang (Ngaoundéré, Cameroon). *Cameroon Journal of Experimental Biology, 12*(1), 22-31.

Tchuenguem F. F.-N., Messi J. & Pauly A. (2001). *Activity of Meliponula erythra on Dacryodes edulis flowers and its impact on fruiting. Fruit, 56*(3), 179-188.

Tchuenguem F. F.-N. & Nepide N. C. (2018). Pollinator efficiency of *Apis mellifera* L. (Hymenoptera: Apidae) on Sesamum indicum (Pedaliaceae) var. White and smooth seed in Dang (Ngaoundéré, Cameroon). *International Journal of Biological and Chemical Sciences, 12*(1), 446-461.

Tchuenguem F. F.-N., Nyomo, Hentchoya H. J. & Messi J. 1997. Introduction to the study of the activity of *Apis* mellifica L. (Hymenoptera: Apidae) on the flowers of *Callistemon rigidus* R. Br. (Myrtaceae) in Dang (Adamaoua - Cameroon). *Cameroon Journal of Biological & Biochemical Sciences, 7*(1), 78-85.

Tembo Y., Mkindi A. G., Mkenda P. A., Mpumi N., Mwanauta R. & Stevenson P. C. (2018). Pesticidal plant extracts improve yield and reduce insect pests on vegetable crops without harming beneficial arthropods. *Frontiers Plant Science, 9*(1425)1-10.

Vamosi J. C., Knight T. M., Streets J., Mazer S. J., Burd M. & Ashman T. L. (2006). Pollination decays in biodiversity hotspots. *Proceedings of the National Academy of Sciences, 103*, 956-96.