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RESEARCH ARTICLE

DIVERSITY OF FLORICULTURAL INSECTS OF FIVE SESAME VARIETIES (SESAMUM INDICUM L.) IN NORTHERN CÔTE D'IVOIRE (WEST AFRICA)

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ABSTRACT

Background: Sesame (*Sesamum indicum* L.) represents an important cash crop in many countries of West Africa. It is increasingly cultivated in the north of Côte d'Ivoire and can reproduce by self-pollination or cross-pollination. This latter case involving pollinating insects. Unfortunately, little entomological studies concerning the diversity of floricultural insects have been devoted to this crop. ***Methods:*** This study aims to determine the diversity of floricultural insects on five sesame varieties grown in the north of Cote d'Ivoire. The methodology was based on observation, capture and identification of insects visiting the flowers. It was consisted also to assess insects' activity in order to determine their foraging effectiveness. ***Results:*** The results showed that all sesame varieties were visited by a large diversity of insects. Hymenoptera were the most abundant order on the varieties SI 097, SI 100, SI 129 and SI 143 while, Orthoptera were more abundant on a single variety SI 099. The calculated indices showed that the variety SI 143 was the most diverse (H' = 1.79) with a more equitable distribution of floricultural insects (E = 0.92). Bee activity was mostly intense on the varieties SI 097, SI 100, SI 129 and SI 143 with a maximum peak of activity between 9 a.m. and 10 a.m. As for the locusts, their activity was mostly intense on the variety SI 099 with a maximum peak of activity between 9 a.m. and 10 a.m. The foraging speed of bees was higher than that of other insect groups. ***Conclusion:*** The findings on the diversity of sesame floricultural insects are very relevant because they allow to consider a study on their impact on fruit production. Also, determining the diversity of insects on several sesame varieties makes it possible to manage entomological issues related to pollination; which could lead to a varietal selection.

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INTRODUCTION

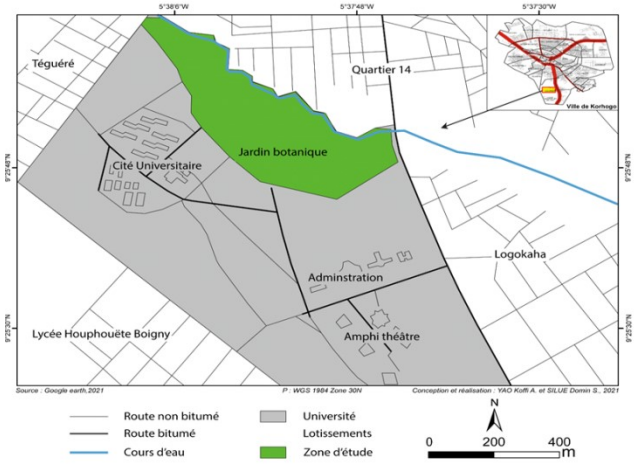
Sesame (*Sesamum indicum* L.) is an herbaceous plant belonging to the family of Pedaliaceae[1]. It is one of the most important oilseed crops grown by human[2]. It is also the most cultivated edible oilseed species among more than 30 species from *Sesamum* genera[3,4]. Its flowers are hermaphroditic, zygomorphic and each, contain one calyx with five slits, one corollary tube formed by one upper lip with two lobes and one lower lip with three lobes, four stamens, one ovary, one style with a bifid stigma and a nectariferous disc surrounding the ovary[1,5]. It easily adapts to different growing conditions and is drought resistant[6]. It's cultivated mainly in the tropical and subtropical regions of Asia, Africa and South America for its edible seeds from which oil is also extracted[7,8]. Sesame oil ranks sixth in the world among vegetable oils[9].

Sesame seeds contain 50% oil and are consumed and used in the pharmaceutical and chemical industries[1] as well as in oil production[10]. These seeds, which are small, oval and slightly flattened, contain antioxidants such as sesamin and sesamolin[11,12]. Globally, sesame ranks ninth among the top thirteen oil crops and its demand continues to increase[13,14]. Burma is the top producer of sesame seeds in the world, followed by India, China, Ethiopia, Sudan, Nigeria, Uganda, Tanzania, Niger and Burkina Faso[9]. For a production around to 3.83 million tonnes of sesame in the world, Asia and Africa have 2.29 million and 1.38 million tonnes, respectively[9]. However, sesame seed production in Africa is still low due to its socio-economic importance. In Côte d'Ivoire, its cultivation is localized in the West and North-West regions. However, sesame is recognized as a plant with low production potential compared to other oilseeds in its production areas. This low production of sesame would be linked to several factors including the gap of knowledge about this crop, changing

agronomic conditions and probably the decline of pollination services. Indeed, sesame being a hermaphrodite plant, it can reproduce by self-pollination or by cross-pollination involving, in the latter case, pollinating insects. In addition, *Sesamum* genera includes many varieties which differ by their dimensions, shape, type of growth, color of flowers, size, color and composition of seeds[15]. Sesame flower visitors can then vary depending on the varieties grown. Therefore, the knowledge of insects visiting sesame flowers is essential to improve the quality and quantity of fruits. However, very little studies have been devoted to sesame in Africa. The rare studies carried out on sesame pollination by floricultural insects including *Apis mellifera* are those carried out in Egypt[16,17,18,19], in Tanzania[20] and in North-West of Cameroon[21]. These authors reported that the main pollinators of sesame are Hymenoptera including *Apis mellifera*. In sub-Saharan Africa, where the economy is based mainly on agriculture, the only study on sesame pollinators is that carried out in Burkina Faso[22]. In Cote d'Ivoire, there are very little information about the sesame flower visitors, particularly in the region of Korhogo, where sesame cultivation is growing. Our study, for the first time, aims to determine the floricultural insect diversity on five varieties of sesame grown in Korhogo. Specifically, it will consist (i) to identify all insect groups visiting sesame flowers and (ii) to assess their foraging effectiveness.

MATERIALS AND METHODS

Study site: This study was carried out from June to November 2022 in Korhogo city (9° 26' 47.06" LN; 5° 38' 40.74" LW), north of Cote d'Ivoire. This period corresponds to the rainy season and the beginning of dry season in the north of Cote d'Ivoire. The experiments were carried out in the vegetable patch within the Botanical garden of University Peleforo Gon Coulibaly (Figure 1). We selected 9 varieties of sesame for this study but only, 5 varieties were able to germinate and allowed the experiments to be carried out. These varieties are SI 097, SI 099, SI 100, SI 129 and SI 143. The experimental fields were each 100 m^2 in size, typically embedded in a matrix of other small fields of wind-pollinated cereal crops such as maize, millet and sorghum, or entomophilous crops such as beans and peanut, with a maximum distance of 50 m from the forest fragment. At all sites, usual agricultural practices continued during the study period: fertilizers were applied at the start of the planting season, insecticides and fungicides were applied irregularly depending on the infestation rate. Weeds were removed manually.



Analyze to the diversity of floricultural insects: Insects were sampled directly on the flowers during the sesame flowering period in order to identify their main visitors. The observed insects on the flowers were identified on site or captured using a sweep net. The captured specimens were stored in ethyl alcohol (70%), and thereafter pinned and identified to genus or species if possible. All identifications were made under a binocular magnifying glass using keys of insect identification.

Analyze to the foraging efficiency: Insects were observed directly on the flowers once a week during the flowering period. The observations were carried out from 5 a.m. to 6 p.m. and data were grouped by time slot. Each observation turn lasted 15 minutes per time slot. The classification criteria based on the quality of visits were used to categorize visitors, knowing that insect posture changes depending on whether they are looking for nectar or pollen. Insects which limited themselves to gathering nectar after having pierced a hole at the base of the corolla or those which used these holes to collect nectar, were considered to carry out "negative visits" because their activity does not allow the flower fertilization. On the other hand, insects which collected nectar and pollen through the natural opening of flower corolla were considered as positive visits ("positive visits") because these frontal visits trigger the staminal column which thus comes into contact with the stigma. The nature of visits (positive or negative) and an estimate of foraging speed were considered in the choice of the main visitors, knowing that the rate at which flowers were foraged could vary depending on the pollinator species. Using a stopwatch, we followed the insects' movement and the number of visited flowers as well as the duration of visits were counted. Only one visit was counted per insect, that is to say, when an insect left the observed plot, we immediately stopped counting its visits.

Data analysis: Several indices were calculated to express the results of the study. These are species richness (S), average abundance (A), Shannon index (H'), and Pielou's species evenness (E). All indices were calculated using EstimateS software (Version 7.0). Data were analyzed using STATISTICA version 7.1 software. The variance (ANOVA) and the Duncan test at the 5% threshold were used to compare calculated means.

RESULTS

Diversity of floricultural insects

Taxonomic richness

Overall richness: In total, seven orders of insects were observed on five sesame varieties flowers. They are Hymenoptera (bees, wasps and ants), Odonata (dragonflies), Diptera (flies), Orthoptera (locusts), Coleoptera (beetles), Hemiptera (bugs) and Lepidoptera (butterflies).

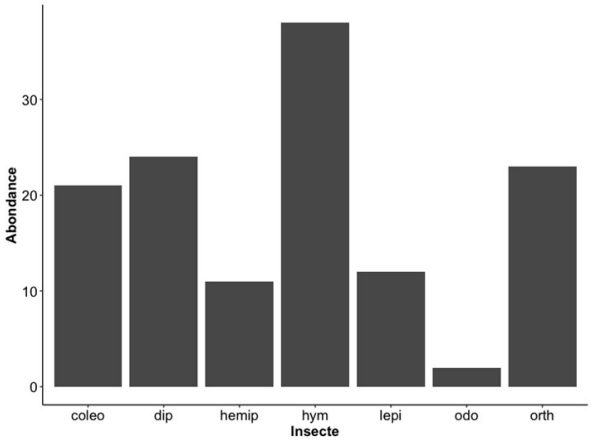
Richness by variety: All the seven orders of insects have been observed on two varieties SI 100 and SI 143. However, the order Odonata was not observed on the varieties SI 097, SI 099 and SI 129. These three varieties of sesame were therefore visited by six orders of insects. The calculated indices showed that the variety SI 143 was the most diverse (H = 1.79) with a more equitable distribution of the insect orders abundance (E = 0.92) (Table 1).

Table 1. Indices of diversity

Varieties	Richness (Order)	Shannon (H')	Pielou's species evenness (E)
SI 097	6	1.66	0.86
SI 099	6	1.56	0.80
SI 100	7	1.62	0.83
SI 129	6	1.58	0.81
SI 143	7	**1.79**	**0.92**

Relative abundance of floricultural insects

Overall relative abundance: A total of 131 insect specimens were recorded on the five sesame varieties flowers (Figure 2). Hymenoptera (29% of specimens) were the most abundant order. It was followed respectively by Diptera (18.32%), Orthoptera (17.56%), Coleoptera (16.03%), Lepidoptera (9.16%), Hemiptera (8.39%) and Odonata (1.53%).



Relative abundance by variety: The order Hymenoptera was more abundant on four varieties of sesame (SI 097, SI 100, SI 129 and SI 143). However, Orthoptera was the most abundant order on the variety SI 099 (Table 2).

Table 2. Abundance of insect orders on each variety of sesame

Orders	Varieties				
	SI 097	SI 099	SI 100	SI 129	SI 143
Hymenoptera	9 (33.33)	1 (5.88)	13 (39.39)	7 (29.17)	8 (26.67)
Odonata	0 (0)	0 (0)	1 (3.03)	0 (0)	1 (3.33)
Diptera	3 (11.11)	3 (17.65)	6 (18.18)	6 (25)	6 (20)
Orthoptera	6 (22.22)	7 (41.18)	6 (18.18)	1 (4.17)	3 (10)
Coleoptera	2 (7.41)	3 (17.65)	4 (12.12)	6 (25)	6 (20)
Hemiptera	3 (11.11)	2 (11.76)	1 (3.03)	3 (12.5)	2 (6.67)
Lepidoptera	4 (14.81)	1 (5.88)	2 (6.06)	1 (4.17)	4 (13.33)
Total	27 (100)	17 (100)	33 (100)	24 (100)	30 (100)

Foraging efficiency of floricultural insects

Proportion of visits: The order Orthoptera made the most percentage of visits (41%) on the variety SI 099. However, on the other four varieties, the highest percentage of visits was made by Hymenoptera. They achieved 33%, 40%, 29% and 27% of visits respectively on the varieties SI 097, SI 100, SI 129 and SI 143 (Figure 3).

Nature of visits and collected nutrients

- **Variety SI 097:** Eight groups of insects (flies, bees, ants, butterflies, wasps, locusts, beetles and bedbugs) were observed on the variety SI 097. Approximately, 98% of visits made by bees were positives, i.e. that they have taken at least one nutrient (pollen or nectar) during their passage. The positive visits by wasps and flies were 7% and 2%, respectively. The other groups of insects did not make any positive visits. They visited the sesame flowers without taking any nutrients. Concerning the nutrients taken by bees, 35.42% consisted of pollen, 19.79% of nectar and 44.79% of both nutrients.

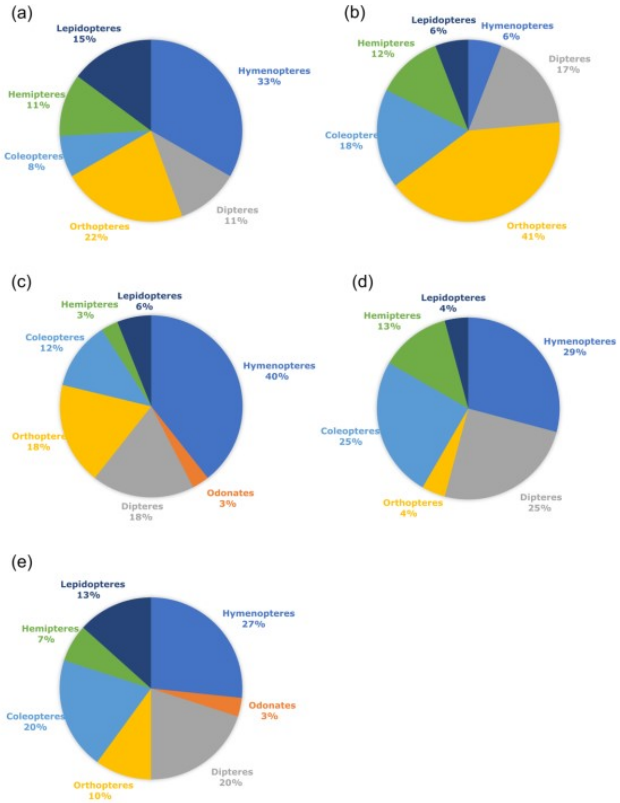


Figure 3. Percentage of insect visits depending on their abundance on the varieties SI 097 (a), SI 099 (b), SI 100 (c), SI 129 (d) and SI 143 (e)

- **Variety SI 099:** The variety SI 099 was visited by seven groups of insects (bees, flies, locusts, butterflies, wasps, beetles, bedbugs). The positive visits made by bees represented 96% of all their visits. Wasps and flies made 3% and 1% of positive visits, respectively. Although numerous on the flowers of the variety SI 099, locusts and other groups of insects did not take any nutrients. Concerning the nutrients taken by bees, 27.89% consisted of pollen, 22.13% of nectar and 49.98% of both nutrients.

- **Variety SI 100:** Eight groups of insects (flies, bees, ants, butterflies, dragonflies, locusts, beetles, bedbugs) were observed on the variety SI 100. Around 99% of visits made by bees were positives. The positive visits by dragonflies and flies were 2% and 1%, respectively. The other groups of insects did not make any positive visits. As for the nutrients taken by the bees, 29.33% consisted of pollen, 23.55% of nectar and 47.12% of both nutrients.

- **Variety SI 129:** This variety was visited by eight groups of insects (flies, bees, ants, butterflies, beetles, wasps, locusts, bedbugs). All visits (100%) carried out by bees were positives. Wasps, flies and butterflies made 5%, 2% and 1% positive visits, respectively. The other groups of insects did not take up any nutrients.

Concerning the nutrients taken, 31.02% of bees had a preference for pollen, 18.87% for nectar and 50.11% for both nutrients.

- **Variety SI 143:** Nine groups of insects (flies, bees, ants, butterflies, wasps, dragonflies, beetles, locusts, bedbugs) were observed on the variety SI 143. Around 99% of visits made by bees were positives. Wasps and dragonflies made 5% and 1% of positive visits, respectively. The other groups of insects did not take up any nutrients. Concerning the nutrients taken, 34.66% of bees had a preference for pollen, 23.35% for nectar and 41.99% for both nutrients.

Foraging speed: The calculated average foraging speed for each group of insects showed that the most frequent visits were those of bees regardless the sesame variety (Table 3). The statistical analyzes showed a significant difference between the average foraging speed of bees and those of other insect groups. Indeed, bees collected flowers from the variety SI 097 at an average rate of 11.92 flowers per minute; the variety SI 099 (10.78 flowers per minute); the variety SI 100 (10.95 flowers per minute); the variety S 129 (11.39 flowers per minute) and the variety SI 143 (12.45 flowers per minute).

Daily variation of insect visits

- **Variety SI 097:** Insects on the variety SI 097 were composed of flies, bees, ants, butterflies, wasps, locusts, beetles and bedbugs. Bee activity was the most intense on this variety. It started at 6 a.m. and reached its maximum peak between 9 a.m. and 10 a.m. After this time slot, a drop in bee activity was observed to practically disappear between 12 p.m. and 3 p.m.

  A new resumption of bee activity was observed and a second peak is reached between 3 p.m. and 4 p.m. After this time slot, bee activity drops again until 6 p.m. The other groups of insects were less active. The peak of wasp activity was reached between 7 a.m. and 8 a.m.; that of butterflies was reached between 11 a.m. - 12 p.m. and between 2 p.m. - 3 p.m. As for flies and beetles, they reached their peak of activity respectively between 1 p.m. - 2 p.m. and between 3 p.m. - 4 p.m. The activity of ants, locusts and bugs did not show any peak; it remained stationary (Figure 4).

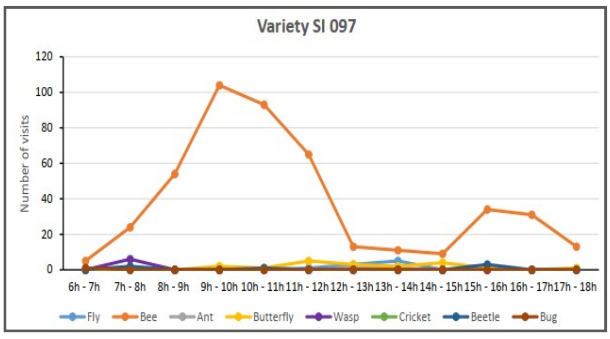


Figure 4. Daily variation of insect visits on the variety SI 097

- **Variety SI 099:** Insects on the variety SI 099 were composed of bees, flies, locusts, butterflies, wasps, beetles and bedbugs. Locust activity was the most intense on the variety SI 099. It started at 6 a.m., suffering a slight decrease between 7 a.m. and 8 a.m. before evolving very quickly to reach its maximum peak between 9 a.m. and 10 a.m. After this time slot, locust activity dropped suddenly and stabilized between 12 p.m. and 2 p.m. A small resumption of locust activity was observed, reaching a slight peak between 3 p.m. and 4 p.m. before falling again. Bee activity started also at 6 a.m. and reached its maximum peak between 11 a.m. and 12 p.m. After this time slot, it dropped and finally disappeared between 5 p.m. and 6 p.m. Two small peaks of activity were observed with the butterflies, the first between 8 a.m. and 9 a.m. and the second between 11 a.m. and 12 p.m. The activity of the other insect groups remained stationary and showed no peak (Figure 5).

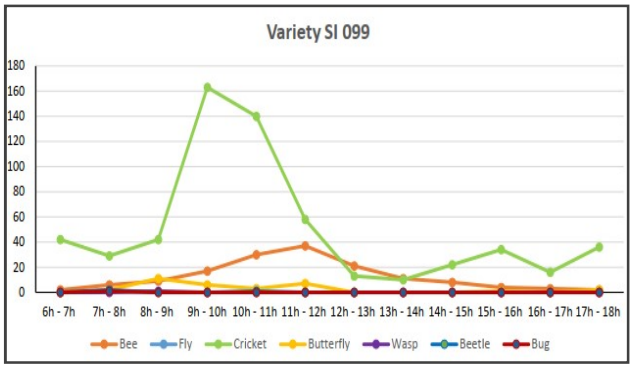


Figure 5. Daily variation of insect visits on the variety SI 099

- **Variety SI 100:** Insects observed on the variety SI 100 include flies, bees, ants, butterflies, dragonflies, locusts, beetles and bedbugs. Bee activity began at 6 a.m. It evolved to reach its maximum peak between 9 a.m. and 10 a.m. After this time slot, bee activity dropped to practically zero between 12 p.m. and 2 p.m. Then, a small recovery in bee activity was observed from 2 p.m. to reach a slight peak between 3 p.m. and 4 p.m. before falling again to stabilize between 4 p.m. and 6 p.m. No peak activity was observed in the other groups of insects (Figure 6).

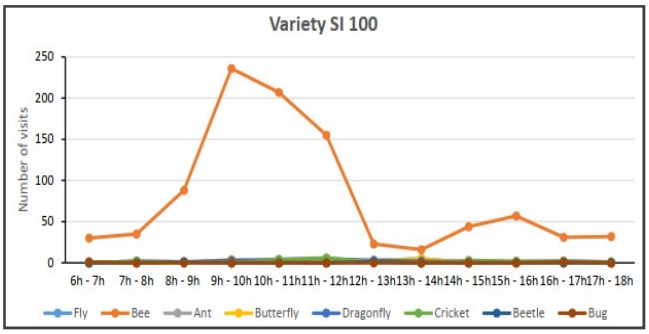


Figure 6. Daily variation of insect visits on the variety SI 100

- **Variety SI 129:** Insects observed on the variety SI 129 included flies, bees, ants, butterflies, beetles, wasps, locusts and bedbugs. Bee activity was the most intense compared to other insects. It started at 6 a.m. and reached its maximum peak between 9 and 10 a.m. Then, a gradual decline in activity was observed until the 12 p.m. – 1 p.m. time slot. After this time slot, a small resumption of bee activity was observed, reaching a second peak between 3 p.m. and 4 p.m. before falling again. Three peaks of activity were observed in the butterflies respectively between 11 a.m.-12 p.m., between 1 p.m.-2 p.m. and

Table 3. Foraging speed of insect groups on the five varieties of sesame

Varieties	Foraging speed (number of flowers visited/minute)								
	Bee	Fly	Ant	Wasp	Butterfly	Dragonfly	Beetle	Locust	Bug
SI 097	11.92 ± 2.01^{a}	0.17 ± 0.05^{b}	0.02 ± 0.01^{b}	1.34 ± 0.12^{b}	0.04 ± 0.01^{b}	0	0.01 ± 0.01^{b}	0.03 ± 0.01^{b}	0.01 ± 0.01^{b}
SI 099	10.78 ± 3.44^{a}	0.09 ± 0.03^{b}	0	1.66 ± 0.09^{b}	0.07 ± 0.02^{b}	0	0.02 ± 0.01^{b}	0.06 ± 0.02^{b}	0.01 ± 0.01^{b}
SI 100	$10.95 \pm 2.,57^{a}$	0.11 ± 0.03^{b}	0.03 ± 0.01^{b}	0	0.03 ± 0.01^{b}	0.04 ± 0.02^{b}	0.01 ± 0.01^{b}	0.04 ± 0.02^{b}	0.02 ± 0.01^{b}
SI 129	11.39 ± 4.01^{a}	0.06 ± 0.03^{b}	0.01 ± 0.01^{b}	1.51 ± 0.11^{b}	0.05 ± 0.02^{b}	0	0.01 ± 0.01^{b}	0.02 ± 0.01^{b}	0.01 ± 0.01^{b}
SI 143	12.45 ± 3.83^{a}	0.16 ± 0.05^{b}	0.02 ± 0.01^{b}	0.77 ± 0.08^{b}	0.03 ± 0.01^{b}	0.07 ± 0.03^{b}	0.01 ± 0.01^{b}	0.02 ± 0.01^{b}	0.01 ± 0.01^{b}

between 3 p.m.-4 p.m. The other groups of insects showed no peak of activity (Figure 7).

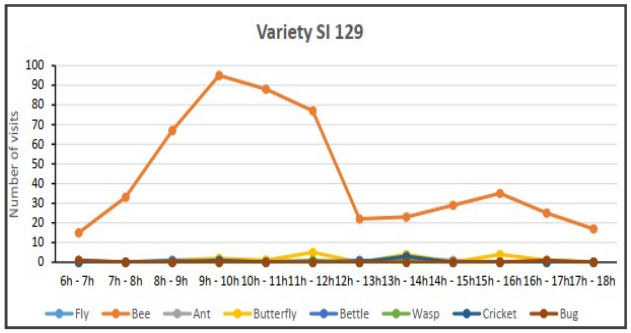


Figure 7. Daily variation of insect visits on the variety SI 129

- **Variety SI 143:** Insects observed on the variety SI 143 were composed of flies, bees, ants, butterflies, wasps, dragonflies, beetles, locusts and bedbugs. Bee activity was the most intense on the variety SI 143 compared to the other insects. It started at 6 a.m. and reached its maximum peak between 9 and 10 a.m. After this time slot, bee activity gradually dropped to almost zero between 12 p.m. and 2 p.m. Then, a resumption of bee activity was observed to reach a second peak between 3 p.m. and 4 p.m. before falling again. The other groups of insects did not show any peak in activity. The activity of these insects remained stationary (Figure 8).

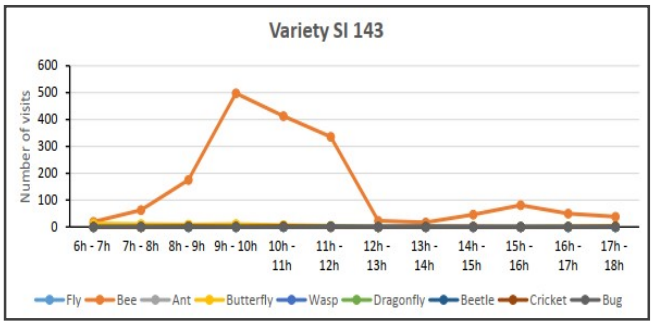


Figure 8. Daily variation of insect visits on the variety SI 143

DISCUSSION

This study is the first of its kind to assess the diversity of floricultural insects of several sesame varieties grown in northern Cote d'Ivoire. It could contribute to the monitoring of biodiversity in these areas under great pressure from the misuse of land due to the population growth and extensive agriculture which, at the same time, requires a high demand for pollination services to maintain natural vegetation and to secure crop yields[23]. It revealed that sesame flowers are very attractive to insects. Because the flower insects collected during the study period belong to seven orders. These results are consistent with those obtained by Coulibaly[23] who found approximately the same number of insect orders in the sesame fields in Burkina Faso.

The five varieties of sesame were visited by the same insect orders. Maybe, because they were in the same array of fields. However, at the level of insect groups belonging to these orders, their abundances varied from one variety of sesame to another. Several reasons may explain this variation. First, the average concentration in total sugars of the nectar could be different from one variety of sesame to another. In a study carried out on the attractiveness of sesame compared to other plant species[24], noted that the determining factor was the concentration in total sugars in the sesame nectar (29.67%) which was well above that of other plant species. Second, some varieties would produce more pollen than others. Indeed, the scarcity of pollen on a variety could direct the choice of bees towards the most productive variety. The most regular flower insects belonged mainly to the Hymenoptera and Orthoptera orders. Indeed, Hymenoptera were more frequent on four varieties of sesame while Orthoptera were frequent on a single variety of sesame. The work carried out by Coulibaly[23] focused on a single variety of sesame in Burkina Faso. In this study, the majority of visits were made by insects belonging to the order Hymenoptera. Similar results were obtained by Mahmoud[16] and Kamel[18] in Egypt who showed that Apoidea (with more than 96% visits) were the most abundant floricultural insects on sesame flowers. The strong presence of Hymenoptera on sesame flowers could be due to the abundance of bees including the honey bee, considered an excellent visitor to sesame flowers[23]. The strong presence of Orthoptera on a single variety of sesame could be explained by a low production of nectar and pollen by this variety.

This low production of nectar and pollen could reduce the frequency of visits by bees and increase that of other insect groups. Among the order Hymenoptera, bees represent the most important group of floricultural insects. They were the most frequent on four varieties of sesame. The maximum peak of bee activity was generally between 9 a.m. and 10 a.m. and a second slight peak was observed between 3 p.m. and 4 p.m. Indeed, bees are constantly looking for pollen and nectar. However, the quantity and quality of nectar varies depending on the blooming of flowers, plant species, weather conditions and, above all, the time of day[25]. Because the presence of bees on flowers could be influenced by the intensity of the scent emitted by them. The daily activity of bees on flowers is therefore a function of the pollen production[26] or nectar[27] during the day. These time slots of intense bee activity would certainly coincide with the period during which the scent released by sesame flowers is quite significant. In addition, the strong morning bee activity would be synchronized with maximum nectar secretion[28]. Also, bees frequently forage on flowers whose nectar sugar concentration is relatively high (more than 15%)[29]. For sesame, sugar production is likely high in the morning between 9 a.m. and 10 a.m. and late in the afternoon between 3 p.m. and 4 p.m. The results of our study are substantially identical to those of[21] Otiobo *et al.*[21] who showed that the peak of bee activity on sesame flowers in Cameroon was between 10 a.m. and 11 a.m. Mahmoud[16] also

showed that the peak of bee activity on sesame flowers in Egypt was between 11 a.m. and 12 p.m. As for Kamel[18], they noted two peaks of bee activity on sesame flowers in Egypt, one located between 11 a.m. and 1 p.m. and the other, between 1 p.m. and 3 p.m.

CONCLUSION

This study aimed to identify the floricultural insects on five varieties of sesame in the north of Côte d'Ivoire. The results showed that all varieties of sesame are visited by a diversity of insects. However, insects belonging to the order Hymenoptera represented the main visitors among which, bees were the most abundant. The foraging speed of bees was greater than that of other insect groups. The results obtained are very relevant because they allow us to consider a study on sesame pollination in the north of Côte d'Ivoire.

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CONFLICT OF INTEREST: None declared.

AUTHORS' CONTRIBUTIONS

DC and YT designed the study. DC and DSS collected data in the field. DC determined insect specimens and their traits. DC and SK analyzed and plotted output data. DC wrote the first draft of the manuscript. MK, BSB and KHK contributed to improve the draft. All authors contributed substantially to revisions. ORCID https://orcid.org/0000-0002-8495-5773

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