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Research Article

Effect of the Botanical Insecticides on *Amegilla* Friese, 1897 (Hymenoptera: Apidae) Foraging on the Cowpea Flowers in Dang (Adamaoua, North-Cameroon)

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Abstract

Synthetic pesticides present risks of pollution of the environment, humans and livestock and the alternative proposed today is to use botanical extracts in the fields against crop pests. But in North Cameroon, little information exists concerning the effect of these extracts on useful pollinating insects in general and no information exists in particular on foragers of the genus *Amegilla* Friese, 1897 (Apidae: Apinae: Anthophorini). The frequency and foraging activities of *Amegilla*, on newly blooming flowers of *Vigna unguiculata* (L.) Walp., 1843 (Fabales: Fabaceae) were recorded during five consecutive days in 2021 and 2022 planting campaigns. Plants were divided into untreated plots and plots treated using the synthetic insecticide Parastar (l p.c..ha^{-1}) or 10%, 20% and 30% aqueous leaf extracts of *Calotropis procera* (Aiton) Aiton, 1811 (Gentianales: Apocynaceae), *Eucalyptus camaldulensis* Dehnh., 1832 (Myrtales: Myrtaceae) and *Tithonia diversifolia* (Hemsley) Gray, 1883 (Asterales: Asteraceae) respectively. Among 8,987 insects collected (48.9% in 2021), *Amegila calens* Le Peletier. 1841 with stockier foragers (2021 campaign: 2.2% of the total collection, entomophily $F_{A.\ calens}$=4.5%; 2022 campaign: 0.7%, $F_{A.\ calens}$=1.3%; pooled campaigns: 2.9%, $F_{A.\ calens}$=2.9%) and *Amegilla* sp. with slender foragers (2021: 3.8%, $F_{Amegilla\ sp.}$=7.7%; 2022: no data) were recorded. Foragers started activity from 6 a.m. and stopped foraging before noon, with a peak of activity in 8 to 9 a.m. time slot for *A. calens* and 10 to 11 a.m. time slot for *Amegilla* sp.. During the five consecutive days from the first blooming day of the flowers, 598 visits (89.8% in 2021 and 10.2% in 2022) were recorded with a peak of visits during the 3rd day and then declined until it stopped during the 5th day. Treatments including the synthetic insecticide (which was the most repellent to the wild bees), did not significantly reduce the frequency of visits. But 20% aqueous extract of *Ca. procera* showed a significant increased of the mean duration of visits of the bees, compare to the results recorded in Parastar-treated plots.

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Therefore, the tested extracts, especially 20% aqueous leaves extract of *Ca. procera* may be recommended to control field insect pests and for preservation of foraging activities of *Amegilla* genus.

Keywords

Wild Bees, *Vigna unguiculata*, Synthetic Insecticide, Leaves Extract, Inhibition Effect, Dang

1. Introduction

Apoids are excellent useful pollinator insects [1-5]. Pest insects (case of Hemipteran [6]) and phytophagous insects (case of Coleoptera and Lepidoptera larvae) damage organs of wild or cultivated plants. *Vigna unguiculata* (L.) Walp., 1843 (Fabales: Fabaceae) is a largely cultivated plant species in West and Central Africa [6-9]. Several studies on the floricultural entomofauna highlighted the negative effect of pest insects [2, 3, 8-15]. Farmers frequently use approved synthetic insecticides [16] or unapproved ones in order to control harmful insects. In Adamaoua Region (Cameroon), the synthetic insecticide Parastar (mixture of 20 $g.l^{-1}$ imidacloprid and 20 $g.l^{-1}$ lamda-cyhalothrin, l $p.c..ha^{-1}$) is frequently used [8, 9, 17]. The abusive use of synthetic pesticides leads very often to harmful effects on the health of humans, the environment and on useful insects [18-21]. They often cause the emergence of resistant forms of pests, the situation being amplified by the impacts of climate change. The negative consequences linked to the excessive and inappropriate use of synthetic chemicals have led researchers to develop alternative methods, including the search for genetically resistant plant varieties and nowadays, more studies are focused on plant extracts which are less expensive, respectful of the environment, accessible to farmers and have little effect on useful insects [5, 8, 9, 15, 23]. In Cameroon as in all poor countries, many market gardeners are dragging their feet by adopting very little use of plant extracts, the majority of them declaring using plant extracts in the event of a lack of money for the purchase of synthetic pesticides. The use of plant extracts is now well documented. Among plants of exotic origin, the literature reports the use of leaves extracts of *Eucalyptus camaldulensis* Dehnh., 1832 (Myrtales: Myrtaceae) native to Australia and the invasive grass *Hyptis suaveolens* (L.) Poit., 1806 (Lamiales: Lamiaceae) native to tropical America against insects harmful to the cotton *Gossypium hirsutum* L., 1753 (Malvales: Malvaceae) [5]. Among the local origin plants, the literature reports the use of leaves extracts of *Gnidia kaussiana* Meisner (Myrtyales: Thymeleaceae) and the domesticated wild basil *Ocimum canum* Sims, 1824 (Lamiales: Lamiaceae), against the cowpea's post-harvest pest *Callosobruchus maculatus* (Fabricius, 1775) (Coleoptera: Chrysomelidae) [20]. This is also the case of the use of aqueous leaves extract of the "false kinkeliba" *Cassia occidentalis* L., 1753 (=*Senna occidentalis* (L.) Link, 1829) (Fabales: Fabaceae) against pest insects on *Gossypium hirsutum* [5]. In the savannah region of Northern-Cameroon, despite the high floral diversity and the flourishing market gardening activity, there is very little information on the insecticidal potential of native plant extracts against pest insects except works concerning the foraging activity and the effect of plant extracts on *Apis mellifera* Latreille. 1804 (Hymenoptera: Apidae) [8, 9, 24]. The wild bees *Amegilla* Friese, 1897 (Hymenoptera: Apidae) contains about 260 species including unidentified morphospecies [25]. Like other species of the Anthophorini tribe, *Amegilla* are solitary species, do not produce honey, and most of them nest in dry ground in arid or sub arid biomes, steppes, and deserts, giving their English name "digger bees". They are fast flyers, some taxa being nearly impossible to catch because of their incredible agility. Nothing is known about the insecticidal effect of the local wild plant extracts (easily accessible and able to replace Parastar) on *Amegilla* foragers [24]. It was therefore necessary to carry out studies in Adamaoua (Cameroon) on the effect of the leaves extracts of three plant species proposed as botanical insecticides by Mohammadou et al. [8, 9].

2. Materials and Methods

2.1. Study Site

The study was set up from June to September 2021 and June to October 2022.

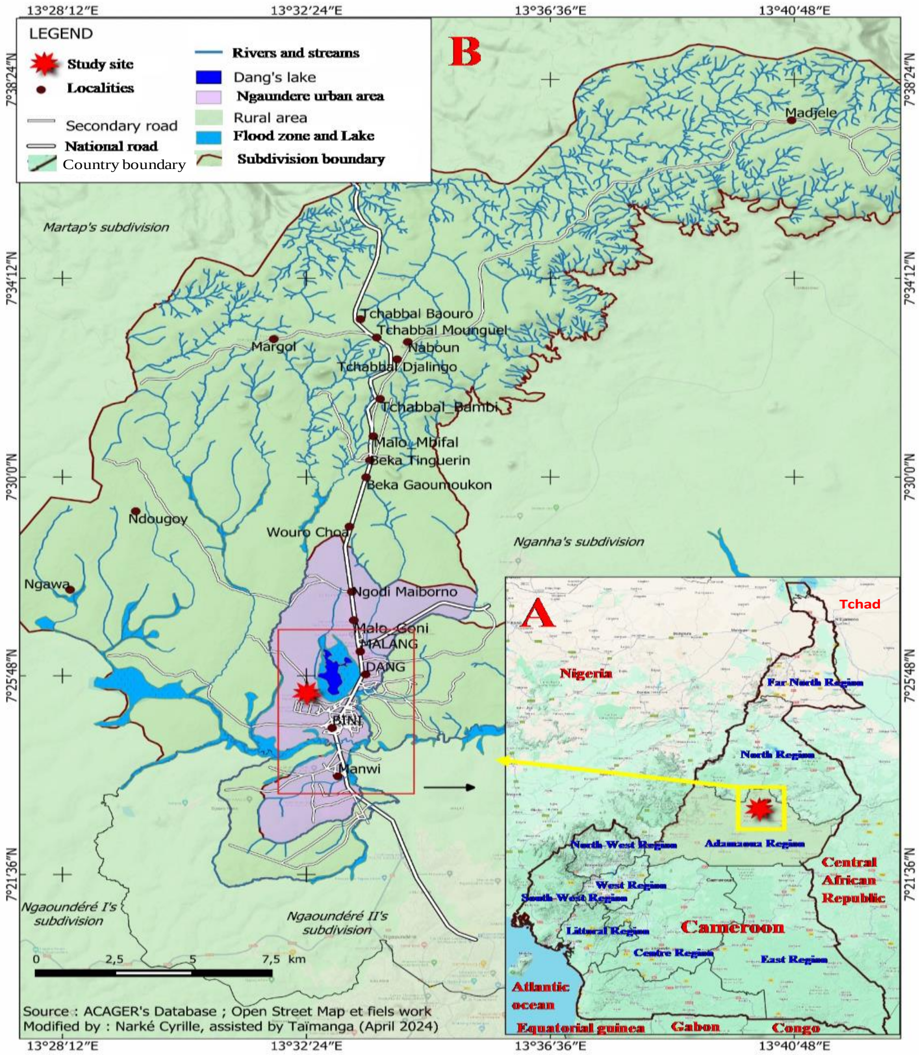


Figure 1. *Location of the study site in Dang. A: Adamaoua Region in Cameroon; B: Dang locality (Ngaoundere III suburb).*

Cowpea cultivation plots were conducted at Dang locality (7°25'26.42"N, 13°32'24.46" E; 1107.40 m) (Figure 1). Dang is located in a 3rd district of Ngaoundere, in the agro-ecological zone of the high Guinean savannahs with bimodal rainfall and a Sudano-Guinean climate type.

2.2. Biological Material

Plants of *Vigna unguiculata* (L.) Walp., 1843 (Fabales: Fabaceae) were from the "*Feekem*" variety seeds. They were obtained from the station of the Agricultural Research Institute for Development (IRD, Garoua, North-Cameroon) and sown in Dang in experimental plots. Aqueous leaves extracts of *Calotropis procera* (Aiton) Aiton, 1811 (Gentianales: Apocynaceae), *Eucalyptus camaldulensis* Dehnh., 1832 (Myrtales: Myrtaceae), and *Tithonia diversifolia* (Hemsley) Gray, 1883 (Asterales: Asteraceae), were tested as botanical insecticides proposed by Mohammadou et al. [8, 9]. *E. camaldulensis* and *Ti. diversifolia* leaves were collected in Dang. *Ca. procera* leaves were collected in Bockle (North, Cameroon). Bees came naturally from neighboring fallows.

2.3. Experimental Device and Procedure

The study was set up in 1,064 m^2 area using a completely randomized blocks procedure (3.5×4 m^2 each, four treatments repeated 4 times). Four plots were untreated. Four plots were treated with the approved synthetic insecticide Parastar (mixture of 20 $g.l^{-1}$ of imidacloprid and 20 $g.l^{-1}$ of lamda-cyhalothrin, 1 $p.c..ha^{-1}$) [16]. Thirty-six plots were treated with 10%, 20%, and 30% aqueous leaves extracts in accordance of the procedure described by Mohammadou et al. [8, 9].

2.4. Formulation of the Botanical Extracts

The aqueous extracts were formulated based on the procedure described by Sreekanth [21] which stipulates that one kilogram of the plant powder may be diluted in one litter of distilled water and homogenized before application. The formulation of the synthetic insecticide was that reported in the leaflet. Chemicals were introduced into a manual sprayer and were applied 4 times from 5 p.m. at 7 days interval as soon as the cowpea flowered [8, 9].

2.5. Data Collection

Data were collected in the field by direct observation in five consecutive days, from the start of flowering of plants, in six time slots each day: 6 to 7 a.m., 8 to 9 a.m., 10 to 11 a.m., 12 a.m. to 1 p.m., 2 to 3 p.m. and 4 to 5 p.m. as presented in our recent publication [8, 9]. For each time slots, collected insects were counted, identified *in-situ* and captured when possible for the identification confirmation in laboratory. Insects were not marked. Results were expressed in terms of the number of visits. Entomophily of the i^{th} species $F_i=(V_i/V_I)*100$ was determined with V_i as the number of visits on flowers and V_I as the number of visits of all recorded floricultural insects [8, 9]. Abundances in x time period were recorded following direct observation and abundance per 1,000 flowers $A_{1,000}=(A_x/F_x)*1,000$ was determined with F_x as the number of controlled flowers and A_x as the number of the target insect species on 1,000 flowers [8, 9]. The duration of visits per flower was the time taken by an individual to collect the floral products [8, 9]. Foraging speed V_b was the number of flowers visited in one minute $V_b=(F_i/d_i)*60$ with F_i as the number of flowers visited in d_i time period [8, 9].

2.6. Data Analysis

Data were stored in an Excel spreadsheet and analyzed using SigmaStat® Version 2.03 software for Windows [26] and StatXact-3 Version 3.1 software for exact non-parametric inferences. Results were given in terms of mean ± standard error (se) for quantitative series and absolute or relative abundances for occurrences. Comparisons were set up at the bilateral significance level $\alpha=0.05$. Comparison of two mean values was set up using the Student t-test from SigmaStat software when the normality and the equal variance test passed. Otherwise we used the Man-Whitney test or the Wilcoxon paired test from SigmaStat software. The simultaneous comparison of more than two quantitative series was set up using the Analysis of Variance test (ANOVA) from SigmaStat software when the conditions of normality and equality of variances passed, followed by pairwise comparisons using the Student-Newman-Keuls procedure. Otherwise, we used the Kruskall-Wallis test from SigmaStat software followed by Dunn procedure. Comparison of two percentages was made using the Fisher's exact test and the simultaneous comparison of more than two percentages was set up using the asymptotic chi-square test when relevant or the Fisher-Freeman-Halton test from StatXact software. Pairwise comparison of several independent percentages were carried out when using the Fisher's exact test from StatXact software. The p-values were determined and significance levels were corrected using the sequential Bonferroni procedure [27].

3. Results

3.1. Abundance and Entomophily of Foragers

Globally 8,987 insect specimens were collected in both years (48.9% in 2021 and 51.1% in 2022). They belonged to eight species amongst which two morphospecies of *Amegilla* Friese, 1897 (Hymenoptera: Apidae) were identified. Foragers of *Amegilla calens* Le Peletier. 1841 were stockier (Figure 2A) (2021: 2.2%, entomophily $F_{A.\ calens}$=4.5%, one to seven individuals, 2±0, n=99; 2022: 0.7%, $F_{A.\ calens}$=1.3%, one to five individuals, 1±0, n=42; pooled years: 2.9%, $F_{A.\ calens}$=2.9%, one to seven individuals, 2±0, n=141). Foragers of *Amegilla* sp. were slender (Figure 2B) (2021: 3.8%, entomophily $F_{Amegilla\ sp.}$=7.7%, one to eight individuals, 3±0, n=120; 2022: not recorded). Giving in 2021 6.0% of the pooled species (one to eight individuals, 2±0, n=219), 2.9% of *A. calens* in pooled years (entomophily of *Amegilla* $F_{Amegilla}$=12.2%, one to seven individuals, 2±0, n=141) and 6.7% pooled species in pooled years ($F_{Amegilla}$=6.7%, 2±0, n=261).

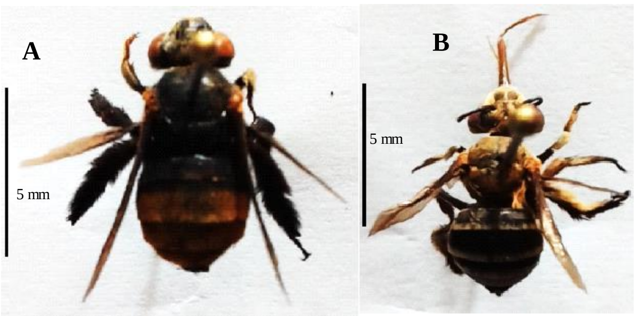


Figure 2. *Illustration of Amagilla Friese, 1897 (Hymenoptera: Apidae) recorded in Dang (North-Cameroon). A: top view of an adult of Amegilla calens Le Peletier, 1841 (Hymenoptera: Apidae); B: top view of an adult of Amegilla sp. Friese, 1897 (Hymenoptera: Apidae).*

In the pooled years, abundances of *Amegilla* sp. varied from one to eight individuals (3±0, n=120) and the entomophily was $F_{Amegilla\ sp.}$=3.8%. Wild bees were abundant in 2021 than 2022 (Fisher's exact test for percentages: p=6.4 x 10-99; Student test for mean values: t=5.994, df=186, p<0.001). Other recorded insects were the sap-sucking *Aphis crassivora* Koch, 1854 (Hemiptera: Aphididae) (17.9%), the honey-bee *Apis mellifera* Linnaeus, 1758 (Hymenoptera: Apidae) (34.9%), *Danaus plexipus* (Linnaeus, 1758) (Lepidoptera: Nymphalidae) (1.0%), *Hypolimnas misippus* (Linnaeus, 1764) (Lepidoptera: Nymphalidae) (0.8%), the big green grasshopper *Tettigonia viridissima* (Linnaeus, 1758) (Orthoptera: Tettigoniidae) (2.7%), and *Xylocopa olivacea* (Fabricius 1778) (Hymenoptera: Apidae) (5.6%).

3.2. Foraging Rhythm of Activity

In the pooled species, foragers began activity around 6 a.m. and stopped it before noon, with a peak of activity between 8 and 9 a.m. (Figure 3A). *A. calens* showed a daily activity rhythm similar to the pooled species while in *Amegilla* sp., the peak of activity was noted in 10 to 11 a.m. time slot (Figure 3B). Occurrences of *Amegilla* sp. recorded in the 6 to 7 a.m. time slot was low in 2021 than 2022 (Fisher-Freeman-Halton test: df=2; $p=6.7\times10^{-5}$) and it was the same in the 8 to 9 a.m. time slot (Fisher-Freeman-Halton test: df=2; $p=1.4\times10^{-4}$). The difference was not significant in the 10 to 11 a.m. time slot (Fisher-Freeman-Halton test: df=2; p=0.980) (Figure 3B).

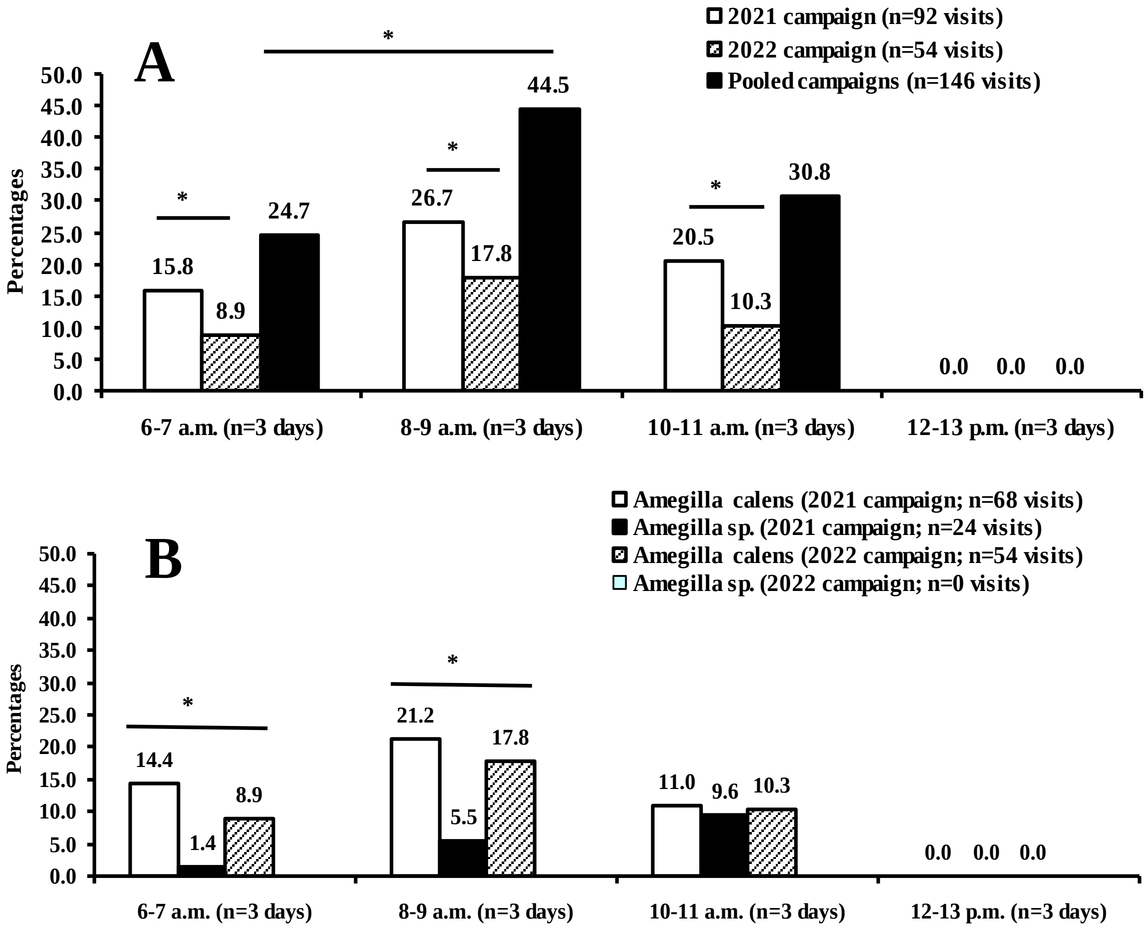


Figure 3. *Daily activity rhythm of* Amegilla *on cowpea flowers at Dang (Adamaoua Region, North-Cameroon) in 2021 and 2022. A: overall daily activity rhythm of the pooled species showing the peak of activity in 8-9 a.m. time slot; B: daily activity rhythm of* Amegilla calens *and* Amegilla *sp. foragers during each campaign.*

3.3. Abundance on 1,000 Blooming Flowers

A total of 1,007 essays were set up (402 *A. calens* in 2021, 252 *Amegilla* sp. in 2021; 654 pooled species in 2021, 353 *A. calens* in 2022, and 755 *A. calens* in pooled years). The number of foragers recorded in one minute A_1 varied from one to nine (*A. calens* in 2021: 2±0; *Amegilla* sp. in 2021: 4±0; pooled species in 2021: A_1=3±0; *A. calens* in 2022: A_1=3±0; pooled species and years: A_1=3±0). Between species in 2021 A_1 mean index was higher in *Amegilla* sp. than *A. calens* (Student test: t=1.670, df=652, p<0.001). The number of flowers visited in one minute F_1 varied from five to 689 (*A. calens* in 2021: five to 689, F_1=178±8; *Amegilla* sp. in 2021: 24 to 689, F_1=328±13; pooled species in 2021; F_1=236±8; *A. calens* in 2022: F_1=244±10; pooled species and years: F_1=239±6). Between the two species in 2021 F_1 was high in *Amegilla* sp. than *A. calens* (Student test: t=10.216, df=652, p<0.001). The abundance per 1,000 flowers $A_{1,000}$ varied from one to 800 (*A. calens* in 2021: two to 400, $A_{1,000}$=18±1; *Amegilla* sp. in 2021: one to 179, $A_{1,000}$=20±2; pooled species in 2021: one to 400 and $A_{1,000}$=19±1, *A. calens* in 2022: one to 800 and $A_{1,000}$=29±5; pooled species in pooled years: $A_{1,000}$=22±2). Between the two species in 2021 the mean value of $A_{1,000}$ was not significant (Student test: t=0.968, df=652, p=0.333). Making A_1=2±0, F_1=209±7, $A_{1,000}$=23±2 for *A. calens* in the pooled years, A_1=3±2, F_1=239±6 and $A_{1,000}$=22±2 for the pooled species in the pooled years, A_1 values were in average in 2021, significantly low in *A. calens*, high in *Amegilla* sp. while in 2022 they were intermediate between the two extremes in *A. calens* (ANOVA: $F_{(2; 1,004)}=6.381$, $p<0.001$; Student-Newman-Keul test: *A. calens* in 2021 *vs. Amegilla* sp. in 2021: $p=2x10^{-5}$; *A. calens* in 2021 *vs. A. calens* in 2022: $p=1x10^{-5}$; *Amegilla* sp. in 2021 *vs. A. calens* in 2022: $p=1x10^{-5}$). Similar results were noted in F_1 ($F_{(2; 1,004)}=4.950$, $p<0.001$; *A. calens* in 2021 vs. *Amegilla* sp. in 2021: $p=2x10^{-5}$; *A. calens* in 2021 *vs. A. calens* in 2022: $p=1x10^{-5}$; *Amegilla* sp. in 2021 *vs. A. calens* in 2022: $p<0.001$). In 2021, between the two species $A_{1,000}$ variation was significant ($F_{(2; 1,004)}=4.004$, $p=0.019$; *A. calens* in 2021 *vs. Amegilla* sp. in 2021: $p=0.651$; *A. calens* in 2021 *vs. A. calens* in 2022: $p=0.018$; *Amegilla* sp. in 2021 *vs. A. calens* in 2022: $p=0.049$).

3.4. Foraging Rate in Five Consecutive Days

In five consecutive days, 598 visits were recorded (89.8% in 2021 and 10.2% in 2022). In both years, occurrences increased in the two first days, reaching the peak in the 3rd day and then declined until it stopped in the 5th day (Figure 4A). Between the five days, differences in activity were significant in 2021 except between the 1st and 4th day (Figure 4A).

In 2022, not significant differences were noted between the 1st and 2nd day, the 1st and 4th day, the 2nd and 3rd or 4th day, and between the 4th and 5th day (Figure 4A). For both years, the differences were significant except between the 1st and the 2nd or 4th day (Figure 4A). For *A. calens*, on each day, foragers were more active in 2021 than 2022 (Figure 4B). In 2021 *A. calens* foragers showed no significant difference between the 1st and 4th day, and between the 2nd and 3rd day (Figure 4B).

In 2022, their behavior was similarly to the situation recorded in the pooled years and pooled species (Figure 4A and 4C). Not significant differences were noted between the 1st and 2nd or 4th day, between the 2nd and 3rd or 4th day, between the 4th and 5th day. In the pooled years, the difference was not significant between the 1st and 2nd or 4th day (Figure 4B). *Amegilla* sp., showed in 2021 no significant difference between the 1st and 2nd or 4th day (Figure 4C).

3.5. Foraging Duration and Speed

In the pooled years, collected only nectar from flowers in one to nine seconds (3.8±0.1, n=1,292). The duration was high in *A. calens* (one to nine seconds; 4.3±0.1, n=931) than *Amegilla* sp. (one to eight seconds; 2.7±0.1, n=961) (Student test: $t=12.671$; $df=1,290$; $p<0.001$).

In 2021, the duration varied from one to eight seconds (3.1±0.1, n=403). In *Amegilla* sp. it was 2.7±0.1 (n=361) in 2021, making a global duration of 2.9±0.1 (n=764).

In 2022, the duration noted in *A. calens* varied from one to nine seconds (5.2±0.1, n=528). It was higher in 2022 than 2021 (Student-Newman-Keuls test: $p<0.001$). In pooled years, flowers F_i visited in 60 seconds (mean delay: $d_i=16.4\pm0.5$ seconds, n=778) varied from one to three ($F_i=1\pm0$, n=778). Foraging speed V_b varied from one to 24 flowers per minute (8±0, n=778). The overall flowers visited by *A. calens* in three to 60 seconds ($d_i=16.2\pm0.5$, n=563) varied from one to three ($F_i=1\pm0$, n=563) and the foraging speed V_b varied from one to 24 flowers per minute ($V_b=8\pm0$; n=563).

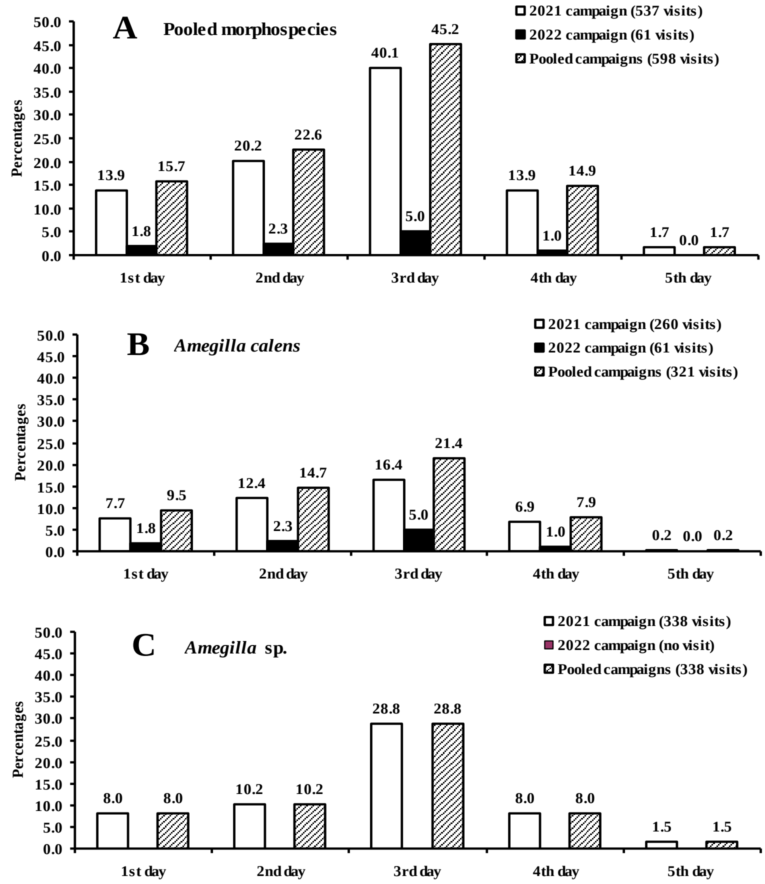
In 2021, *A. calens* visited in $d_i=16.4\pm0.7$ seconds (n=343), one to three flowers (1±0, n=343). The foraging speed varied from one to 24 flowers per minute ($V_b=8\pm0$, n=343). *Amegilla* sp. visited in $d_i=17.0\pm0.9$ seconds (n=215) one to three flowers ($F_i=1\pm0$, n=215). The foraging speed V_b varied from one to 24 flowers per minute ($V_b=8\pm0$, n=215).

In 2022, *A. calens* visited in three to 60 seconds ($d_i=15.8\pm0.8$, n=220) one to three flowers ($F_i=1\pm0$, n=220) and the foraging speed varied from one to 24 flowers per minute ($V_b=8\pm0$, n=220).

3.6. Effect of the Leaves Extracts

Parastar inhibited the foraging visits in the pooled years (Figure 5A) and in the pooled species in 2021 (Figure 5B) compared to untreated plots. Plant extracts were between the two extremes. Effect of the plant extracts was little accentuated in 2022 (Figure 5C). In plant extracts plots, inhibition was less accentuated than in Parastar plots. The strongest inhibition was in plots treated with 30% *Ti diversifolia* (Td30) and the lowest inhibition was in plots treated with 30% *E. camaldulensis* (Ec30). Plots treated with 10% aqueous leaves extract of *Ca. procera* (Cp10) or 30% aqueous leaves extract of *Ca. procera* (Cp30) or even 20% aqueous leaves extract of *Ti. diversifolia* (Td20) showed comparable effects. Between the two years, variations in the occurrences of the pooled bees and of *A. calens* foragers were significant except in Parastar plots (Figure 5).

In the pooled years and the pooled bees, occurrences in the treated plots were low compared to untreated plots except comparisons to plots treated with 10% aqueous leaves extract of *E. camaldulensis* (Ec10) or Ec30 plots (Figure 5A; Table 1A upper part matrix). Occurrences in the Parastar plots were low than the records in plots treated with plant extracts (Figure 5A; Table 1A upper part matrix). Cp10 was not different from other treated plots except when compared to Ec30 plots (Figure 5A; Table 1A upper part matrix). Combinations between other treated plots were not significant except between Ec30 and Td30 (Figure 5A; Table 1A upper part matrix).



Fisher's exact test: p-value

	1^{st} day	2^{nd} day	3^{rd} day	4^{th} day	5^{th} day
2021 *vs.* 2022: *A. calens*:	p=2x10^{-6} *	p=1x10^{-11} *	p=2x10^{-10} *	p=1x10^{-7} *	p=1.00 ns

Pairwise comparison using the Bonferroni correction procedure for the pooled morphospecies: α' (p-value):

	2021 campaign	2022 campaign	Pooled campaigns
1^{st} day *vs.* 2^{nd} day	0.025 (4x10^{-3}) *	0.050 (0.687) ns	0.025 (0.003) ns
1^{st} day *vs.* 3^{rd} day	0.006 (6x10^{-25}) *	0.009 (0.004) *	0.007 (6x10^{-29}) *

Pairwise comparison using the Bonferroni correction procedure for the pooled morphospecies: α' (p-value):

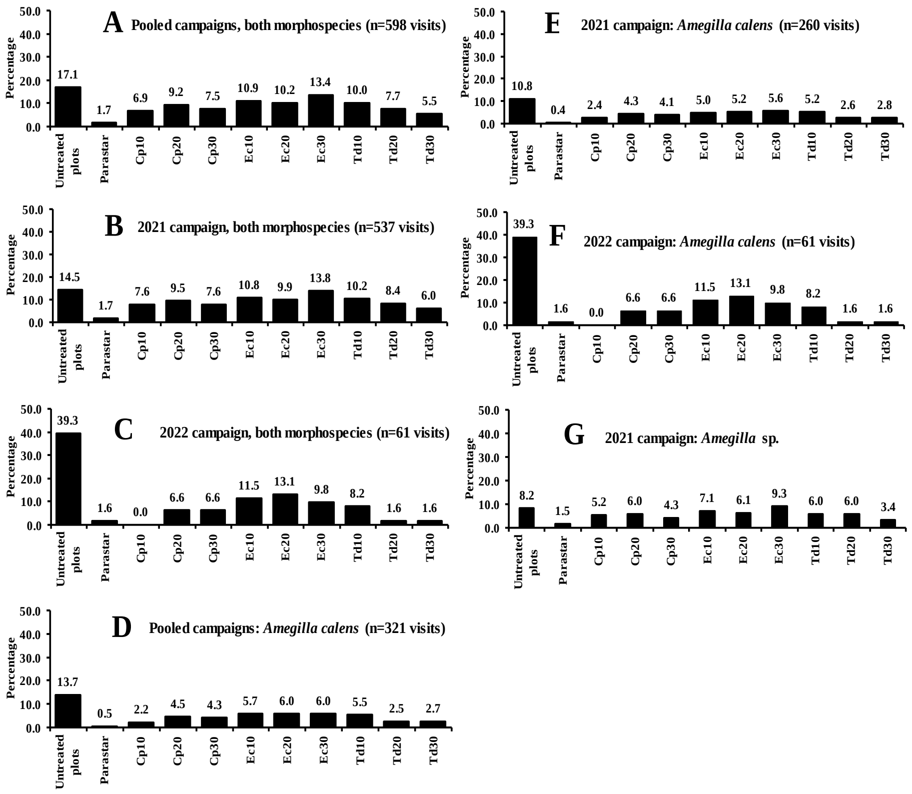
	2021 campaign	2022 campaign	Pooled campaigns
1^{st} day *vs.* 4^{th} day	1.00 (0.050) ns	0.025 (0.329) ns	0.050 (0.748) ns
1^{st} day *vs.* 5^{th} day	0.009 (2x10^{-16}) *	0.007 (9x10^{-4}) *	0.009 (1x10^{-19}) *
2^{nd} day *vs.* 3^{rd} day	0.013 (7x10^{-14}) *	0.010 (0.020) ns	0.013 (2x10^{-16}) *
2^{nd} day *vs.* 4^{th} day	0.017 (4x10^{-3}) *	0.017 (0.112) ns	0.017 (0.001) *
2^{nd} day *vs.* 5^{th} day	0.006 (7x10^{-28}) *	0.006 (1x10^{-4}) *	0.006 (2x10^{-32}) *
3^{rd} day *vs.* 4^{th} day	0.007 (6x10^{-25}) *	0.006 (6x10^{-5}) *	0.006 (7x10^{-31}) *
3^{rd} day *vs.* 5^{th} day	0.005 (2x10^{-70}) *	0.005 (2x10^{-9}) *	0.005 (5x10^{-83}) *
4^{th} day *vs.* 5^{th} day	0.010 (2x10^{-16}) *	0.013 (0.031) ns	0.010 (3x10^{-18}) *

Pairwise comparison using the Bonferroni correction procedure: α' (p-value):

	A. calens		*Amegilla* sp.	
	2021 campaign	2022 campaign	Pooled campaigns	2021 campaign
1^{st} day *vs.* 2^{nd} day	0.017 (0.009) *	0.050 (0.687) ns	0.025 (0.008) *	0.025 (0.228) ns
1^{st} day *vs.* 3^{rd} day	0.010 (5x10^{-6}) *	0.009 (0.004) *	0.010 (2x10^{-4}) *	0.006 (5x10^{-21}) *
1st day *vs.* 4^{th} day	0.050 (0.656) ns	0.025 (0.329) ns	0.050 (0.356) ns	0.050 (1.00) ns
1st day *vs.* 5^{th} day	0.006 (3x10^{-13}) *	0.007 (9x10^{-7}) *	0.006 (1x10^{-16}) *	0.010 (7x10^{-8}) *
2^{nd} day *vs.* 3^{rd} day	0.025 (0.058) ns	0.010 (0.020) ns	0.017 (0.003) *	0.007 (3x10^{-16}) *
2^{nd} day *vs.* 4^{th} day	0.013 (0.002) *	0.017 (0.112) ns	0.013 (2x10^{-4}) *	0.017 (0.228) ns
2^{nd} day *vs.* 5^{th} day	0.006 (4x10^{-22}) *	0.006 (1x10^{-4}) *	0.006 (1x10^{-26}) *	0.009 (4x10^{-11}) *
3^{rd} day *vs.* 4^{th} day	0.009 (3x10^{-7}) *	0.006 (6x10^{-5}) *	0.009 (3x10^{-11}) *	0.006 (5x10^{-21}) *
3^{rd} day *vs.* 5^{th} day	0.005 (5x10^{-30}) *	0.005 (1.3x10^{-9}) *	0.005 (2x10^{-40}) *	0.005 (7x10^{-46}) *
4^{th} day *vs.* 5^{th} day	0.007 (1x10^{-11}) *	0.013 (0.031) ns	0.007 (1x10^{-13}) *	0.013 (8x10^{-8}) *

ns: not significant difference (p≥α=0.05); * significant difference (p<α or p<α'): α': Bonferroni corrected significance level.

Figure 4. *Activity rhythm of* Amegilla *in five consecutive days from the first day of the flower blooming.*



2021 vs. 2022: Fisher's exact test

	Pooled	*A. calens*		Pooled	*A. calens*		Pooled	*A. calens*
Untreated:	$p=2.0x10^{-8}$ *	$p=1.3x10^{-4}$ *	Cp30:	$p=5.2x10^{-9}$ *	$p=4.7x10^{-4}$ *	Td10:	$p=3.5x10^{-12}$ *	$p=5.3x10^{-5}$ *
Parastar:	p=0.021 ns	p=1.00 ns	Ec10:	$p=1.4x10^{-11}$ *	$p=6.9x10^{-4}$ *	Td20:	$p=5.9x10^{-13}$ *	$p=9.1x10^{-4}$ *
Cp10:	$p=4.5x10^{-13}$ *	$p=2.3x10^{-4}$ *	Ec20:	$p=1.2x10^{-9}$ *	p=0.001 *	Td30:	$p=5.3x10^{-9}$ *	$p=4.8x10^{-4}$ *
Cp20:	$p=7.9x10^{-12}$ *	$p=2.7x10^{-4}$ *	Ec30:	$p=7.0x10^{-17}$ *	$p=5.5x10^{-5}$ *	Pooled:	$p=3.2x10^{-190}$ *	$p=8.2x10^{-6}$ *

ns: not significant; * significant (p-value<α or p-value<α'): α': Bonferroni corrected significance level. Significant differences are in bold.

Figure 5*. Effect of the chemical treatments on the visiting rate of the cowpea flowers at Dang locality (Adamaoua Region, North-Cameroon) in 2021 and 2022. Parastar: synthetic insecticide (mixture of 20 $g.l^{-1}$ of imidacloprid and 20 $g.l^{-1}$ of lamda-cyhalothrin, 1 p.c..ha^{-1}); Cp10, Cp20 and Cp30: 10%, 20% and 30% respectively of aqueous leaves extract of* Calotropis procera *(Aiton) Aiton, 1811 (Gentianales: Apocynaceae); Ec10, Ec20 and Ec30: 10%, 20% and 30% respectively of* Eucalyptus camaldulensis *Dehnh., 1832 (Myrtales: Myrtaceae); Td10, Td20 and Td30: 10%, 20% and 30% respectively of the aqueous leaves extract of* Tithonia diversifolia *(Hemsley) Gray, 1883 (Asterales: Asteraceae).*

Table 1*. Pairwise comparisons of the occurrences presented in Figure 5.*

	Aqueous leaves extract: α' (p-value)										
	Unt.	**Para**	**Cp10**	**Cp20**	**Cp30**	**Ec10**	**Ec20**	**Ec30**	**Td10**	**Td20**	**Td30**
A. Pooled species in the pooled years (upper part matrix); pooled species in 2021 (lower part matrix)											
Unt.		0.001 (10^{-21})*	0.001 (10^{-7})*	0.001 (10^{-4})*	0.001 (10^{-6})*	0.002 (0.003)ns	0.001 (10^{-3})*	0.002 (0.09)ns	0.001 (10^{-3})*	0.001 (10^{-6})*	0.001 (10^{-9})*
Para.	0.001 (10^{-14})*		0.001 (10^{-7})*	0.001 (10^{-8})*	0.001 (10^{-5})*	0.001 (10^{-9})*	0.001 (10^{-9})*	0.001 (10^{-9})*	0.001 (10^{-9})*	0.001 (10^{-6})*	0.001 (10^{-3})*
Cp10	0.001 (0.001)ns	0.001 $(4x10^{-6})$*		0.003 (0.17)ns	0.013 (0.74)ns	0.002 (0.019)ns	0.002 (0.049)ns	0.001 $(2x10^{-4})$*	0.002 (0.061)ns	0.007 (0.656)ns	0.005 (0.40)ns
Cp20	0.001 (0.02) ns	0.001 (10^{-8})*	0.003 (0.329)ns		0.004 (0.35)ns	0.005 (0.39)ns	0.006 (0.63)ns	0.002 (0.03)ns	0.009 (0.70)ns	0.006 (0.41)ns	0.002 (0.02)ns
Cp30	0.001 (0.001)ns	0.001 (4x10-6)*	0.050 (1.00)ns	0.003 (0.33)ns		0.002 (0.057)ns	0.003 (0.127)ns	0.001 (0.001)ns	0.003 (0.152)ns	0.025 (1.00)ns	0.004 (0.197)ns

Table 1. *Continued.*

			Aqueous leaves extract: α' (p-value)								
	Unt.	**Para**	**Cp10**	**Cp20**	**Cp30**	**Ec10**	**Ec20**	**Ec30**	**Td10**	**Td20**	**Td30**
A. Pooled species in the pooled years (upper part matrix); pooled species in 2021 (lower part matrix)											
Ec10	0.002 (0.08)ns	0.001 (10^{-9})*	0.002 (0.09)ns	0.005 (0.55)ns	0.002 (0.09)ns		0.017 (0.78)ns	0.004 (0.22)ns	0.010 (0.71)ns	0.002 (0.07)ns	0.001 (0.001)ns
Ec20	0.002 (0.03)ns	0.001 (10^{-8})*	0.003 (0.24)ns	0.017 (0.92)ns	0.003 (0.24)ns	0.006 (0.69)ns		0.002 (0.11)ns	0.050 (1.00)ns	0.003 (0.16)ns	0.002 (0.004)ns
Ec30	0.010 (0.80)ns	0.001 (10^{-14})*	0.001 (0.002)ns	0.002 (0.04)ns	0.001 (0.002)ns	0.002 (0.17)ns	0.002 (0.06)ns		0.002 (0.09)ns	0.002 (0.002)ns	0.001 (10^{-5})*
Td10	0.002 (0.04)ns	0.001 (10^{-9})*	0.002 (0.17)ns	0.009 (0.76)ns	0.002 (0.17)ns	0.013 (0.84)ns	0.025 (0.92)ns	0.002 (0.09)ns		0.003 (0.19)ns	0.002 (0.01)ns
Td20	0.001 (0.002)ns	0.001 $(4x10^{-7})$*	0.006 (0.74)ns	0.005 (0.60)ns	0.007 (0.74)ns	0.003 (0.22)ns	0.004 (0.46)ns	0.001 (0.007)ns	0.004 (0.35)ns		0.003 (0.16)ns
Td30	0.001 (10^{-5})*	0.001 $(3x10^{-4})$*	0.003 (0.33)ns	0.002 (0.04)ns	0.004 (0.33)ns	0.001 (0.01)ns	0.002 (0.02)ns	0.001 (10^{-4})*	0.001 (0.01)ns	0.002 (0.16)ns	
B. Pooled species in 2022 (upper matrix); *A. calens* in the pooled years (lower matrix)											
Unt.		0.001 (10^{-11})*	0.001 (10^{-12})*	0.001 (10^{-8})*	0.001 (10^{-8})*	0.001 (10^{-6})*	0.001 (10^{-6})*	0.001 (10^{-7})*	0.001 (10^{-7})*	0.001 (10^{-11})*	0.001 (10^{-11})*
Para.	0.001 (10^{-21})*		0.013 (1.00)ns	0.002 (1.0)ns	0.002 (0.37)ns	0.001 (0.07)ns	0.001 (0.04)ns	0.002 (0.12)ns	0.002 (0.22)ns	0.017 (1.00)ns	0.025 (1.00)ns
Cp10	0.001 (10^{-13})*	0.002 (0.020)ns		0.002 (0.12)ns	0.002 (0.12)ns	0.001 (0.02)ns	0.001 (0.01)ns	0.001 (0.03)ns	0.001 (0.06)ns	0.004 (1.00)ns	0.005 (1.0)ns
Cp20	0.001 (10^{-7})*	0.001 (10^{-5})*	0.002 (0.035)ns		0.005 (1.00)ns	0.003 (0.55)ns	0.002 (0.39)ns	0.003 (0.753)ns	0.006 (1.00)ns	0.002 (0.37)ns	0.002 (0.37)ns
Cp30	0.001 (10^{-8})*	0.001 (10^{-5})*	0.002 (0.049)ns	0.013 (1.0) ns		0.003 (0.55)ns	0.003 (0.39)ns	0.003 (0.753)ns	0.006 (1.00)ns	0.002 (0.37)ns	0.002 (0.37)ns
Ec10	0.001 (10^{-5})*	0.001 (10^{-7})*	0.001 (0.003)ns	0.004 (0.431)ns	0.004 (0.354)ns		0.007 (1.00)ns	0.009 (1.00)ns	0.004 (0.77)ns	0.001 (0.07)ns	0.001 (0.07)ns
Ec20	0.001 (10^{-5})*	0.001 (10^{-7})*	0.001 (0.001)ns	0.003 (0.300)ns	0.003 (0.240)ns	0.009 (0.902)ns		0.004 (0.79)ns	0.003 (0.58)ns	0.001 (0.04)ns	0.001 (0.04)ns
Ec30	0.001 (10^{-5})*	0.001 (10^{-7})*	0.001 (0.001)ns	0.004 (0.30)ns	0.003 (0.24)ns	0.010 (0.90)ns	0.025 (1.0) ns		0.010 (1.0)ns	0.001 (0.12)ns	0.002 (0.12)ns
Td10	0.001 (10^{-5})*	0.001 (10^{-7})*	0.002 (0.004)ns	0.005 (0.51)ns	0.002 (0.111)ns	0.017 (1.0)ns	0.006 (0.80)ns	0.006 (0.80)ns		0.002 (0.22)ns	0.002 (0.22)ns
Td20	0.001 (10^{-12})*	0.002 (0.01)ns	0.007 (0.85)ns	0.002 (0.08)ns	0.003 (0.11)ns	0.002 (0.01)ns	0.001 (0.004)ns	0.001 (0.004)ns	0.002 (0.01)ns		0.050 (1.0)ns
Td30	0.001 (10^{-12})*	0.002 (0.004)ns	0.005 (0.71)ns	0.003 (0.12)ns	0.003 (0.16)ns	0.002 (0.01)ns	0.002 (0.01)ns	0.002 (0.01)ns	0.002 (0.02)ns	0.050 (1.0)ns	
C. *A. calens* in 2021 (upper matrix) and in 2022 (lower matrix)											
Unt.		0.013 (10^{-15})*	0.005 (10^{-7})*	0.006 (10^{-4})*	0.006 (10^{-4})*	0.007 (10^{-3})*	0.009 (0.001)*	0.010 (0.003)*	0.017 (0.001)*	0.025 $(1x10^{-7})$*	0.050 (10^{-6})*
Para.	0.001 (10^{-6})*		0.002 (0.01)ns	0.002 (10^{-5})*	0.003 (10^{-4})*	0.003 (10^{-6})*	0.003 (10^{-6})*	0.003 (10-7)*	0.003 (10^{-6})*	0.003 (0.004)ns	0.004 (0.002)*
Cp10	0.001 (10^{-7})*	0.013 (1.0)ns		0.001 (0.13)ns	0.001 (0.17)ns	0.001 (0.04)ns	0.001 (0.13)ns	0.001 (0.01)ns	0.001 (0.03)ns	0.001 (1.0)ns	0.001 (0.85)ns

Table 1. *Continued.*

	Aqueous leaves extract: α' (p-value)										
	Unt.	**Para**	**Cp10**	**Cp20**	**Cp30**	**Ec10**	**Ec20**	**Ec30**	**Td10**	**Td20**	**Td30**
C. *A. calens* in 2021 (upper matrix) and in 2022 (lower matrix) (Continued)											
Cp20	0.001 (10^{-4})*	0.002 (0.37)ns	0.002 (0.12)ns		0.001 (1.0)ns	0.001 (0.67)ns	0.001 (0.57)ns	0.001 (0.40)ns	0.001 (0.57)ns	0.001 (0.18)ns	0.001 (0.25)ns
Cp30	0.001 (10^{-4})*	0.002 (0.37)ns	0.002 (0.12)ns	0.005 (1.0)ns		0.001 (0.56)ns	0.001 (0.47)ns	0.001 (0.32)ns	0.001 (0.47)ns	0.001 (0.24)ns	0.001 (0.32)ns
Ec10	0.001 (0.003)ns	0.001 (0.07)ns	0.001 (0.02)ns	0.003 (0.55)ns	0.003 (0.55)ns		0.002 (1.0)ns	0.002 (0.79)ns	0.002 (1.0)ns	0.002 (0.06)ns	0.002 (0.08)ns
Ec20	0.001 (0.01)ns	0.001 (0.04)ns	0.001 (0.01)ns	0.002 (0.39)ns	0.003 (0.39)ns	0.007 (1.0)ns		0.002 (0.89)ns	0.002 (1.0)ns	0.002 (0.04)ns	0.002 (0.06)ns
Ec30	0.001 (0.001)ns	0.002 (0.12)ns	0.001 (0.03)ns	0.003 (0.75)ns	0.003 (0.75)ns	0.009 (1.0)ns	0.004 (0.79)ns		0.002 (0.89)ns	0.002 (0.02)ns	0.002 (0.03)ns
Td10	0.001 (10^{-3})*	0.002 (0.22)ns	0.001 (0.06)ns	0.006 (1.0)ns	0.006 (1.0)ns	0.004 (0.77)ns	0.003 (0.58)ns	0.010 (1.0)ns		0.004 (0.040)ns	0.004 (0.06)ns
Td20	0.001 (10^{-6})*	0.017 (1.0)ns	0.004 (1.0)ns	0.002 (0.37)ns	0.002 (0.37)ns	0.001 (0.07)ns	0.001 (0.04)ns	0.001 (0.12)ns	0.002 (0.22)ns		0.005 (1.0)ns
Td30	0.001 (10^{-6})*	0.025 (1.0)ns	0.005 (1.0)ns	0.002 (0.37)ns	0.002 (0.37)ns	0.001 (0.07)ns	0.001 (0.04)ns	0.002 (0.12)ns	0.002 (0.22)ns	0.050 (1.0)ns	
D. *Amegilla* sp. in 2021											
Unt.		0.001 (10^{-6})*	0.002 (0.068)ns	0.002 (0.192)ns	0.001 (0.011)ns	0.004 (0.57)ns	0.002 (0.24)ns	0.004 (0.59)ns	0.002 (0.19)ns	0.002 (0.192)ns	0.001 (10^{-3})*
Para.			0.001 (0.001)ns	0.001 (10^{-4})*	0.001 (0.010)ns	0.001 (10^{-5})*	0.001 (10^{-4})*	0.001 (10^{-8})*	0.001 (10^{-4})*	0.001 ($1x10^{-4}$)*	0.002 (0.07)ns
Cp10				0.006 (0.69)ns	0.004 (0.57)ns	0.002 (0.25)ns	0.005 (0.60)ns	0.001 (0.01)ns	0.006 (0.69)ns	0.007 (0.691)ns	0.002 (0.18)ns
Cp20					0.002 (0.27)ns	0.003 (0.54)ns	0.009 (1.0)ns	0.001 (0.002)ns	0.010 (1.0)ns	0.013 (1.0)ns	0.001 (0.06)ns
Cp30						0.002 (0.07)ns	0.002 (0.22)ns	0.001 (0.002)ns	0.003 (0.27)ns	0.003 (0.269)ns	0.003 (0.53)ns
Ec10							0.005 (0.63)ns	0.002 (0.22)ns	0.003 (0.54)ns	0.003 (0.54)ns	0.001 (0.01)ns
Ec20								0.002 (0.07)ns	0.017 (1.0)ns	0.025 (1.0)ns	0.001 (0.04)ns
Ec30									0.001 (0.05)ns	0.001 (0.05)ns	0.001 (10-4)*
Td10										0.050 (1.0)ns	0.001 (0.06)ns
Td20											0.002 (0.06)ns

Unt.: untreated plots; Para.: Parastar-treated plots (Parastar is a mixture of 20 $g.l^{-1}$ of imidacloprid and 20 $g.l^{-1}$ of lamda-cyhalothrin, l $p.c..ha^{-1}$); Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5; ns: not significant difference; *: significant difference (p-value<0.05 or p-value<α'): α': Bonferroni corrected significance level.

In 2021, pooled *Amegilla* showed a significant difference between the untreated and Parastar plots or Td30 plots, unlike other comparisons (Figure 5B; Table 1A lower part matrix). Parastar plots were different from plots treated with extracts

(Figure 5B; Table 1A lower part matrix). Between plant extracts plots, differences were not significant except between Ec30 and Td30 (Figure 5B; Table 1A lower part matrix).

In 2022, bees showed significant differences between untreated plots and all treated plots. Comparisons between treated plots were not significant (Figure 5C; Table 1B upper part matrix). *A. callens* presented significant differences between untreated plots and treated ones, Parastar plots were different from those treated with plant extracts except when compared to Cp10, Td20 or Td30. Between plots differences were not significant (Figure 5D; Table 1B lower part matrix).

In the case of *A. calens* in 2021, differences were significant between untreated plots and all treated plots (Figure 5E; Table 1C upper part matrix). Parastar plots were different from others except when compared to Cp10 or Td10. Combinations between plant-extracts plots were not significant (Figure 5E; Table 1C upper part matrix). In the case of *A. calens* in 2022, untreated plots were different from treated plots except when compared to plots treated with concentrations of *E. camaldulensis* while comparisons between plots treated with plant extracts (Figure 5F; Table 1C lower part matrix). *Amegila* sp., showed in 2021, no significant difference between untreated plots and treated plots except between Parastar-treated plots or Td30 plots (Figure 5G; Table 1D). Occurrences noted in Parastar plots were different from other treated plots except from Cp10, Cp30 and Td30 plots. Combinations between plant extract plots were not significant except between EC30 and Td30 (Figure 5G; Table 1D).

During the five consecutive days, occurrences of the bees were less than 10.0% of the total collection (Figure 6). Parastar inhibited the visits of foragers (Figure 6A, 6E, 6I, 6M). The pooled occurrences of the two bee species were in each day, high in untreated plots (Figure 6A, 6M) than in Parastar plots (Figure 6A, 6E, 6M), than records in 2021 (Figure 6E) or 2022 (Figure 6I, 6M) except in the 2nd day in 2021 (Figure 6E) and the 5th day in the pooled years (Figure 6E). *Ca. procera* extracts inhibited the visits of the bees but less strongly than the Parastar in 2022. Foragers were no longer recorded in Cp10 plots. They were noted in Cp30 plots (Figure 6B, 6F, 6J). A similar effect was noted in plots treated with *E. camaldulensis* extracts so that in 2022, visits were absent in the 4th day (Figure 6C, 6G, 6K). A similar situation was noted in 2022 in plots treated with *Ti. diversifolia* extracts. Visits were not recorded in the 1st day and the 5th day in plots treated with 20% or 30% extracts (Figure 6D, 6H, 6L). In each day, comparisons were not significant except the case of *Ti. diversifolia* extracts in the 3rd day (Figure 6N). Between the two years, in the 1st day, the differences in the occurrences were significant except in the untreated plots, Parastar plots, Cp30 (Figure 6B, 6F, 6J, 6O), Ec10 or plots treated with 20% aqueous leaves extract of *E. camaldulensis* (Ec20) (Figure 6C, 6G, 6K, 6O) and Td30 (Figure 6D, 6H, 6L, 6O). In the 2nd day, differences were not significant in untreated plots (Figure 6A, 6E, 6I, 6O), in Parastar plots and in Td30 plots (Figure 6D, 6H, 6L, 6O). On the 3rd day, the not significant difference was noted in Parastar plots (Figure 6). On the 4th day, not significant differences were noted in untreated plots, in Cp30 plots and Td30 plots respectively (Figure 6D, 6H, 6L, 6O). On the 5th day, the differences were not significant except in the combined plots (Figure 6).

In the pooled five days, the differences were all significant between the untreated plots and the plots treated with plant extracts (Figure 6). During the five consecutive days, *A. calens* occurrence was in all plots and for each plant extract, less than 5.0% of the overall collection (Figure 7). Parastar inhibited the occurrence of foragers, the differences in occurrence being significant except in the 5th day in 2021, the 1st and 4th day in 2022 (Figure 7A, 7E, 7I). In each day, the effect of the three extract concentrations of each plant was significant in 2021 on the 3rd day for *Ca. procera*, and in the overall data for *Ti. diversifolia* (Figure 7B, 7F, 7J).

In 2022, the significant variation was noted in *Ca. procera* extract in the 3rd day (Figure 7C, 7G, 7J). Between the two years, the significant variation was noted in the 1st day for 10% *Ti. diversifolia* and the pooled plots (Figure 7C, 7G, 7J). In the 2nd day, the variation was significant in the untreated plots, plots treated with 20% aqueous leaves extract of *Ca. procera* (Cp20), Cp30 or Ec30 even or Td20 plots and in the pooled plots (Figure 7D, 7H, 7K). On the 3rd day, the variation was significant only in untreated plots and the pooled plots (Figure 7D, 7H, 7K). In the 4th day, the variation was significant in the plots Td10 and in the pooled plots (Figure 7D, 7H, 7K). On the 5th day, no variation was significant (Figure 7D, 7H, 7K). The pooled data showed significant variations except in the case of the Parastar plots (Figure 7D, 7H, 7K). In the case of *Amegilla* sp., during the two years, the occurrences of *A. calens* were in all plots and each concentration extract, less than 4.0% of the total collection (Figure 8). The inhibition by Parastar was significant except in the 2nd and the 5th days (Figure 8A, 8E). *Ca. procera* and *E. camaldulensis* extracts did not show any significant variation (Figure 8B, 8F). In the case of *Ti diversifolia* extracts, the inhibition variation of the visitation rate was significant in the 2nd day (Figure 8D, 8E). The visit duration was high in 2022 (one to 800 seconds, 29±5, n=353) than 2021 (one to 400 seconds, 19±1, n=654) (Table 2). $A_{1,000}$ index showed no significant variation (ANOVA test: $F_{(10; 643)}$=0.864, p=0.567 for the years and the pooled bees; $F_{(10; 744)}$=0.612, p=0.805 for the pooled years in *A. calens* (Table 2A); $F_{(10; 643)}$=0.864, p=0.567 for the pooled *Amegilla* in 2021 (Table 2B); $F_{(10; 391)}$=1.249, p=0.258 for *A. calens* in 2021 (Table 2C); $F_{(10; 241)}$=1.093, p=0.368 for *Amegilla* sp. in 2021 (Table 2D); $F_{(10; 342)}$=0.525, p=0.872 for *A. calens* in 2022 (Table 2E). Parastar inhibited the visit duration, dropping it from 4±2 seconds (n=158) in untreated plots to 3.3±0.3 seconds (n=77) in Parastar plots. Plots treated with plant extracts presented intermediate values between the extremes. Plant extracts were not different compared to untreated plots. In *Amegilla* sp., the untreated plots were not different from Parastar-treated plots or those treated with plant extracts.

Table 2. *Number of visits of the wild bees on the blooming flowers.*

		A_1			F_1			$A_{1,000}=(A_1/F_1)*1000$		
	n	**Min.**	**Max.**	**Mean±se**	**Min.**	**Max.**	**Mean±se**	**Min.**	**Max.**	**Mean±se**
A. Pooled years and *Amegilla* species										
Untreated	145	1	8	3±0	5	689	222±16	2	800	24±6
Parastar	61	1	7	2±0	5	640	208±22	2	400	25±7
Cp10	109	1	8	3±0	5	689	250±18	1	800	24±7
Cp20	101	1	8	3±0	15	689	256±20	1	179	19±2
Cp30	56	1	8	3±0	15	689	249±28	1	133	**21±3**
Ec10	125	1	9	3±0	5	650	212±16	2	800	28±7
Ec20	117	1	9	2±0	5	689	218±18	1	800	27±7
Ec30	54	1	7	3±0	25	689	251±29	1	100	20±3
Td10	102	1	8	3±0	24	689	261±20	1	179	17±2
Td20	91	1	8	3±0	24	689	286±23	1	87	17±2
Td30	46	1	8	3±0	24	650	222±30	3	42	17±2
Pooled plots	1007	1	9	3±0	5	689	239±6	1	800	22±2
ANOVA		$F_{(10; 996)}$=1.013, p=0.430 ns			$F_{(10; 996)}$=1.463, p=0.148 ns			$F_{(10; 996)}$=5.238, p=0.874 ns		
B. Pooled *Amegilla* in 2021										
Untreated	95	1	8	2±0	15	689	198±18	2	80	17±1
Parastar	37	1	7	2±0	5	630	237±27	2	400	23±11
Cp10	71	1	8	3±0	24	650	238±23	4	179	19±3
Cp20	65	1	7	3±0	15	650	219±24	3	179	21±3
Cp30	36	1	8	3±0	100	689	342±31	1	59	13±2
Ec10	83	1	9	2±0	15	650	211±21	3	179	20±3
Ec20	77	1	9	2±0	15	650	194±21	3	179	22±3
Ec30	35	1	7	3±0	100	689	330±34	1	59	13±2

Table 2. *Continued.*

		A_1			F_1			$A_{1,000}=(A_1/F_1)*1000$		
	n	**Min.**	**Max.**	**Mean±se**	**Min.**	**Max.**	**Mean±se**	**Min.**	**Max.**	**Mean±se**
B. Pooled *Amegilla* in 2021 (Continued)										
Td10	65	1	8	3±0	24	650	241±26	6	179	20±3
Td20	60	1	8	3±0	24	650	255±27	3	87	17±2
Td 30	30	1	8	3±0	35	650	276±42	3	40	14±2
Pooled plots	654	1	9	3±0	5	689	236±8	1	400	19±1
ANOVA		$F_{(10; 643)}$=2.726, p=0.003 *			$F_{(10; 643)}$=3.008, p=0.001 *			$F_{(10; 643)}$=0.864, p=0.567 ns		
C. *Amegilla calens* in 2021										
Untreated	60	1	6	2±0	15	600	119±15	3	80	21±2
Parastar	20	1	6	2±0	5	630	185±29	2	400	32±19

	n	A_1 Min.	Max.	Mean±se	F_1 Min.	Max.	Mean±se	$A_{1,000}=(A_1/F_1)*1000$ Min.	Max.	Mean±se
Cp 10	43	1	6	2±0	48	650	174±23	6	69	16±2
Cp 20	40	1	6	2±0	15	650	168±24	3	69	18±3
Cp 30	22	1	8	4±0	100	689	351±40	2	30	11±1
Ec 10	53	1	6	2±0	15	650	160±22	3	69	19±2
Ec 20	50	1	6	2±0	15	650	155±23	3	69	19±2
Ec 30	22	1	7	3±0	100	650	335±40	4	30	11±1
Td 10	39	1	6	2±0	48	650	160±24	6	69	17±2
Td 20	35	1	6	2±0	48	650	171±27	3	69	16±2
Td 30	18	1	6	2±0	48	650	172±41	3	40	14±2
Pooled plots	402	1	8	2±0	5	689	178±8	2	400	18±1
ANOVA	$F_{(10; 391)}$=6.464, p<0.001 *				$F_{(10; 391)}$=6.147, p<0.001 *			$F_{(10; 391)}$=1.249, p=0.258 ns		
D. *Amegilla* sp. in 2021										
Untreated	35	1	8	3±0	100	689	333±32	2	22	10±1
Parastar	17	1	7	3±0	100	630	299±45	2	35	13±3
Cp 10	28	1	8	4±0	24	650	337±42	4	179	24±7
Cp 20	25	1	7	4±0	24	650	302±43	4	179	25±7
Cp 30	14	1	8	3±1	102	689	326±53	1	59	16±6
Ec 10	30	1	9	3±0	28	650	303±38	4	179	22±6
Ec 20	27	1	9	3±0	24	640	267±39	4	179	28±7
Ec 30	13	1	7	3±1	102	689	322±65	1	59	16±5
Td 10	26	1	8	4±0	24	650	362±45	6	179	25±7
Td 20	25	1	8	5±0	24	650	372±41	6	87	19±3
Td 30	12	1	8	5±1	35	650	431±63	6	29	14±2
Pooled plots	252	1	9	4±0	24	689	328±13	1	179	20±2
ANOVA	$F_{(10; 241)}$=2.680, p=0.004 *				$F_{(10; 241)}$=0.833, p=0.597 ns			$F_{(10; 241)}$=1.093, p=0.368 ns		
E. *Amegilla calens* in 2022										
Untreated	50	1	8	4±0	5	650	267±28	2	800	37±16
Parastar	24	1	6	2±0	25	640	164±37	2	100	28±5

***Table 2**. Continued.*

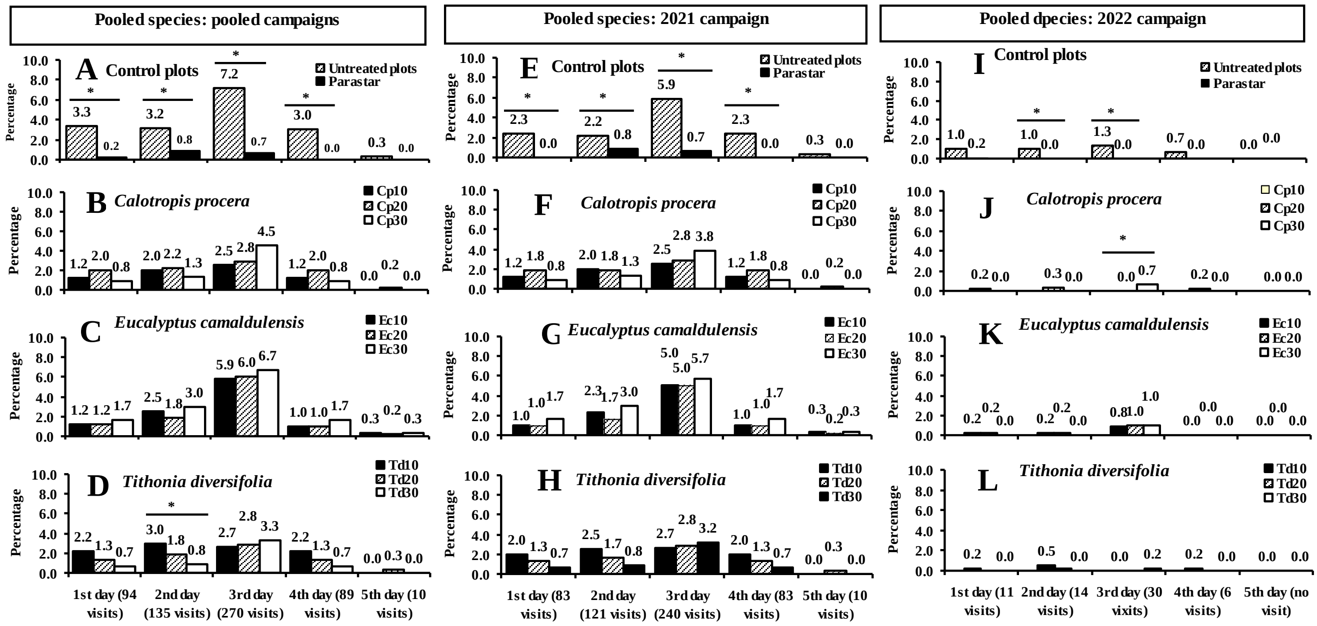
	n	A_1 Min.	Max.	Mean±se	F_1 Min.	Max.	Mean±se	$A_{1,000}=(A_1/F_1)*1000$ Min.	Max.	Mean±se
E. *Amegilla calens* in 2022 (Continued)										
Cp 10	38	1	7	2±0	5	689	273±28	1	800	33±21
Cp 20	36	1	8	3±0	29	689	323±36	1	79	15±3
Cp 30	20	1	6	2±0	15	600	83±28	2	133	35±7
Ec 10	42	1	9	3±0	5	630	214±26	2	800	44±19

	n	A_1 Min.	Max.	Mean±se	F_1 Min.	Max.	Mean±se	$A_{1,000}=(A_1/F_1)*1000$ Min.	Max.	Mean±se
Ec 20	40	1	8	3±0	5	689	264±31	1	800	36±20
Ec 30	19	1	6	2±0	25	600	105±33	2	100	32±6
Td 10	37	1	7	2±0	100	689	296±31	1	36	11±2
Td 20	31	1	8	3±0	29	689	347±41	1	79	17±4
Td 30	16	1	8	2±1	24	300	121±22	7	42	22±3
Pooled plots	353	1	9	3±0	5	689	244±10	1	800	29±5
ANOVA	$F_{(10; 342)}$=2.497, p=0.007 *				$F_{(10; 342)}$=6.020, p<0.001 *			$F_{(10; 342)}$=0.525, p=0.872 ns		

Pairwise comparisons: Student-Newman-Keul test

A_1: pooled *Amegilla* in 2021:	Untreated *vs.* Cp30:	p=0.023 *;	Other comparisons were not significant			
A_1: *A. calens* in 2021:	Untreated *vs.* Cp30:	p=1x10^{-5} *;	Cp20 *vs.* Cp30:	p=4x10^{-5} *;	Cp30 *vs.* Td30:	p=1.6x10^{-4} *
	Untreated *vs.* Ec30:	p=1x10^{-5} *	Cp20 *vs.* Ec30:	p=5.5x10^{-4} *;	Ec 30 *vs.* Ec 10:	p=4.2x10^{-4} *
	Parastar *vs.* Ec30:	p=0.006 *	Cp30 *vs.* Ec10:	p=4x10^{-5} *;	Ec 30 *vs.* Ec 20:	p=3.6x10^{-4} *
	Parastar *vs.* Cp30:	p=6.5x10^{-4} *;	Cp30 *vs.* Ec20:	p=2x10^{-5} *	Ec 30 *vs.* Td 10:	p=6.8x10^{-4} *
	Cp10 *vs.* Cp30:	p=2.1x10^{-4} *;	Cp30 *vs.* Td10:	p=6x10^{-5} *;	Ec 30 *vs.* Td 20:	p=0.001 *
	Cp10 *vs.* Ec30:	p=0.001 *	Cp30 *vs.* Td20:	p=8x10^{-5} *;	Ec 30 *vs.* Td 30:	p=0.002 *
	Other comparisons were not significant					
A_1: *Amegilla* sp. in 2021:	Parastar *vs.* Td20:	p=0.029 *	Other comparisons were not significant			
A_1: *A. calens* in 2022:	Untreated *vs.* Cp10:	p=0.045 *;	Untreated *vs.* Cp30:	p=0.019 *;		
	Other comparisons were not significant					
F_1: pooled *Amegilla* in 2021:	Untreated *vs.* Cp30:	p=0.006 *;	Cp30 *vs.* Ec10:	p=0.021 *	Ec10 *vs.* Ec30:	p=0.047 *
	Untreated *vs.* Ec30:	p=0.016 *	Cp30 *vs.* Ec20:	p= 0.007 *;	Ec20 *vs.* Ec30:	p=0.020 *;
	Cp20 *vs.* Cp30:	p=0.048 *;	Other comparisons were not significant			
F_1: *A. calens* in 2021:	Untreated *vs.* Cp30:	p=1x10^{-5} *;	Cp20 *vs.* Cp30:	p=1.8x10^{-4} *;	Cp30 *vs.* Td30:	p=0.003 *
	Untreated *vs.* Ec30:	p=1x10^{-5} *	Cp20 *vs.* Ec30:	p=6.8x10^{-4} *;	Ec10 vs. Ec30:	p=2.4x10^{-4} *
	Parastar *vs.* Cp30:	p=0.001 *;	Cp30 *vs.* Ec10:	p=5x10^{-5} *;	Ec20 vs. Ec30:	p=2.1x10^{-4} *
	Parastar *vs.* Ec30:	p=0.002 *	Cp30 *vs.* Ec20:	p=4x10^{-5} *	Ec 30 vs. Td 10:	p=4.7x10^{-4} *
	Cp10 *vs.* Cp30:	p=8x10^{-5} *;	Cp30 *vs.* Td10:	p=1.3x10^{-4} *;	Ec 30 vs. Td 20:	p=9.3x10^{-4} *
	Cp10 *vs.* Ec30:	p=2x10^{-4} *	Cp30 *vs.* Td20:	p=2.8x10^{-4} *;	Ec 30 vs. Td 30:	p=0.005 *
	Other comparisons were not significant					
F_1: *A. calens* in 2022:	Untreated *vs.* Cp30:	p=0.015 *;	Cp20 *vs.* Cp30:	p=1.4x10^{-4} *;	Ec10 *vs.* Td20:	p=0.039 *;
	Untreated *vs.* Ec30:	p=0.015 *;	Cp20 *vs.* Ec30:	p=0.001 *;	Ec20 vs. Ec30:	p=0.016 *
	Untreated *vs.* Td30:	p=0.046 *;	Cp20 *vs.* Td30:	p=0.006 *;	Ec20 *vs.* Td30:	p=0.042 *
	Parastar *vs.* Cp20:	p=0.019 *;	Cp30 *vs.* Ec20:	p=0.004 *	Ec 30 vs. Td10:	p=0.006 *
	Parastar *vs.* Td20:	p=0.007 *;	Cp30 *vs.* Td10:	p=0.001 *;	Ec30 vs. Td20:	p=3.0x10^{-4} *
	Cp10 *vs.* Cp30:	p=0.005 *;	Cp30 *vs.* Td20:	p=4.0x10^{-5} *;	Td20 *vs.* Td30:	p=0.002 *
	Cp10 *vs.* Ec30:	p=0.020 *;	Td10 *vs.* Td30:	p=0.025 *;	Other comparisons not significant	

A_1: number of foragers recorded during one minute on the blooming flowers; F_1: number of the blooming flowers visited in one minutes; A_{1000}: visitation rate per 1000 blooming flowers. ns: not significant difference (p≥0.05); * significant difference (p<0.05). Abbreviations Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5.



M. Untreated *vs.* Parastar:	1st day	2nd day	3rd day	4th day	5th day	Global
Pooled species and campaigns:	p=3x10^{-9} *	p=0.006 *	p=2x10^{-9} *	p=7x10^{-6} *	p=0.500 ns	p=7x10^{-19} *
2021 campaign:	p=1x10^{-4} *	p=0.094 ns	p=2x10^{-7} *	p=1x10^{-4} *	p=0.500 ns	p=9x10^{-16} *
2022 campaign:	p=0.124 ns	p=0.031 *	p=0.008 *	p=0.124 ns	-	p=1x10^{-6} *

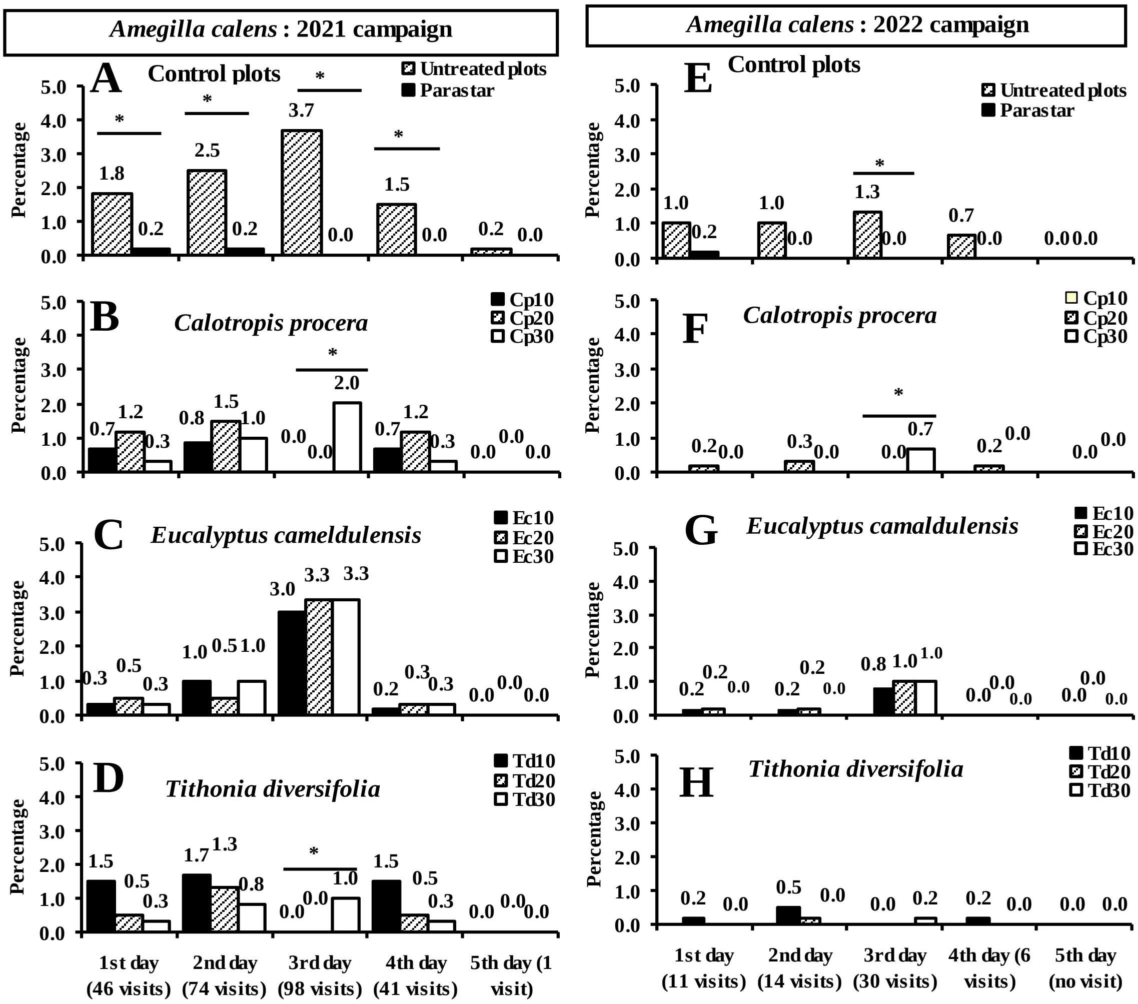
N. Simultaneous comparison of the three occurrences in each day: Fisher-Freeman-Halton test exact p-value (df=2)

Global:	*Ca. procera*:	p=0.248 ns	p=0.535 ns	p=0.124 ns	p=0.248 ns	p=1.00 ns	p=0.305 ns
	E. camaldulensis:	p=0.785 ns	p=0.448 ns	p=0.860 ns	p=0.514 ns	p=1.00 ns	p=0.201 ns
	Ti. diversifolia:	p=0.095 ns	p=0.024 *	p=0.826 ns	p=0.095 ns	p=0.333 ns	p=0.015 *
2021 campaign:	*Ca. procera*	p=0.338 ns	p=0.724 ns	p=0.380 ns	p=0.338 ns	p=1.00 ns	p=0.466 ns
	E. camaldulensis:	p=0.514 ns	p=0.331 ns	p=0.847 ns	p=0.514 ns	p=1.00 ns	p=0.119 ns
	Ti. diversifolia:	p=0.144 ns	p=0.083 ns	p=0.908 ns	p=0.144 ns	p=0.333 ns	p=0.038 *
2022 campaign:	*Ca. procera:*	p=1.00 ns	p=0.199 ns	p=0.020 *	p=1.00 ns	-	p=0.141 ns
	E. camaldulensis:	p=1.00 ns	p=1.00 ns	p=1.00 ns	-	-	p=0.961 ns
	Ti. diversifolia:	p=1.00 ns	p=0.333 ns	p=1.00 ns	p=1.00 ns	-	p=0.231 ns

O. 2021 campaign *vs.* 2022 campaign: Fisher's exact test p-value

Untreated plots	p=0.112 ns	p=0.164 ns	p=3x10^{-5} *	p=1.00 ns	p=0.500 ns	p=2x10^{-8} *	
Parastar treated plots	p=1.00 ns	p=0.062 ns	p=0.124 ns	-	-	p=0.021 *	
Ca. procera:	Cp10:	p=0.015 *	p=5x10^{-4} *	p=6x10^{-5} *	p=0.015 *	-	p=4x10^{-13} *
	Cp20:	p=0.006 *	p=0.022 *	p=1x10^{-5} *	p=0.006 *	p=1.00 ns	p=8x10^{-12} *
	Cp30:	p=0.062 ns	p=0.008 *	p=3x10^{-4} *	p=0.062 ns	-	p=5x10^{-9} *
E. camaldulensis	Ec10:	p=0.124 ns	p=5x10^{-4} *	p=2x10^{-5} *	p=0.031 *	p=0.500 ns	p=1x10^{-11} *
	Ec20:	p=0.124 ns	p=0.011 *	p=5x10^{-5} *	p=0.031 *	p=1.00 ns	p=1x10^{-9} *
	Ec30:	p=0.002 *	p=7x10^{-6} *	p=6x10^{-6} *	p=0.002 *	p=0.500 ns	p=7x10^{-17} *
Ti. diversifolia:	Td10:	p=0.003 *	p=0.007 *	p=3x10^{-5} *	p=0.003 *	-	p=4x10^{-12} *
	Td20:	p=0.008 *	p=0.011 *	p=1x10^{-5} *	p=0.008 *	p=0.500 ns	p=6x10^{-13} *
	Td30:	p=0.124 ns	p=0.062 ns	p=4x10^{-5} *	p=0.124 ns	-	p=5x10^{-9} *
Pooled plots		p=4x10^{-16} *	p=9x10^{-25} *	p=3x10^{-52} *	p=1x10^{-19} *	p=0.002 *	p=3x10^{-180} *

Figure 6. *Effect of the chemical treatments during five first consecutive days of flower blooming on the visiting rate of the cowpea flowers at Dang locality (Adamaoua Region, North-Cameroon) during 2021 and 2022 campaigns. ns: not significant difference ($p\geq0.05$); * significant difference ($p<0.05$). Abbreviations Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5.*



I. Untreated plots vs. Parastar treated-plots: Fisher's exact test p-value

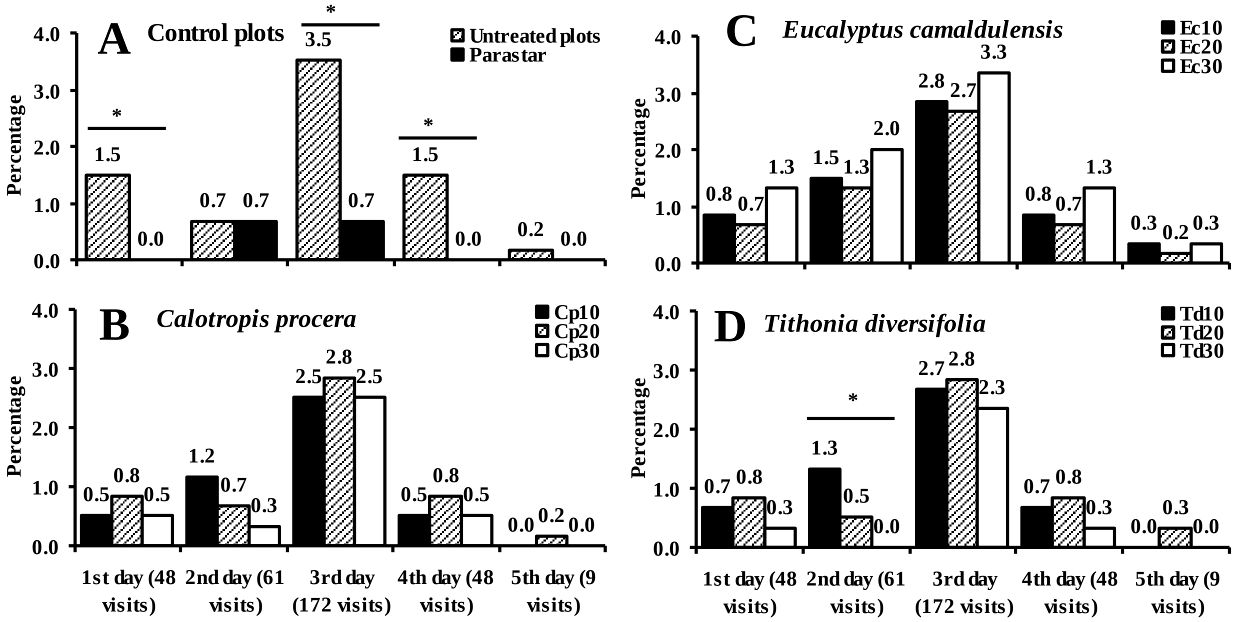
	1st day	2nd day	3rd day	4th day	5th day	Global
Pooled species in 2021:	p=0.006 *	p=5x10^{-4} *	p=4x10^{-7} *	p=0.004 *	p=1.00 ns	p=8x10^{-16} *
Pooled species in 2022:	p=0.124 ns	-	p=0.008 *	p=0.124 ns	-	p=1x10^{-6} *

J. Simultaneous comparison of the three occurrences in each day: Fisher-Freeman-Halton test exact p-value (df=2).

		1st day	2nd day	3rd day	4th day	5th day	Global
2021 campaign:	*Calotropis procera*:	p=0.266 ns	p=0.610 ns	p=5x10^{-6} *	p=0.266 ns	-	p=0.196 ns
	E. camaldulensis:	p=1.00 ns	p=0.587 ns	p=0.957 ns	p=1.00 ns	-	p=0.941 ns
	Ti. diversifolia:	p=0.079 ns	p=0.472 ns	p=0.004 *	p=0.079 ns	-	p=0.045 *
2022 campaign:	*Ca. procera*:	p=1.00 ns	p=0.333 ns	p=0.037 *	p=1.00 ns	-	p=0.141 ns
	E. camaldulensis:	p=1.00 ns	p=1.00 ns	p=1.00 ns	-	-	p=0.961 ns
	Ti. diversifolia:	p=1.00 ns	p=0.333 ns	p=1.00 ns	p=1.00 ns	-	p=0.231 ns

K. 2021 vs. 2022:		1st day	2nd day	3rd day	4th day	5th day	Global
Untreated plots		p=0.329 ns	p=6x10^{-5} *	p=0.015 *	p=0.264 ns	p=1.00 ns	p=1x10^{-4} *
Parastar treated plots		p=1.00 ns	p=1.00 ns	-	-	-	p=1.00 ns
Ca. procera:	Cp10:	p=0.124 ns	p=0.062 ns	-	p=0.124 ns	-	p=2x10^{-4} *
	Cp20:	p=0.069 ns	p=0.021 *	-	p=0.069 ns	-	p=3x10^{-4} *
	Cp30:	p=0.500 ns	p=0.031 *	p=0.075 ns	p=0.500 ns	-	p=5x10^{-4} *
E. camaldulensis:	Ec10:	p=1.00 ns	p=0.124 ns	p=0.010 ns	p=1.00 ns	-	p=7x10^{-4} *
	Ec20:	p=0.624 ns	p=0.624 ns	p=0.009 *	p=0.500 ns	-	p=0.001 *
	Ec30:	p=0.500 ns	p=0.031 *	p=0.009 *	p=0.500 ns	-	p=5x10^{-5} *
Ti. diversifolia:	Td10:	p=0.021 *	p=0.091 ns	-	p=0.021 *	-	p=5x10^{-5} *
	Td20:	p=0.259 ns	p=0.038 *	-	p=0.259 ns	-	p=9x10^{-4} *
	Td30:	p=0.500 ns	p=0.062 ns	p=0.124 ns	p=0.500 ns	-	p=5x10^{-4} *
	Global	p=2x10^{-6} *	p=1x10^{-11} *	p=1x10^{-10} *	p=1x10^{-7} *	p=1.00 ns	p=3x10^{-40} *

Figure 7*. Effect of the chemical treatments during five first consecutive days of flower blooming on the visiting rate of* Amegilla calens *at Dang (Adamaoua Region, North-Cameroon) in 2021 and 2022. ns: not significant difference (p≥0.05); * significant difference (p<0.05). Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5.*



Control plots in the pooled campaigns: Fisher's exact test p-value

E. Untreated plots vs. Parastar treated plots

1st day	2nd day	3rd day	4th day	5th day	Global
p=0.004 *	p=1.00 ns	$p=8x10^{-4}$ *	p=0.004 *	p=1.00 ns	$p=2x10^{-7}$ *

F. Simultaneous comparison of the three occurrences in each day: Fisher-Freeman-Halton test's exact p-value (df=2)

	1st day	2nd day	3rd day	4th day	5th day	Global
Ca. procera:	p=0.803 ns	p=0.266 ns	p=0.948 ns	p=0.803 ns	p=1.00 ns	p=0.488 ns
E. camaldulensis:	p=0.560 ns	p=0.709 ns	p=0.826 ns	p=0.560 ns	p=1.00 ns	p=0.138 ns
Ti. diversifolia:	p=0.646 ns	p=0.009 *	p=0.899 ns	p=0.567 ns	p=0.333 ns	p=0.071 ns

*: significant difference (p<0.05). Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5.

Figure 8. *Effect of the chemical treatments during five first consecutive days of flower blooming on the visiting rate of* Amegilla *sp. on the cowpea flowers at Dang (Adamaoua Region, North-Cameroon) during the 2021 campaign. ns: not significant difference (p≥0.05).*

The Parastar plots were different from Cp10 or Cp20 and Td10. Plots Cp10 or Ec10 were different from Td10 or Td30 plots. The pooled species in the pooled years showed visit durations varying from one to nine seconds (3.8±0.1, n=1292). Pairwise comparisons showed a significant difference only between Parastar plots and Cp20, between Cp20 and Ec30, Td10, Td20 unlike other comparisons (Table 3A, 4A upper part matrix). *A. calens* in the pooled years showed values varying from one to nine seconds (4.3±0.1, n=931) and a significant difference was noted only between Parastar plots and Cp20, between Cp20 and Ec30 or Td10 (Table 3B, 4A lower part matrix). *A. calens* in 2021 showed visit durations varying from one to eight seconds (3.06±0.08, n=403) and pairwise comparisons between the untreated plots and those treated, the differences were not significant except when compared to Parastar plots (Table 3C, 4B upper part matrix). Between Parastar plots and treated plots differences were significant except comparisons to Ec20 and Td20 plots (Table 3C, 4B upper part matrix). The Cp10 plots were different only from the Td10 plots (Table 3C, 4B upper part matrix). Cp20 plots were different from Ec20, Td10 and Td20 (Table 3C, 4B upper part matrix). Other comparisons were non-significant (Table 3C, 4B upper matrix). *Amegilla* sp. in 2021 showed visit durations varying from one to eight seconds (2.66±0.08, n=361). Between the untreated plots and treated ones, the differences were not significant except when compared to Parastar plots (Table 3D, 4B lower part matrix).

In 2022, *A. calens* showed not significant between plots variation (Table 3E), contrary when compare Parastar plots to Cp20, Cp20 and Ec30 (Table 4C upper part matrix). The difference was significant between Parastar plots and Cp10 or Cp20 or Ec10, between Cp20 and Ec30, Td10 or Td20 (Table 4C lower part matrix). Parastar inhibited the speed from 11±1 flowers per minute (n=115) in untreated plots to 6±1 flowers per minute (n=43) in Parastar plots (Table 5A, 6A upper part matrix). Plots treated with plant extracts were intermediate between the two extremes. Cp20 and Td30 were not different from untreated plots. Parastar plots and Cp10 showed a speed inhibition different from *Ti. diversifolia* plots. Cp20 or Cp30 presented a foraging speed reduction different from plots treated with *E. camaldulensis* extracts or Td10. Plots treated with *E. camaldulensis* extracts showed a significant difference compared to *Ti. diversifolia* plots. The reduction of the speed in Td10 was different from Td20 or Td30 plots. *A. calens* in the pooled years showed a not significant difference between Untreated plots and Cp20 or Cp30, Td20 or Td30 (Table 4B, 5A lower part matrix). Not significant differences were noted between Parastar plots and Cp10, Ec10, Ec20 or Ec30. Cp10 plots were different from Cp20 or Cp30, and from *Ti diversifolia* treated plots. Effect of *E. camaldulensis* was significant compared to Cp20 or Cp30. Td10 were different from Cp30 and concentrations of *E. camaldulensis*. Td20 showed a foraging speed different from *E. camaldulensis* extracts plots. Td30 plots presented a foraging speed different from *E. camaldulensis* plots or Td10.

Table 3. Mean duration of the visits (in seconds) of the wild bees on the blooming cowpea flowers.

	A. Pooled species in the pooled years				B. *Amegilla calens* in the pooled years				C. *A. calens* in 2021			
Plots	n	Min.	Max.	Mean ±se	n	Min.	Max.	Mean ±se	n	Min.	Max.	Mean ±se
Unt.	158	1.0	9.0	4.0 ±0.2	109	1.0	9.0	4.5 ±0.2	44	1.0	8.0	3.1 ±0.3
Para.	77	1.0	9.0	3.3 ±0.3	67	1.0	9.0	3.6 ±0.3	24	1.0	3.0	1.5 ±0.1
Cp10	132	1.0	9.0	4.1 ±0.2	96	1.0	9.0	4.4 ±0.2	44	2.0	8.0	3.6 ±0.2
Cp20	137	1.0	9.0	4.5 ±0.2	96	1.0	9.0	5.1 ±0.2	41	1.0	6.0	3.8 ±0.2
Cp30	90	1.0	9.0	3.8 ±0.2	67	1.0	9.0	4.2 ±0.3	35	2.0	7.0	3.5 ±0.3
Ec10	142	1.0	9.0	4.1 ±0.2	100	1.0	9.0	4.5 ±0.2	43	1.0	6.0	3.3 ±0.3
Ec20	144	1.0	9.0	3.7 ±0.2	98	1.0	9.0	4.4 ±0.3	40	1.0	7.0	2.5 ±0.3
Ec30	102	1.0	8.0	3.4 ±0.2	74	1.0	8.0	3.9 ±0.2	34	1.0	7.0	3.0 ±0.3
Td10	105	1.0	9.0	3.4 ±0.2	75	1.0	9.0	4.0 ±0.3	30	1.0	7.0	2.5 ±0.3
Td20	133	1.0	9.0	3.6 ±0.2	93	1.0	9.0	4.1 ±0.2	41	1.0	5.0	2.5 ±0.2
Td30	72	1.0	8.0	3.7 ±0.3	56	1.0	8.0	4.3 ±0.3	27	2.0	8.0	3.5 ±0.3
Pooled plots	1,292	1.0	9.0	3.8 ±0.1	931	1.0	9.0	4.30 ±0.07	403	1.0	8.0	3.06 ±0.08
ANOVA	$F_{(10; 1281)}$=3.043, p=8x10^{-5} *				$F_{(10; 920)}$=2.534, p=0.005 *				$F_{(10; 392)}$=5.708, p<0.001 *			
Unt. vs. Para	Student test: t=2.326, df=233, p=0.021*				Student test: t=2.731, df=174, p=0.007 *				Student test: t=4.205, df=66, p=8.0x10^{-5} *			

	D. *Amegilla* sp. in 2021				E. *A. calens* in 2022			
Plots	n	Min.	Max.	Mean ±se	n	Min.	Max.	Mean ±se
Unt.	49	1.0	8.0	2.8 ±0.2	65	1.0	9.0	5.5 ±0.3
Para.	10	1.0	2.0	1.3 ±0.2	43	2.0	9.0	4.7 ±0.3
Cp10	36	2.0	8.0	3.4 ±0.3	52	1.0	9.0	5.0 ±0.3
Cp20	41	1.0	6.0	3.1 ±0.2	55	2.0	9.0	6.0 ±0.2
Cp30	23	2.0	7.0	2.7 ±0.3	32	1.0	9.0	5.0 ±0.4
Ec10	42	1.0	6.0	3.2 ±0.3	57	2.0	9.0	5.3 ±0.2

Table 3. Continued.

	D. *Amegilla* sp. in 2021				**E. *A. calens* in 2022**			
Plots	**n**	**Min.**	**Max.**	**Mean ±se**	**n**	**Min.**	**Max.**	**Mean ±se**
Ec20	46	1.0	7.0	2.4 ±0.2	58	1.0	9.0	5.6 ±0.3
Ec30	28	1.0	7.0	2.3 ±0.3	40	1.0	8.0	4.6 ±0.4
Td10	30	1.0	5.0	2.1 ±0.2	45	1.0	9.0	4.9 ±0.3

	D. *Amegilla* sp. in 2021				E. *A. calens* in 2022			
Plots	**n**	**Min.**	**Max.**	**Mean±se**	**n**	**Min.**	**Max.**	**Mean±se**
Td20	40	1.0	5.0	2.4±0.2	52	1.0	9.0	5.3±0.3
Td30	16	1.0	4.0	1.8±0.2	29	1.0	8.0	5.0±0.4
Pooled plots	361	1.0	8.0	2.66±0.08	528	1.0	9.0	5.2±0.1
ANOVA	$F_{(10; 350)}$=3.956, p=4x10^{-5} *				$F_{(10; 517)}$=1.786, p=0.060 ns			
Unt. vs. Para.	Student test: t=2.856, df=57, p=0.006 *				Student test: t=1.882, df=106, p=0.063 ns			

Unt: Untreated; ns: not significant (p≥0.05); * significant (p<0.05). Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are in Figure 5.

Table 4. *Student-Newman-Keul pairwise multiple comparisons of the mean values presented in Table 3.*

			Aqueous leaves extract: p-value								
	Unt.	**Para**	**Cp10**	**Cp20**	**Cp30**	**Ec10**	**Ec20**	**Ec30**	**Td10**	**Td20**	**Td30**
A. Pooled species in the pooled years (upper part matrix); *Amegilla calens* in the pooled years (lower part matrix)											
Unt.			0.899ns	0.249 ns	0.591ns	0.739ns	0.549ns	0.339ns	0.392ns	0.515ns	0.786ns
Parastar			0.184ns	0.006 *	0.630ns	0.180ns	0.667ns	0.867ns	0.615ns	0.736ns	0.745ns
Cp10	0.901ns	0.281ns		0.177 ns	0.806ns	0.913ns	0.609ns	0.279ns	0.309ns	0.461ns	0.806ns
Cp20	0.091ns	0.001 *	0.929ns		0.213ns	0.298ns	0.054ns	0.010 *	0.010 *	0.022 *	0.198ns
Cp30	0.959ns	0.413ns	0.972ns	0.240ns		0.695ns	0.713ns	0.709ns	0.791ns	0.837ns	0.919ns
Ec10	0.791ns	0.234ns	0.866ns	0.135ns	0.976ns		0.535ns	0.264ns	0.299ns	0.431ns	0.760ns
Ec20	0.952ns	0.268ns	0.166ns	0.195ns	0.930ns	0.964ns		0.726ns	0.828ns	0.852ns	0.930ns
Ec30	0.588ns	0.410ns	0.750ns	0.022 *	0.776ns	0.711ns	0.717ns		0.992ns	0.597ns	0.708ns
Td10	0.686ns	0.550ns	0.806ns	0.038 *	0.740ns	0.785ns	0.760ns	0.824ns		0.849ns	0.852ns
Td20	0.815ns	0.453ns	0.890ns	0.061ns	0.693ns	0.884ns	0.838ns	0.806ns	0.694ns		0.722ns
Td30	0.940ns	0.543ns	0.921ns	0.259ns	0.978ns	0.951ns	0.755ns	0.883ns	0.884ns	0.914ns	
B. *A. calens* in 2021 (upper part matrix); *Amegilla* sp. in 2021 (lower part matrix)											
Unt.			0.566ns	0.408ns	0.712ns	0.574ns	0.384ns	0.765ns	0.366ns	0.183ns	0.641ns
Parastar			2x10^{-5}*	2x10^{-5} *	5x10^{-5}*	1x10^{-4}*	0.011ns	0.002*	0.043 *	0.050ns	2x10^{-4} *
Cp10	0.340ns	0.005 *		0.672ns	0.731ns	0.792ns	0.033ns	0.536ns	0.060ns	0.021 *	0.914ns
Cp20	0.371ns	0.018 *	0.718ns		0.742ns	0.674ns	0.012 *	0.375ns	0.026 *	0.008 *	0.869ns
Cp30	0.748ns	0.167ns	0.448ns	0.553ns		0.858ns	0.116ns	0.702ns	0.155ns	0.074ns	0.935ns
Ec10	0.411ns	0.010 *	0.664ns	0.721ns	0.534ns		0.185ns	0.689ns	0.211ns	0.097ns	0.686ns
Ec20	0.504ns	0.218ns	0.053ns	0.175ns	0.702ns	0.099ns		0.513ns	0.982ns	0.999ns	0.179ns
Ec30	0.558ns	0.273ns	0.079ns	0.225ns	0.761ns	0.138ns	0.767ns		0.417ns	0.176ns	0.679ns
Td10	0.353ns	0.275ns	0.024 *	0.098ns	0.650ns	0.048 *	0.740ns	0.697ns		0.993ns	0.203ns
Td20	0.432ns	0.267ns	0.067ns	0.175ns	0.487ns	0.114ns	0.917ns	0.923ns	0.849ns		0.108ns
Td30	0.223ns	0.392ns	0.019 *	0.066ns	0.450ns	0.036 *	0.536ns	0.567ns	0.486ns	0.632ns	

Unt: Untreated; ns: not significant (p≥0.05); * significant (p<0.05). Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5.

Table 5. Foraging speed (number of the visited flowers per minute) of the wild bees foragers.

Plots	n	F_i Min.-Max. (Mean±se)	d_i Min.-Max. (Mean±se)	V_b Min.-Max. (Mean±se)	n	F_i Min.-Max. (Mean±se)	d_i Min.-Max. (Mean±se)	V_b Min.-Max. (Mean±se)
	A. *Amegilla calens* in the pooled years				B. *A. calens* in 2021			
Untreated	83	1-2 (1±0)	5.0-33.0 (9.5±0.7)	2-24 (11±1)	49	1-2 (1±0)	5.0-33.0 (9.2±0.9)	2-24 (11±1)
Parastar	31	1-2 (1±0)	3.0-60.0 (21.1±2.9)	1-20 (6±1)	19	1-2 (1±0)	3.0-60.0 (22.5±4.1)	1-20 (6±1)
Cp 10	61	1-3 (1±0)	3.0-60.0 (21.0±1.8)	1-20 (6±0)	38	1-3 (1±0)	3.0-60.0 (21.7±2.5)	1-20 (6±1)
Cp 20	58	1-2 (1±0)	5.0-25.0 (11.1±0.8)	3-24 (10±1)	37	1-2 (1±0)	5.0-25.0 (11.1±1.0)	3-24 (10±1)
Cp 30	25	1-2 (1±0)	5.0-8.0 (7.0±0.2)	8-24 (13±1)	16	1-2 (1±0)	5.0-8.0 (7.1±0.3)	8-24 (12±1)
Ec 10	73	1-3 (1±0)	3.0-60.0 (23.6±1.9)	1-20 (6±0)	44	1-3 (1±0)	3.0-60.0 (24.2±2.5)	1-20 (6±1)
Ec 20	67	1-2 (1±0)	3.0-60.0 (23.7±1.9)	1-20 (5±0)	41	1-2 (1±0)	3.0-60.0 (23.6±2.6)	1-20 (5±1)
Ec 30	39	1-2 (1±0)	9.0-50.0 (21.5±1.6)	1-13 (5±1)	23	1-2 (1±0)	9.0-50.0 (21.2±2.0)	1-13 (5±1)
Td 10	49	1-2 (1±0)	5.0-33.0 (13.8±1.0)	2-24 (8±1)	28	1-2 (1±0)	5.0-33.0 (13.9±1.3)	2-24 (8±1)
Td 20	50	1-2 (1±0)	5.0-25.0 (10.7±0.8)	3-24 (10±1)	31	1-2 (1±0)	5.0-25.0 (11.7±1.1)	3-24 (9±1)
Td 30	27	1-2 (1±0)	5.0-8.0 (7.3±0.2)	8-24 (12±1)	17	1-2 (1±0)	5.0-8.0 (7.3±0.3	8-24 (12±1)
ANOVA		$F_{(10; 552)}$=17.939, p<0.001 *				$F_{(10; 332)}$=10.383, p<0.001 *		
	C. *Amegilla* sp. in 2021				D. *A. calens* in 2022			
Untreated	32	1-2 (1±0)	5.0-33.0 (10.2±1.3)	2-24 (11±1)	34	1-2 (1±0)	5.0-33.0 (9.9±1.3)	2-24 (11±1)
Parastar	12	1-2 (1±0)	3.0-60.0 (25.7±6.2)	1-20 (6±2)	12	1-2 (1±0)	7.0-56.0 (18.9±4.0)	1-9 (6±1)
Cp 10	24	1-3 (1±0)	5.0-60.0 (22.6±3.6)	1-12 (5±1)	23	1-2 (1±0)	5.0-60.0 (19.8±2.7)	1-12 (6±1)
Cp 20	24	1-2 (1±0)	5.0-25.0 (10.3±1.1)	3-24 (10±1)	21	1-2 (1±0)	5.0-25.0 (11.1±1.4)	3-24 (10±1)
Cp 30	9	1-2 (1±0)	5.0-8.0 (7.1±0.4)	8-17 (11±1)	9	1-2 (1±0)	5.0-8.0 (6.9±0.4)	8-24 (13±2)
Ec 10	27	1-3 (2±0)	3.0-56.0 (25.8±3.3)	1-20 (6±1)	29	1-3 (2±0)	3.0-60.0 (22.8±3.1)	1-20 (6±1)
Ec 20	24	1-2 (1±0)	3.0-56.0 (26.0±3.3)	1-20 (5±1)	26	1-2 (1±0)	5.0-60.0 (23.8±2.9)	1-13 (5±1)
Ec 30	15	1-2 (1±0)	10.0-33.0 (20.7±2.0)	2-12 (5±1)	16	1-2 (1±0)	9.0-50.0 (21.9±2.7)	1-13 (5±1)
Td 10	18	1-2 (1±0)	6.0-25.0 (14.2±1.4)	3-15 (7±1)	21	1-2 (1±0)	5.0-33.0 (13.6±1.7)	2-24 (9±1)
Td 20	21	1-2 (1±0)	5.0-25.0 (10.6±1.3)	3-24 (10±1)	19	1-2 (1±0)	5.0-25.0 (9.1±1.1)	4-24 (11±1)
Td 30	9	1-2 (1±0)	6.0-8.0 (7.4±0.2)	8-17 (12±1)	10	1-2 (1±0)	5.0-8.0 (7.3±0.4)	8-24 (12±2)
ANOVA		F(10; 204)=6.181, p<0.001 *				F(10; 209)=7.579, p<0.001 *		

Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5. ns: not significant difference (p≥0.05); * significant (p<0.05). F_i= Number of the visited flowers; d_i=delay in seconds of the control; V_b: Foraging speed (flowers per minute) using the formula V_b=60 (F_i/d_i).

In 2021, *A. calens* behaved differently (Table 4C, 5B upper matrix). Cp20, Cp30, Td20, or Td30 were not different from untreated plots. The difference was not significant between Parastar plots and Cp10, Ec10, Ec20 or Ec30, Td10 or Td20. Cp10 plots were not different from *E. camaldulensis* plots or Td10. Cp20 were not different from Cp30 and from all *Ti. diversifolia* plots. Cp30 plots showed no significant difference compared to plots Td20 or Td30. Ec10, Ec20 or Ec30 were different from Td20 or Td30. *Amegilla* sp. presented differences in foraging speed (Table 5D, 6B lower matrix). Untreated plots were not different from Cp20 or Cp30 and *Ti. diversifolia* plots. Parastar plots were not different from plant extracts plots. Cp10 plots were different from Cp20 or Cp30 and *Ti. diversifolia*.

Table 6. *Pairwise comparisons. Compared means are presented in Table 4.*

	Aqueous leaves extracts: α' (p-value)										
	Unt.	**Para**	**Cp10**	**Cp20**	**Cp30**	**Ec10**	**Ec20**	**Ec30**	**Td10**	**Td20**	**Td30**
A. Pooled campaigns: pooled *Amegilla* (upper part matrix); Pooled campaigns: *Amegilla calens* (lower part matrix)											
Unt.		$2x10^{-5}$*	$3x10^{-5}$*	0.123ns	0.446ns	$2x10^{-5}$*	$3x10^{-5}$*	$1x10^{-5}$*	$3x10^{-5}$*	0.084ns	0.419ns
Parastar	$2x10^{-5}$*		0.875ns	$5x10^{-5}$*	$3x10^{-5}$*	0.695ns	0.848ns	0.893ns	0.036*	$7x10^{-5}$*	$2x10^{-5}$*
Cp10	$3x10^{-5}$*	0.983ns		$2x10^{-5}$*	$1x10^{-5}$*	0.888ns	0.698ns	0.852ns	0.011*	$2x10^{-5}$*	$3x10^{-5}$*
Cp20	0.094ns	$7x10^{-4}$*	$5x10^{-5}$*		0.080ns	<0.001*	$2x10^{-5}$*	$3x10^{-5}$*	0.011*	0.893ns	0.127ns
Cp30	0.436ns	$3x10^{-5}$*	$1x10^{-5}$*	0.060ns		$3x10^{-5}$*	$1x10^{-5}$*	$1x10^{-5}$*	$1x10^{-3}$*	0.080ns	0.731ns
Ec10	$2x10^{-5}$*	0.885ns	0.966ns	$2x10^{-5}$*	$3x10^{-5}$*		0.848ns	0.905ns	0.007*	$2x10^{-5}$*	$3x10^{-5}$*
Ec20	$3x10^{-5}$*	0.953ns	0.670ns	$2x10^{-5}$*	$1x10^{-5}$*	0.876ns		0.838ns	0.005*	$3x10^{-5}$*	$1x10^{-5}$*
Ec30	$1x10^{-5}$*	0.966ns	0.832ns	$7x10^{-5}$*	$1x10^{-5}$*	0.921ns	0.831ns		0.014*	$3x10^{-5}$*	$1x10^{-5}$*
Td10	0.002*	0.019*	0.014*	0.148ns	0.003*	0.006*	0.005*	0.016*		0.056*	$3x10^{-4}$*
Td20	0.106ns	$7x10^{-4}$*	$4x10^{-5}$*	0.733ns	0.092ns	$2x10^{-5}$*	$3x10^{-5}$*	$6x10^{-5}$*	0.196ns		0.105ns
Td30	0.522ns	$3x10^{-5}$*	$3x10^{-5}$*	0.142ns	0.617ns	$3x10^{-5}$*	$1x10^{-5}$*	1x10-5*	0.010*	0.167ns	
B. 2021 campaign: *A. calens* (upper part matrix) and *Amegilla* sp. (lower part matrix)											
Unt.		$2x10^{-4}$*	$3x10^{-5}$*	0.079ns	0.698ns	$2x10^{-5}$*	$3x10^{-5}$*	$1x10^{-5}$*	0.014*	0.088ns	0.657ns
Parastar	0.044*		0.958ns	0.032*	$9x10^{-4}$*	0.783ns	0.979ns	0.978ns	0.138ns	0.055ns	0.002*
Cp10	$3x10^{-4}$*	0.801ns		0.003*	$4x10^{-5}$*	0.990ns	0.886ns	0.922ns	0.158ns	0.017*	$1x10^{-4}$*
Cp20	0.707ns	0.083ns	0.003*		0.167ns	0.002*	0.002*	0.008*	0.385ns	0.680ns	0.193ns
Cp30	0.773ns	0.164ns	0.025*	0.853ns		$5x10^{-5}$*	$3x10^{-5}$*	$9x10^{-5}$*	0.031*	0.136ns	0.757ns
Ec10	$3x10^{-4}$*	0.618ns	0.853ns	0.003*	0.025*		0.986ns	0.978ns	0.082ns	0.008*	$7x10^{-5}$*
Ec20	$3x10^{-4}$*	0.903ns	0.952ns	0.003*	0.027*	0.967ns		0.791ns	0.161ns	0.013*	$6x10^{-5}$*
Ec30	0.004*	0.965ns	0.995ns	0.020*	0.062ns	0.994ns	0.966ns		0.235ns	0.033*	$2x10^{-4}$*
Td10	0.017*	0.853ns	0.782ns	0.782ns	0.115ns	0.706ns	0.856ns	0.939ns		0.378ns	0.050ns
Td20	0.789ns	0.092ns	0.009*	0.036*	0.883ns	0.008*	0.011*	0.044*	0.033*		0.182ns
Td30	0.885ns	0.147ns	0.017*	0.891ns	0.883ns	0.018*	0.018*	0.044*	0.105ns	0.894ns	

Table 6. *Continued.*

	Aqueous leaves extracts: α' (p-value)										
	Unt.	**Para**	**Cp10**	**Cp20**	**Cp30**	**Ec10**	**Ec20**	**Ec30**	**Td10**	**Td20**	**Td30**
C. *A. calens* in 2022											
Unt.		0.006*	$2x10^{-4}$*	0.272ns	0.779ns	$4x10^{-5}$*	0.006*	$5x10^{-4}$*	0.142ns	0.933ns	0.891ns
Parastar			0.944ns	0.108ns	0.014*	0.993ns	0.738ns	0.949ns	0.263ns	0.018*	0.035*
Cp10				0.024*	0.003*	0.963ns	0.874ns	0.972ns	0.089ns	0.002*	0.009*
Cp20					0.461ns	0.009*	0.009*	0.043*	0.478ns	0.552ns	0.612ns
Cp30						0.002*	$8x10^{-4}$*	0.003*	0.234ns	0.691ns	0.679ns
Ec10							0.941ns	0.987ns	0.030*	$7x10^{-4}$*	0.005*

	Aqueous leaves extracts: α’ (p-value)									
	Unt.	**Para**	**Cp10**	**Cp20**	**Cp30**	**Ec10**	**Ec20**	**Ec30**	**Td10**	**Td20**	**Td30**
Ec20								0.997 ns	0.063 ns	$3x10^{-4}$ *	0.003 *
Ec30									0.178 ns	0.003 *	0.010 *
Td10										0.308 ns	0.378 ns
Td20											0.719 ns

Unt: Untreated plots; ns: not significant difference (p≥0.05); * significant difference (p<0.05). Cp10, Cp20, Cp30, Ec10, Ec20, Ec30, Td10, Td20 and Td30 are presented in Figure 5. ns: not significant difference (p≥0.05); * significant (p<0.05).

Cp20 were not different from Cp30, Td10 or Td30. Cp30 were different from Ec10 or Ec20 plots. Ec10, Ec20 or Ec30 were different from Td20 or Td30 plots. Td20 were different from Td10. In 2022, the foraging speed variation was significant in *A. calens* (Table 5D, 6C). Untreated plots were not different from Cp20, Cp30 or *Ti. diversifolia* plots. Parastar plots were different from Cp30, Td20 or Td30 (Table 5D, 6C). Cp10 was different from Cp20, Cp30 or *Ti. diversifolia* plots (Table 5D, 6C). Cp20 or Cp30 were different from *E. camaldulensis* plots (Table 5D, 6C). Ec10 was different from *Ti. diversifolia* plots. Ec20 was different from Td20 or Td30 (Table 5D, 6C).

4. Discussion

Floricultural insects in Dang showed a significant activity of *Amegilla* known as sporadic pollinators [5, 23, 28]. The occurrence of *Amegilla* would depend on the variation of air temperature, humidity, light intensity, precipitations, and the wind. According to Wang et al. [29], bee’s activity increases with light (up to 1000 µmol.m-2.s-1), temperature (up to 28˚C), air humidity (up to 40%), and it decreases at high values [30]. In fact, environmental factors have direct impact on flowers and on the sugar content of nectar [30]. The peak of activities at the 3rd day may probably correspond to the maximum flowering period. According to Manggoel and Uguru [31], 50% of plant's flowers bloom within two to six days. Absence of *Amegilla* sp. in 2022 and the variation of the peak of activity mean that wild bees responded differently to the environmental change. *Amegilla calens* (peak of activity between 8 to 9 a.m.) required certainly low air conditions than *Amegilla* sp. (activity peak between 10 and 11 a.m.). Plant extracts showed a significant negative impact on wild bees. Plant extracts are least toxic to pollinators [32], easily accessible, inexpensive and biodegradable (pers. obs.). Further studies could elucidate the active molecules. It is well known that imidacloprid is toxic to bees [33], affecting insect’s memory [34] and decreasing their longevity [35]. The increase of the visits duration may increase the plant’s pollination. *Amegilla* collected nectar, from 6 a.m. until before noon. This would be due to the availability, attractiveness of the floral products, and the scents from flowers [36]. A little earlier activity was noted than what reported at Obala (Centre-Cameroon) with a peak of activity between 9 and 10 a.m. [37]. The shift may be due to the prevailing climate which is equatorial forest type in Central Region (Cameroon) and Sudano-Guinean in Dang. Abundance per 1,000 flowers highlighted the attractiveness of the nectar in Ec20 or *Ca. procera* plots. The low abundance of bees in Parastar plots could be due to the repellent effect of the pesticide. Bees stay longer on flowers very rich in products than on flowers very poor in products. Foraging visit varied according to the treatment type, proving the differential effect of tested pesticides. The variations in the foraging speed could be due to the accessibility, availability of products, distance between flowers and the influence of the plant extracts. Among the approved pesticides [16], Parastar induces changes in reproductive parameters and testicular oxidative stress biomarkers in Wistar male rats [17]. Moreover, imidacloprid and lamda-cyhalothrin present a high persistence in the environment. The chronic contact contaminates pollen and nectar and indirectly affect bees [38-41]. Imidacloprid (neonicotinoid pesticide) present a long half-life in soils (32 days in sandy loam soils, 38 days in loamy sand soils, 43 days in clay loam soils) [38-41]. A long half-life is reported in neurotoxic pyrethroid lamda-cyhalothrin (30 days in average) [41]. An abnormal behavior was reported in bees in Taiwan, induced by sub lethal dosage of imidacloprid [42]. Five-days control was certainly insufficient (the pesticide not having acted sufficiently) and pesticides were certainly cleaned by rainwater, or insects were reinforced by new ones from neighboring fallows.

5. Conclusions

Untreated plots, Cp20 and Ec20 plots allowed the bees to carry out their activity, unlike Parastar or 30% plant extracts. It would be wise to replace Parastar by 20% plant extracts.

Abbreviations

α	Significance Level

α'	Bonferroni Corrected Significance Level
A. calens	*Amegilla calens* Le Peletier. 1841
$A_{1,000}$	Abundances Per 1,000 Flowers
ANOVA	Analysis of Variance
Ap. mellifera	*Apis mellifera* Linnaeus, 1758
IRD	Institut de Recherche Agricole Pour le Développement / Agricultural Research Institute for Development
Ca. procera	*Calotropis procera* (Aiton) Aiton, 1811
Cp10	10% Leaves Extract of *Ca. procera*
Cp20	20% Extract of *Ca. procera*
Cp30	30% Extract of *Ca. procera*
d_i	Delay of the Visits
E. camaldulensis	*Eucalyptus camaldulensis* Dehnh., 1832
Ec10	10% Extract of *E. camaldulensis*
Ec20	20% Extract of *E. camaldulensis*
Ec30	30% Extract of *E. camaldulensis*
F_i	Visited Flowers
Max	Maximum
Min.	Minimum
MINADER	Ministry of Agriculture and Rural Development (Cameroon)
ns	Not Significant
p-value	Probability Value
Para.	Parastar
se	Standard Error
Ti. diversifolia	*Tithonia diversifolia* (Hemsley) Gray, 1883
Td10	10% Extract of *Ti. diversifolia*
Td20	20% Extract of *Ti. diversifolia*
Td30	30% Extract of *Ti. diversifolia*
Unt.	Untreated
V. unguiculata	*Vigna unguiculata* (L.) Walp., 1843
V_b	Foraging Speed

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interests

The authors declare no conflicts of interest.

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Research Field

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Moise Adamou: Botanical insecticides, Bees, Biological agriculture, Yield agricultural products, Cotton (*Gossypium hirsutum*), Pollinization

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Alice Virginie Tchiaze Ifoue: Applied entomology, Insects biology, biostatistics and pollinators, Plant physiology, Soil fertilization

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