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Bee Visits Improves Production Parameters of Maize in Northern Côte d'Ivoire (West Africa)

Yalamoussa Tuo[1], Drissa Coulibaly[1*], Laya Kansaye[2], Pôrôlô Soro[1], Mouhamadou Kone[1]

[1]University Peleforo Gon Coulibaly, Biological Sciences Unity, Department of Animal Biology, BP 1328 Korhogo, Côte d'Ivoire

[2]Rural Polytechnic Institute of Training and Applied Research (IPR/IFRA) of Katibougou, Mali

ABSTRACT

Maize (Zea mays) is one of cereal rich in nutrients and antioxidants essential for human health. Many studies showed that this speculation is pollinated indirectly by wind. However, we observed a strong presence of bees on the male flowers of maize as soon as they open. The high activity of bees on these flowers, causes an intense release of pollen, which could impact positively the fruit set. This study was carried out in the botanical garden of the university Peleforo Gon Coulibaly of Korhogo located in northern Cote d'Ivoire. Two varieties of maize (EV8728-SR and LG501) were used for this study. For each variety, 15 plants were protected from insect visits and 15 other plants were still unprotected. Ear mass, seed mass and seed number resulting from each treatment were analyzed. The findings showed that the average number of seeds per ear resulting from unprotected plants (V1: 445.8 ± 17.92 and V2: 442.27 ± 6.8) was significantly higher compared to the protected plants (V1: 242.13 ± 4.39 and V2: 208.6 ± 9.52) for each variety. The average mass of seeds resulting from unprotected plants (V1: 205.31 ± 2.23g and V2: 169.45 ± 5.15g) was also higher compared to the protected plants (V1: 101.79 ± 1.93g and V2: 77.49 ± 1.70g). Whatever the maize variety, the germination rate of seeds resulting from unprotected plants (V1: Tg = 96.67% and V2: Tg = 100%) was higher compared to the protected plants (V1: Tg = 66.67% and V2: Tg = 56.67%). This study are very relevant for farmers and scientists because, it showed clearly bee contribution in the maize production improvement.

Key Words: Fruit set, Germination rate, Korhogo, Maize, Protected.

1. INTRODUCTION

Maize (*Zea mays*), rice (*Oryza* sp) and wheat (*Triticum* sp) are the basic crops for food security [1]. Among these three cereals, maize is the most cultivated in the world quantitatively and in sown area [2]. Its seeds are used directly for human and animal consumption. They are used also as a raw material in industrial products [3]. A study conducted in Burkina Faso, Ghana, Mali and Nigeria (West Africa), as well as Ethiopia, Kenya, Tanzania, Uganda and Zambia (East Africa) demonstrated that the average production of maize which was 1.7 t/ha in 2010 should reach 6.8 t/ha per year, to be able to meet the expected demand in 2050 [4]. To achieve this goal, the production of maize per hectare must increase approximately by 3.5% per year, a rate never seen at national or supranational scales in the world with regard to rain-fed agriculture. The corresponding nutrient inputs must, for their part, increase by more than 7% per year, to avoid depletion and further soil degradation. Thus, all research programs aimed at increasing maize production will concern especially fertility, pest control and varietal selection. Very few programs will focus on the pollination. However, the life maintenance on the earth is largely based on the relationships and interdependencies between living species [5]. Throughout the world, the majority of flowering plants are fertilized by pollinators. It is one of the most important nature actions [5]. It is necessary for a large part of plants, right down to the tropical forest heart. As a result, the importance of pollinating insects in agricultural production, mainly honey bee and wild bees, is no longer to be proven but, unfortunately, it remains poorly known. About 70% of plant species grown for human consumption worldwide depend on entomophilous pollination [6]. Maize is an annual herbaceous tropical plant belonging to family Poaceae (grasses). It is a largely allogamous species due to the vertical separation of male and female organs and the earliness of male flowering compared to female flowering (phenomenon of protandry). Around 95% of maize seeds are obtained from cross fertilization [2]. However, wind is known as the main vector of maize pollen. Indeed, the transfer of maize pollen from the dehiscent anthers to the atmosphere is triggered by the agitation of panicles and anthers under the wind action [2]. Nevertheless, studies carried out in Burkina Faso and Cameroon have shown that the panicles of this plant are visited by insects in particular, *Lipotriches rubela* and *Amegilla sp* to collect pollen [7, 8]. According to these authors, once in contact with the anthers during the pollen harvest, insects cause a vibration thus releasing thousands of pollen, which could contribute to increasing the maize pollination. This action of bees on the maize flowers could play an important role for its production. In Côte d'Ivoire, there is no documentation about the entomophilous pollination of maize and even less on the contribution of bees. However, given that the insect diversity can vary from one region to another Joseph *et al*. [8], this study aims to assess bee contribution in the maize production. More specifically, it involves (i) to assess bee diversity in the maize fields and (ii) to assess their impact on some parameters of production.

2. MATERIALS AND METHODS

2.1. Study site

Our study was carried out in the north of Côte d'Ivoire, West Africa. The study site was selected in the Botanical garden of Peleforo GON COULIBALY University of Korhogo (UPGC-K) during the rainy season, corresponding to the maize cultivation period in the region (Figure 1). There are two pronounced seasons per year: a rainy season from April to October and a dry season from November to April [9].

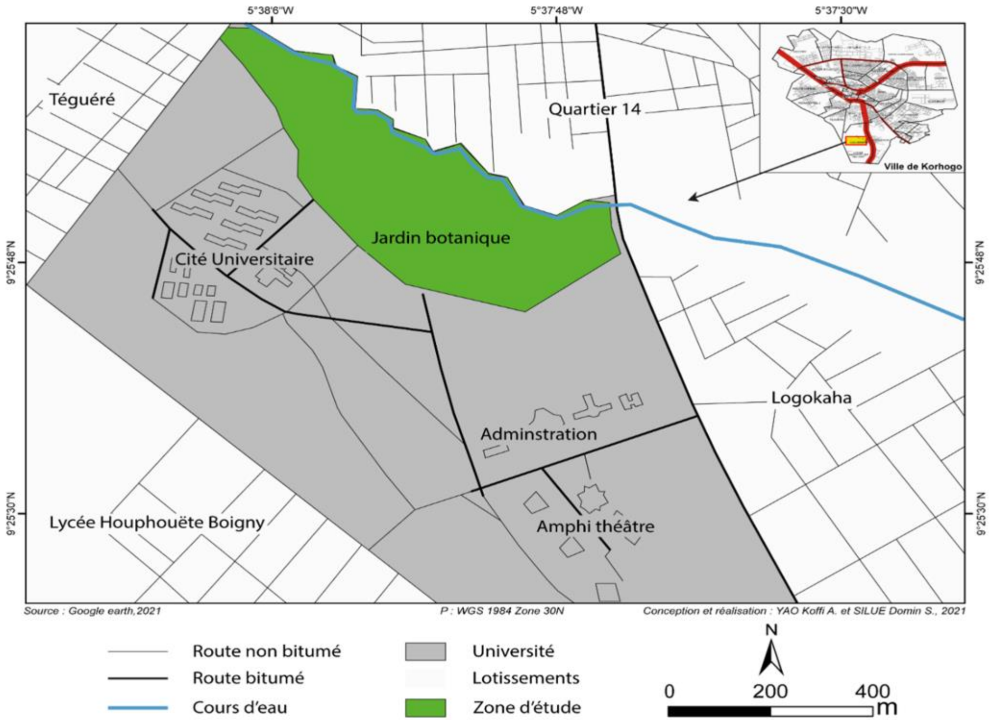

Figure 1: Location of the study site

2.2. Data collection

2.2.1. Study design

The experimental device was a Fisher block, with three repetitions. The different treatments (protected and unprotected plants) were carried out randomly on twelve elementary plots within a grid of 4 m x 3.2 m, each, consisting of four lines (4 m each). The distance between the sowing lines was 0.8 m and the distance between the pockets on the same line was 0.4 m. Two varieties of maize (V1: EV8728-SR and V2: LG501) underwent different treatments. The first variety (V1) is yellow and semi-toothed. It's rich in protein and drought tolerant, with a cycle of 100 days and an intermediate maturity [10]. The second variety (V2) is yellow-orange. It's also rich in protein, has large seeds on the ears and is rust tolerant [10]. Of intermediate maturity, its cycle varies between 105 days and 110 days. The maize was chosen as it's one of the main cash crops in the region. Fertilizers were applied at the beginning of the sowing season, insecticides and fungicides were irregularly applied depending on the infestation rate. Weeds were removed manually.

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2.2.2. Determination of bee diversity

Bees were captured using pan traps (yellow) and sweep net (Figure 2). The pan traps were placed in the plots containing 60 unprotected plants. In each plot, ten pan traps were installed at the panicles height (Total: 60 traps). Each pan trap was filled with salt (NaCl) saturated water and a small drop of detergent. The traps were left activated for 48 hr during each sampling turn. The sweep net was used to complement pan traps. Specimens of bees were collected, stored in ethyl alcohol (70%), and thereafter pinned and identified to genus or species if possible. Bee identification was made under a binocular magnifying glass (Motic) using identification keys of Aberlenc, ABC Taxa and the reference collection of bees, established by Coulibaly since 2015.

A: Pan trap **B: Sweep net**

Figure 2: Techniques for capturing bees

2.2.3. Assessment of bee activity

To assess insect ability to visit maize flowers, we adapted to our study the observation methods used by Djonwangwé et al. [11] and Pando et al. [12]. Indeed, the observations were carried out from 6 a.m. to 5 p.m., corresponding to the periods of high bee activity. Data were recorded by time slots. For each time slot, ten panicles per plot were chosen at random, and observed for ten minutes (one minute per panicle). The number of visits operated by insect was recorded. Only, one visit was counted per insect, i.e. when leaving the panicle, we stopped counting its visits. The collected data were used to determine the frequency of each insect species (Fi) on the panicles according to the following formula: $Fi = ((Vi/VI) \times 100)$, with Vi: number of ''insect i'' visits on unprotected panicles and VI: number of all insect visits on the same panicles [13]. Using a thermo-hygrometer, temperature and relative humidity were recorded.

2.2.4. Impact of bee activity on the parameters of production

For each variety, 15 plants were protected to the insect and 15 other plants were still unprotected (Figure 3). At the end of the season, we recorded whether each variety set fruit, and the quality parameters (size and mass of ears, number and mass of seeds and germination rate). Excepted, the germination rate, the other parameters of production were measured on 60 ears (5 ears per elementary plot). Concerning the germination rate, 120 seeds including 60 seeds per variety resulted from the first generation were used. Indeed, for each variety, 30 seeds were taken at random from 15 ears of protected plants and 30 other seeds from 15 ears of unprotected plants (two seeds per ear). The collected seeds were sown in two alveolar plates containing nursery compost. Each day during one week, we counted germinated seeds until all seeds had either germinated or decayed. The number of germinated seeds was recorded and the germination rate was calculated using the following formula: Tg = (Number of germinated seeds / Number of seeds sown) x 100.

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A


Figure 3: Treatments on the plants of maize (A: unprotected plants; B: protected plants)

2.2.5. Data analysis

All statistical analyses were performed using STATISTICA software version 7.1. To compare the mean abundance of bees, we used the analysis of variance (ANOVA) and Duncan's test at 5% threshold.

3. RESULTS

3.1. Frequency of visits

For the variety EV8728-SR: During the flowering period, 4970 visits were recorded on 30 panicles. These visits were made by four orders of insects (Hymenoptera, Diptera, Odonata and Lepidoptera). Among which, Hymenoptera were the most frequent (F = 93.74%) with an average rate of 12.94 visits per minute per panicle. The frequencies of visits by Diptera, Odonata and Lepidoptera, were F = 4.16%, F = 1.59% and F = 0.5%, respectively. Their average rate of visits were comprised between 0.07 and 0.57 visits per minute per panicle (Table 1).

For the variety LG501: A total of 4211 visits were recorded on 30 panicles during the flowering period. Hymenoptera, Diptera, Odonata and Lepidoptera were responsible of these visits. Hymenoptera were the most frequent visitors (F = 93.49%) with an average rate of 10.94 visits per minute per panicle. Diptera (4.39%), Odonata (1.67%) and Lepidoptera (0.45%) had the lowest average rate of visits, respectively. Their average rate of visits were comprised between 0.053 and 0.51 visits per minute per panicle (Table **1**).

Table 1: Frequency of visits on each variety of maize

Variety EV8728-SR			**Variety LG501**		
Order	Number of visits	Frequency (%)	Order	Number of visits	Frequency (%)
Hymenoptera	4659	93.74	Hymenoptera	3937	93.49
Diptera	207	4.16	Diptera	185	4.39
Odonata	79	1.59	Odonata	70	1.67
Lepidoptera	25	0.5	Lepidoptera	19	0.45
Total	4970	100	Total	4211	100

3.2. Evolution of the frequency of visits according to some abiotic parameters

The curves of activity showed that the bees were active throughout the day from 6 a.m. to 5 p.m. The peak of activity was between 8 a.m. and 9 a.m. which was reached for a temperature corresponding to 31.39° and a relative humidity of 60.58% (Figure 4).

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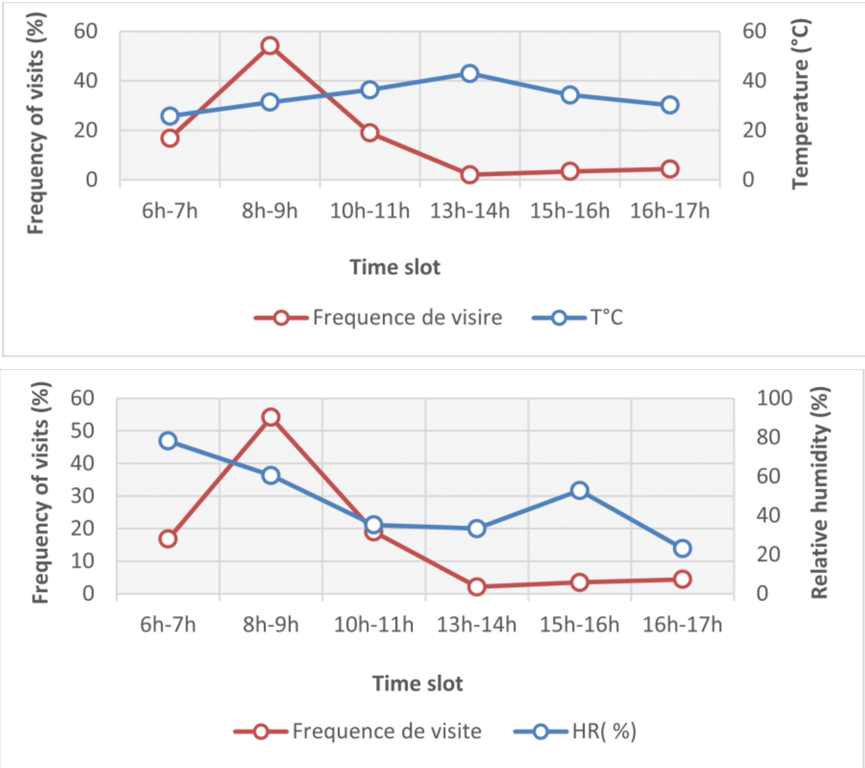

Figure 4: Curves of bee activity as a function of temperature and relative humidity

3.3. Diversity of bees

A total of 68 bee specimens belonging to 9 species, 8 genera and 3 families (Apidae, Halictidae and Megachilidae) were recorded on the variety EV8728-SR (Table 2). Apidae (47 specimens) were the most abundant family, followed by Halictidae (20 specimens) and Megachilidae (1 specimen). Concerning the bee species, *Apis mellifera* (45 specimens) was the most abundant, followed by *Lipotriches* sp (8 species), *Sphecodes* sp (7 species) and *Lasioglossum* sp (3 species). The species *Ceratina* sp, *Hypotrigona* sp, *Leuconomia granulata*, *Leuconomia* sp and *Creightonella discolor* were included a single specimen, each.

A total of 94 bee specimens belonging to 10 species, 10 genera and 3 families (Apidae, Halictidae and Megachilidae) were recorded on the variety LG501 (Table 2). Apidae (68 specimens) were the most abundant family, followed by Halictidae (25 specimens) and Megachilidae (1 specimen). The specie *Apis mellifera* (64 specimens) was the most abundant, followed by *Lipotriches* sp (8 specimens), *Sphecodes* sp (6 specimens), *Lasioglossum* sp (5 specimens), *Leuconomia* sp (4 specimens) and *Meliponula* sp (3 specimens). The other species *Hypotrigona* sp, *Seladonia* sp, *Trinomia* sp and *Megachiles* sp were included a single specimen, each.

Table 2: Taxonomic richness of bees

Varieties	Families	Genera	Species	Total
EV8728-SR	Apidae	*Apis*	*Apis mellifera*	45
		Ceratina	*Ceratina* sp	1
		Hypotrigona	*Hypotrigona* sp	1
	Halictidae	*Lipotriches*	*Lipotriches* sp	8
		Sphecodes	*Sphecodes* sp	7
		Leuconomia	*Leuconomia granulata*	1
		Leuconomia	*Leuconomia* sp	1
		Lasioglossum	*Lasioglossum* sp	3
	Megachilidae	*Creightonella*	*Creightonella discolor*	1
Total	3 families	8 orders	9 species	68
LG501	Apidae	*Apis*	*Apis mellifera*	64
		Meliponula	*Meliponula* sp	3
		Hypotrigona	*Hypotrigona* sp	1
	Halictidae	*Sphecodes*	*Sphecodes* sp	6

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		Lipotriches	*Lipotriches* sp	8
		Lasioglossum	*Lasioglossum* sp	5
		Leuconomia	*Leuconomia* sp	4
		Seladonia	*Seladonia* sp	1
		Trinomia	*Trinomia* sp	1
	Megachilidae	*Megachiles*	*Megachiles* sp	1
Total	3 families	10 orders	10 species	94

3.4. Impact of bee activity on some parameters of production

3.4.1. Mass of ears

The average mass of ears from unprotected plants (EV8728-SR: 169.45 ± 5.15 g and LG501: 205.31 ± 2.23 g) was higher compared to that from protected plants (EV8728-SR: 77.49 ± 1.70 g and LG501: 101 .79 ± 1.93 g). The analysis showed a significant difference between the average mass of ears from unprotected plants and protected plants ($p < 0.05$) (Figure **5**).

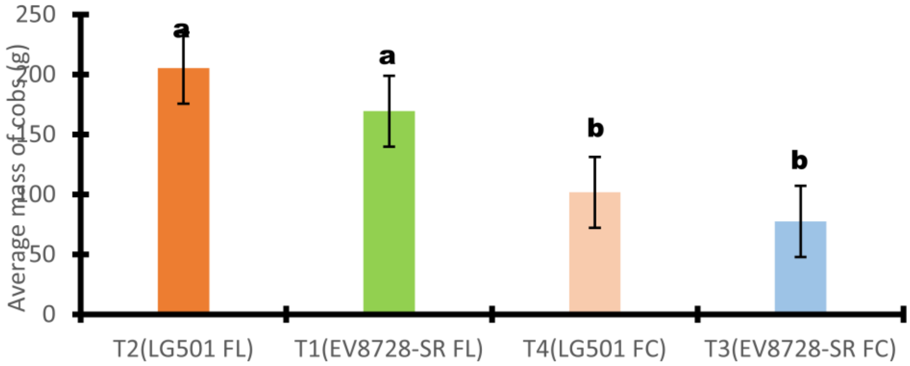

Figure 5: Average mass of ears according to the treatments

3.4.2. Mass of seeds

The average mass of seeds per ear from unprotected plants (EV8728-SR: 135.18±7.78 g and LG501: 165.29±2.97 g) was higher than that from protected plants (EV8728-SR: 61.72±1.73 g and LG501: 77.65±1.64 g). The analysis showed a significant difference between the average mass of seeds per ear from each treatment ($p < 0.05$) (Figure 6).

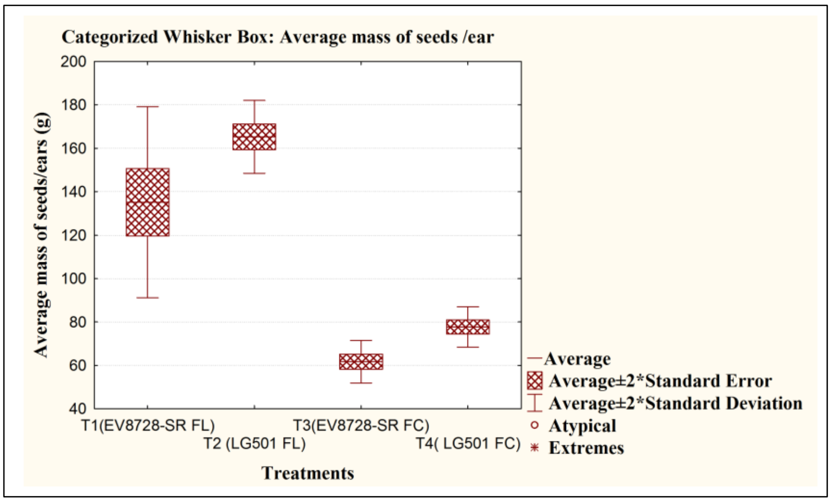

Figure 6: Average mass of seeds according to the treatments

3.4.3. Number of seeds

The average number of seeds per ear from unprotected plants (EV8728-SR: 445.8 ± 17.92 and LG501: 442.27 ± 6.8) was higher compared to that from protected plants (LG501: 242.13 ± 4.39 and EV8728-SR: 208.6 ± 9.52). The analysis showed a significant difference between the average number of seeds from the unprotected plants and the protected plants ($p < 0.05$) (Figure **7**).

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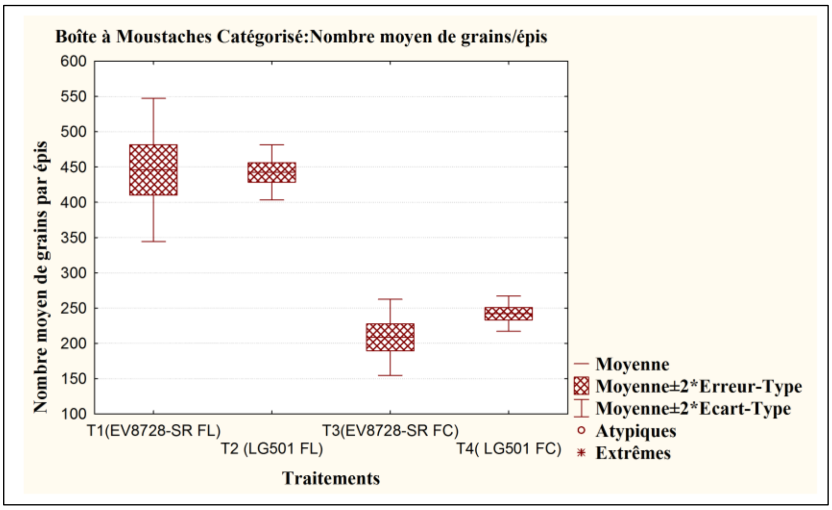

Figure 7: Average number of seeds according to the treatments

3.5. Fruit quality and germination rate

The exclusion of insects decreased significantly fruit quality. Regardless of the variety of maize, ears from unprotected plants had fewer damaged seeds (Figure **8)**. The germination rate of seeds from unprotected plants (Variety EV8728-SR: Tg = 96.67% and Variety LG501: Tg = 100%) was higher compared to the protected plants (Variety EV8728-SR: Tg = 66.67% and Variety LG501: Tg = 56.67%). Seeds from unprotected plants were more viable and germinate better.

Figure 8: Different batches of ears from the two treatments (A: ears from unprotected plants; B: ears

4. DISCUSSION

Our study showed that maize could be considered as a melliferous plants because we recorded a various diversity of bees on this plant. However, the richness of bees recorded in our study was low compared to a similar study carried out in Marouna, in the north of Cameroon [12]. Indeed, the two studies were conducted in areas which differ from an

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environmental and ecological point of view. Marouna city belongs to the Sahelian climate while Korhogo city is located in a Sudano-Sahelian climate. These results confirm the fact that floral entomofauna diversity of a plant varies in time and space [14]. This study showed that the insects which visit maize inflorescences belong mainly to order Hymenoptera. In this order, visits by bees (Apidae, Halictidae and Megachilidae) were the most frequent but, dominated by honey bee (Apidae). Indeed, honey bee is abundant in culture environments because of its life in society and its ability to pollinate a wide variety of flowers. It's also abundant because of beekeeping intensification in the region of Korhogo. The same results were reported by Dounia and collaborators, who showed that *Apis mellifera* was the most frequent on maize panicles in Yaoundé [15]. In a similar study, Phaya in Thailand and Fichtl in Ethiopia showed that honey bee was the most active insect on maize panicles [16, 17]. That could be explained by a strong presence of honey bee in these localities or by its attachment to pollen as a source of food that this speculation offers it. This study revealed that bees are frequents on maize panicles throughout the day of observation. The peak of bee activity between 8 a.m. and 9 a.m. would be linked to the period of high availability of nectar in the maize inflorescences. In a similar study on the oil palm, the peak of bee activity was in the morning at 11 a.m. [18]. Therefore, morning would be the period when most plants secrete a large quantity of nectar. This study showed a non-significant negative correlation between temperature and the frequency of visits. Indeed, many bee species such as honey bee prefer times of low sunlight. These disappear gradually when the temperature increases sharply beyond a threshold. The same is true for relative humidity, which is positively correlated with bee activity. The economically important parameters (mass of ears, mass of seeds and number of seeds) increase significantly when the plants are unprotected. Higher number of seeds and increased mass of ears are an important characteristic for maize from both a commercial and ecological point of view as it is considered an important indicator of plant reproductive success. However, the seeds resulting from the protected plants would be due to the wind action, able of crossing pollen cages through the meshes of the anti-insect net. In addition, seeds resulting from unprotected plants germinated better, while seeds resulting from protected plants had a lower germination rate. This finding is highly relevant for smallholders who make maize production a core economic activity. Because, if the exclusion of pollinators is likely to reduce the germination rate of seeds, the protection of bees remains essential to conserve viable seeds. These results clearly show the impact of bee activity on maize production.

5. CONCLUSION

This study revealed that visitors of maize inflorescences were very diverse insects. Four orders of insects were identified among which, Hymenoptera were the most frequent. Their frequencies of visits were 93.74% on the variety EV8728-SR and 93.49% on the variety LG501. The honey bee "*Apis mellifera*", belonging to family Apidae, was the most abundant and frequent species. Its activity was more intense in morning between 8 am and 9 am. The economically important parameters (mass of ears, mass of seeds and number of seeds) increased when the plants were unprotected. The germination rate was higher for the seeds resulting from unprotected plants. The findings confirmed the contribution of bees in maize production improvement. In addition to use fertilizer, it would be important to monitor bee activity on the inflorescences to ensure a good production of maize.

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AUTHOR’S CONTRIBUTIONS

DC and YT designed the study. PS collected data in the field. DC determined bee species. DC analysed and plotted output data. MK and LK contributed towards data sorting. DC and YT wrote the first draft of the manuscript. All authors contributed substantially to revisions.

CONFLICT OF INTEREST

The authors have no conflict of interest in relation to this work.

DATA AVAILABILITY STATEMENT

The data of this study are available on re-quest from the corresponding author. The data are not publicly available due to privacy restrictions.

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ORCID
https://orcid.org/0000-0002-8495-5773

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