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Effects of maize-cowpea crop association on the caterpillars of certain noctuids in the southern part of the Senegalese agricultural basin

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Abstract

Maize cultivation currently faces numerous challenges, particularly pest infestations. To combat this issue, farmers tend to resort to various control methods. In this context, our study aimed to assess the effect of intercropping maize with cowpea on maize pest caterpillars for sustainable maize production. An experimental split-plot design was set up. Six rows of maize per plot were sown, running parallel to the width of the block. Ten days later, cowpea was intercropped with maize only along the first three rows of each plot in the block. Fifteen days after the maize was sown, the entire block was weeded, and the plots were fertilized with 10-10-20 mineral fertilizer. A second weeding was carried out twenty days after the first. Sampling was conducted once a week. In the laboratory, the caterpillars were identified, and their abundance and frequency of occurrence were determined. Finally, the number of maize plants without ears, with one ear, and with two ears was recorded per plot. The results obtained from the experiment showed that the species *Spodoptera frugiperda*, *Helicoverpa armigera*, and *Chrysodeixis chalcites* were not as abundant in both intercropped and pure maize plots, unlike *Spodoptera littoralis*. Eight surveys were carried out on the experimental site, with one survey conducted per week. From September 2nd, *S. littoralis* populations in pure maize plots reached a significant peak with approximately 78 individuals, then gradually declined until September 9th. In contrast, in the maize–cowpea intercrop, the peak occurred later with around 57 individuals, and the population of *S. littoralis* then sharply declined, becoming nonexistent by September 30th. Intercropping reduced the *S. littoralis* population and delayed the peak of its population growth. The number of maize plants without ears was higher in pure maize plots than in maize–cowpea intercropped plots. The same trend was observed for plants bearing one or two ears.

Keywords: Crop association, maize, caterpillars, noctuidae, agricultural bassin

Introduction

Agriculture plays a key role in the socio-economic development of populations as a major sector of activity (Yarou *et al*., 2017) [48]. In Senegal, local cereals create many opportunities for different actors in agricultural value chains, whether producers, processors or traders (Barro, 2018) [4]. The dominant cereal crops in Senegal are millet and maize, while the most cultivated legumes are peanuts, once the mainstay of the country's economy, and cowpeas (Guèye *et al*., 2011) [22]. Agriculture faces many challenges, including the ravages caused by harmful insects, particularly caterpillars of the Noctuidae family. Each year, pests destroy up to 40% of global production according to the FAO (Sall *et al*., 2023) [40]. The caterpillars of Spodoptera frugiperda (Smith, 1797), *Spodoptera littoralis* (Boisduval, 1833), *Helicoverpa armigera* (Hübner, 1808) and *Chrysodeixis chalcites* (Esper, 1789) are major pests for agricultural crops in Senegal. While all parts of the plant are susceptible to attack, the most noted damage is associated with the stem, ears and grains (Philogène & Arnason, 1995) [36]. Consequently, in the absence of integrated pest management solutions adapted to local realities, Senegalese agriculture would continue to suffer from yield losses. It is in this sense that less expensive synthetic products are often used.However, the intensive use of these chemicals to control pests is common practice, but they are toxic to humans, who can absorb them through contact, inhalation, and ingestion. The presence of this toxicity requires restricting or even eliminating their presence in food and applying strict handling rules (Gagui, 2017) [16]. In this context, it is becoming crucial to seek more ecological and sustainable alternatives to combat caterpillar infestations and maintain the health of agricultural ecosystems. Intercropping is a technique commonly used in tropical regions, promoting sustainable management of soil fertility, increasing yields in traditional agriculture, and improving the incomes of small producers (Perrin & Lefevre, 2019) [35]. Based on this observation, the following hypothesis was put forward: crop association significantly reduces the caterpillar population in agricultural crops in Senegal while protecting the environment and producers.

Materials and Methods

Test site

Located in the district of Mbadakhoune and in the department of Guinguinéo, the commune of Mbadakhoune has an area of 106.63 km² with 78% of arable land. Due to its geographical position, the Commune of Mbadakhoune is limited to the East by the Commune of Ngathie Naoudé, to the West by the Commune of Khelcom Birane and the Commune of Kaolack, to the North by the Communes of Ngagnick and Ourour and to the South by the sea arm "le Saloum" and the Commune of Kahone (PNDL, 2017) [37].

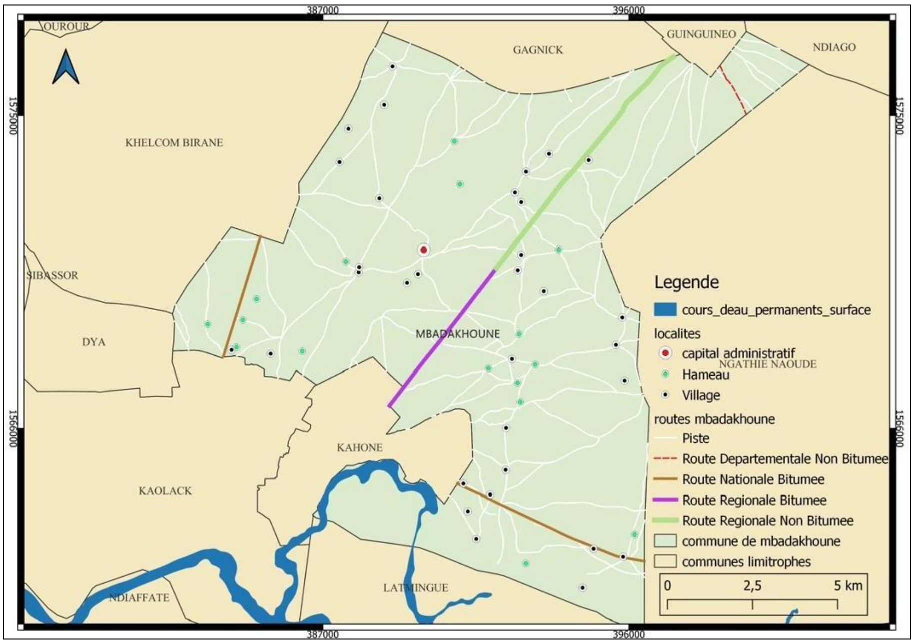


Fig 1: Location map of the experimental site

Biological Material

The biological material used was cowpea, cultivated corn, and insects.

Study Population

The study population consisted of four caterpillars: *Spodoptera frugiperda*, *Spodoptera littoralis*, *Helicoverpa armigera*, and *Chrysodeixis chalcites*.

Experimental device

To study the effect of the corn-cowpea association on *S. frugiperda*, *S. littoralis*, *H. armigera*, and *C. chalcites*, it is essential to design an experimental design to ensure proper implementation of the trial. The test requires the installation of an elementary plot that will be observed at least once and considered alone when the results are reviewed (APMEP 2008) [2].

It consisted of

- Have a 500 m2 block containing manure ploughed over its entire surface with a tractor and delimited a 472.5 m2 (37.8m 12.5m) block using method 3-4-5 to obtain a right angle as a reference.
- Parcelling this block into six equal parts, maintaining an inter-plot space 12.5 m long and 1.6 m wide. The first parcel located at the extreme west representing the elementary parcel is 12.5m long and 4m wide while the other five plots are repetitions,
- Sow six rows of maize per plot parallel to block width with 80 cm line spacing using a twelve-hole disc,
- Ten days after sowing, combine bean and maize only on the first three lines of each block plot and then weed out the entire block 15 days after planting corn,
- Fertilize the plots after weeding with NPK mineral fertilizer at a rate of 7, 08 kg (150 kg/ha) before performing a second weeding twenty days after the first,
- Conduct eight surveys by sampling one weekly using equipment (test tubes, 70% alcohol, sachets, markers, glue, notebook, water, full suits) and observing all corn lines,
- Count stalks with one ear, two ears and no ear in each parcel,
- Finally, identify collected insects in the laboratory using identification keys and laboratory equipment.

Edge bands were also installed on both sides of the experimental system to prevent edge phenomena (APMEP, 2008) [2]. Remark: the used variety is JKMH45/Indian Hybrid that produces usually one corncob.

Technical route

The maize variety used was JKMH45/Indian hybrid. Six rows of maize were sown per plot, parallel to the width of the block. Ten days later, the maize was intercropped with cowpea only in the first three rows of each plot in the block. Fifteen days after sowing the maize, the entire block was weeded and the plots were fertilized with 10 10 20 mineral fertilizer. Twenty days after the first weeding, the second was carried out. Finally, the number of plants with one ear (two ears) was determined per plot.

Sampling

Sampling was conducted once a week using equipment (test tubes, 70% alcohol, sachets, markers, glue, notebook, water, and full body suits) from 20 days after corn emergence until maturity. All corn rows were observed while collecting insects. Insects were collected directly from the plant using insect tweezers. Insects in the larval stages were collected. Subsequently, the pest species present were collected from the cobs. They were placed in labeled tubes containing 70% alcohol to prevent rot.

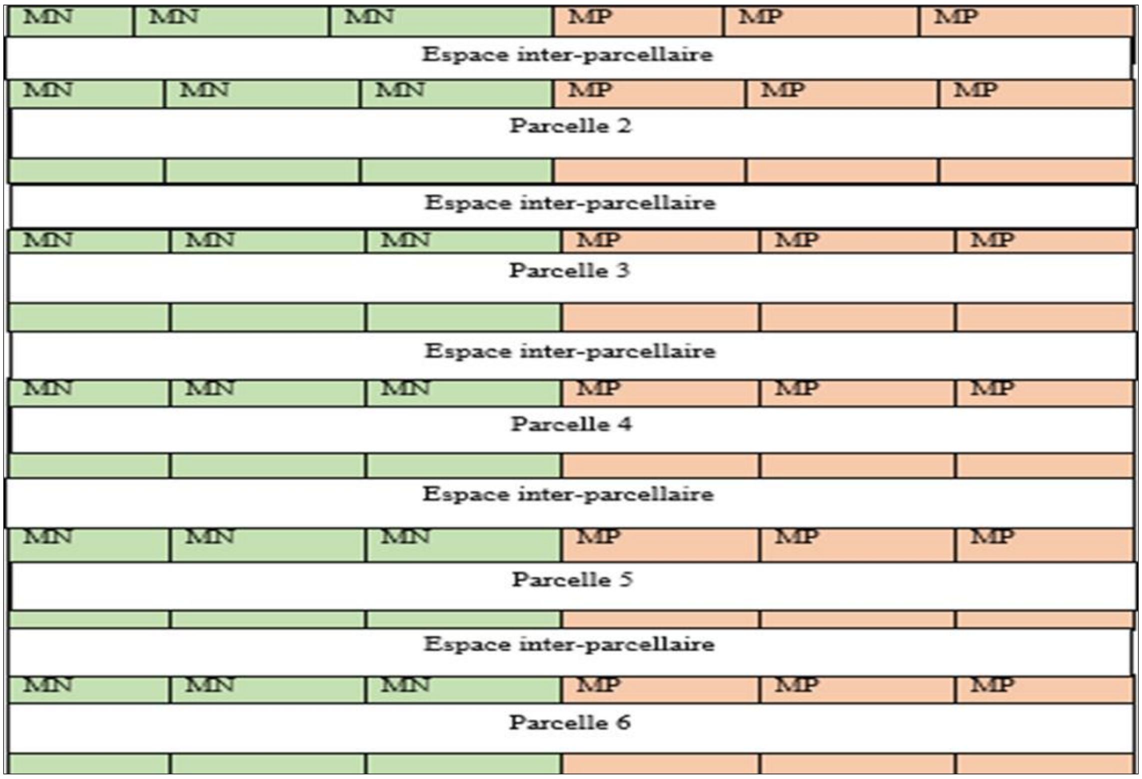


Fig 2: Diagram of the experimental device

Species Identification

To observe the species, magnifying glasses were used. Species are classified according to the sampling location. To identify the species, the insect collection available at the Laboratory of Entomology and Acarology (LEA) in the Department of Animal Biology and the identification keys (Collingwood *et al*., 1984; Delvare & Aberlenc, 1989) [10] [13] were used.

Noctuids are characterized by the presence of three longitudinal stripes in the larval stage. *Spodoptera frugiperda* has, in addition to the stripes, an inverted Y on its head and four black spots forming a square on the last segment. *S. littoralis*, on the other hand, has black triangular spots on the first and eighth segments. In addition to the stripes, *H. armigera* changes color from yellow or green to gray, black, or brown. *C. chalcites* larvae are pale yellow-green in color with a glassy green to gray head bordered by a black band. Below the spiracles on each side is a thicker white line from the head to the tip of the anal leg.

Parameters studied

Absolute abundance

(Aa) is the total number of captured individuals of a species (Faurie *et al*., 2003) [14]. It was obtained by summing the number of individuals from the eight surveys of these species in the associated plots (maize-cowpea) and those not associated (pure maize).

Relative abundance

The relative abundance (Ar) or the centesimal frequency (Fc) of a given species corresponds to the percentage of individuals of this species (ni) compared to the total number of individuals recorded (N) in a population (Dajoz, 1985) [12].

Ar (%) = Aa*100/N

Aa: Total absolute abundance

N: Total number of individuals of all species combined

According to Faurie *et al*. (2003), relative abundance values are classified at several levels: If Ar% < 5% then the species is very rare

If 5% Ar% < 25% the species is rare

If 25% ≤ Ar% < 50% the species is common If 50% ≤ Ar% < 75% the species is abundant If Ar% ≥ 75% the species is very abundant.

Frequency of occurrence or consistency

Consistency is the ratio between the number of records containing species i and the total number of records multiplied by one hundred (Dajoz, 1985) [12].

Fo (%) = Pi*100/P with Pi: number of records where species i is present and P: total number of records. According to Dajoz (1982), depending on the values of Fo, several categories of species are identified:

Rare species if Fo < 5%

Accidental species if 5%≤ Fo < 25%

Incidental species if 25%≤ Fo < 50%

Regular species if 50% ≤ Fo < 75%

Constant species if 75% ≤ Fo < 100

Ubiquitous species if Fo = 100% (Faurie *et al*., 2003) [16]

Statistical analyzes

Data entry was performed using Excel (2010) software. The data obtained were submitted to R version 4.4.1 (R Core team, 2024) [38] for statistical tests on abundance and frequency. According to the statistical tests, the variables that follow the normal distribution were subjected to the Student test and those that do not follow the normal distribution are treated with the Wilcoxon test. The significance threshold is set at 5%.

Results and discussion

Inventory and abundance of caterpillars encountered

In our study, the species *Spodoptera frugiperda*, *Helicoverpa armigera*, *Chrysodeixis chalcites* and *Spodoptera littoralis* were inventoried. The first three are not as abundant or frequent, either in mixed cultivation or in monoculture, unlike *Spodoptera littoralis*.

- **Abundance and constancy of *S. frugiperda* populations**

The absolute abundance and frequency of occurrence of *S. frugiperda* are shown in Table I. The presence of a single individual was observed in the intercropped plots with a frequency of occurrence of 12.5% and its absence in the pure crop plots, during the eight (8) surveys.

Table 1: Abundance and constancy of *Spodoptera frugiperda* populations

Prospecting	Absolute abundance		Frequency of occurrence (%)		Relative abundance (%)	
	Cowpea-corn	Pure corn	Cowpea-corn	Pure corn	Cowpea-corn	Pure corn
26 /08 /2024	0	0	12.5	0	100	0
02 /09 /2024	0	0				
09 /09 /2024	0	0				
16 /09 /2024	0	0				
23 /09 /2024	1	0				
30 /09 /2024	0	0c				
07 /10 /2024	0	0				
14 /10 /2024	0	0				
TOTAL	1	0				

- **Abundance and constancy of *H. armigera* populations**

Table (II) shows a low absolute abundance of *H. armigera* in both intercropping (maize-cowpea) and pure cropping (pure maize), with one individual each. Its frequency of occurrence is 12.5%. *H. armigera* is accidental in both types of crops.

Table 2: Abundance et constancy of *Helicoverpa armigera* populations

Prospecting	Absolute abundance		Frequency of occurrence (%)		Relative abundance (%)	
	Cowpea-corn	Pure corn	Cowpea-corn	Pure corn	Cowpea-corn	Pure corn
26 /08 /2024	0	0	12.5	12.5	50	50
02 /09 /2024	0	0				
09 /09 /2024	1	0				
16 /09 /2024	0	0				
23 /09 /2024	0	1				
30 /09 /2024	0	0				
07 /10 /2024	0	0				
14 /10 /2024	0	0				
TOTAL	1	1				

- **Abundance and constancy of *C. chalcites* populations**

The population of *C. chalcites* is very low (2 individuals) and its frequency of occurrence is 25% in intercrops (corn-cowpea) compared to pure corn with an abundance of one (1) individual and a frequency of occurrence of 12.5% (Table III). Therefore, *Chrysodeixis chalcites* is accidental in crops.

Table 3: Abundance et constancy of *Chrysodeixis chalcites* populations

Prospecting	Absolute abundance		Frequency of occurrence (%)		Relative abundance (%)	
	Cowpea-corn	Pure corn	Cowpea-corn	Cowpea-corn	Pure corn	Cowpea-corn
26 /08 /2024	0	0	25	12.5	66.66	33.33
02 /09 /2024	0	0				
09 /09 /2024	0	0				
16 /09 /2024	0	0				
23 /09 /2024	2	0				
30 /09 /2024	0	0				
07 / 10 /2024	0	1				
14 /10 /2024	0	0				
TOTAL	2	1				

- **Abondance and constancy of *S. littoralis* populations**

The population of *S. littoralis* occurs with an absolute abundance of 118 in corn-cowpea association and 155 in pure corn. The frequency of occurrence is higher in pure corn with percentages of 62.5% and 50% in corn-cowpea (Table IV). The species *S. littoralis* is regular in pure corn crops and accessory in associated corn crops with a relative abundance of 56.77% in non-associated plots and 43.22% in associated plots.

Table 4: Abondance and constancy *Spodoptera littoralis* populations

Prospecting	Absolute abundance		Frequency of occurrence (%)		Relative abundance (%)	
	Cowpea-corn	Pure corn	Cowpea-corn	Cowpea-corn	Pure corn	Cowpea-corn
26 /08 /2024	0	0				
02 /09 /2024	0	0				
09 /09 /2024	20	76				
16 /09 /2024	38	37				
23 /09 /2024	57	36				
30 /09 /2024	3	5				
07 /10 /2024	0	1	50	62.5	43.22	56.77
14 /10 /2024	0	0				
TOTAL	118	155				

Population dynamics of *S. littoralis*

The analysis of Figure 3 shows the evolution of the dynamics of *S. littoralis* populations in the plots consisting of pure maize and those consisting of maize-cowpea. Eight surveys were carried out at the trial level due to one survey per week. The results showed the absence of *S. littoralis* during the surveys from August 28 to September 2 and those from September 30 to October 14 in both types of crops. From September 2, the populations of S. littoralis in pure maize experienced a significant peak with approximately 78 individuals which gradually decreased by September 9. On the other hand, for the maize-cowpea association, the peak was late with approximately 57 individuals then the population of S. littoralis decreased sharply before becoming zero by September 30.

PMN = Corn-cowpea prospecting
PMP = Pure corn prospecting

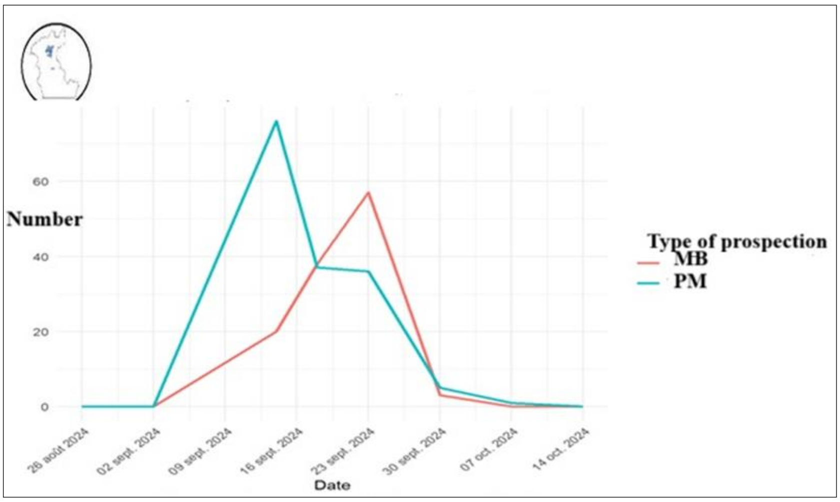
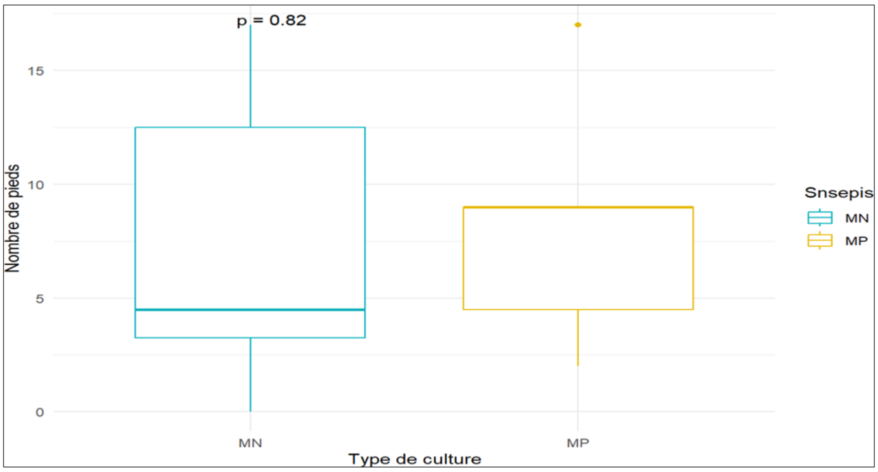


Fig 3: Dynamics of *S. littoralis* populations in terms of time

Variation in the number of feet without ears

The variation in the number of earless plants according to the type of crop is shown in Figure 4 following the Shapiro test with a p-value of 0.82. The number of earless plants in pure corn is higher in absolute value than that in corn-cowpea association.



MN= Cowpea-corn; MP= Pure corn

Figure 4: Variation in the number of earless plants depending on the type of crop

Variation in the number of feet with an ear

The variation in the number of plants with an ear depending on the type of crop is shown in Figure 5 following the comparison test. We note that the production of one ear per plant is higher, in absolute value, in the pure corn plots.

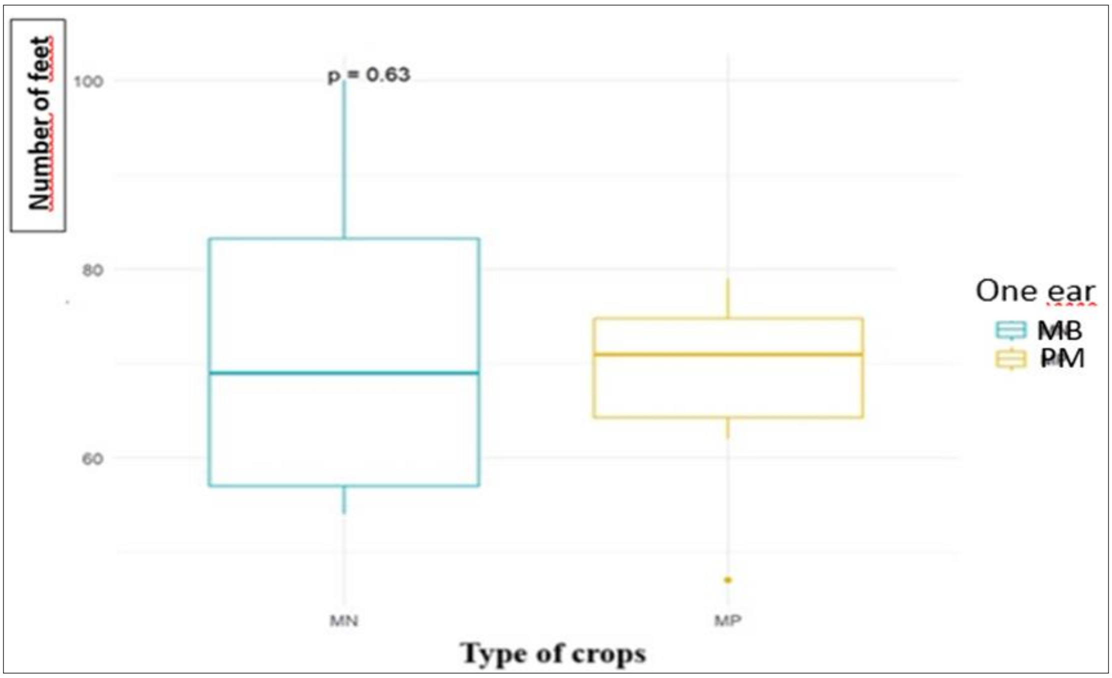


Fig 5: Maize stalks producing a corncob in MB and PM

Variation in the number of feet with two ears

The number of plants with two ears according to the type of crop is shown in Figure 6 following the comparison test with a non-significant p-value of 0.12. In absolute value, its value is higher in pure maize plots than in plots consisting of maize-cowpea.

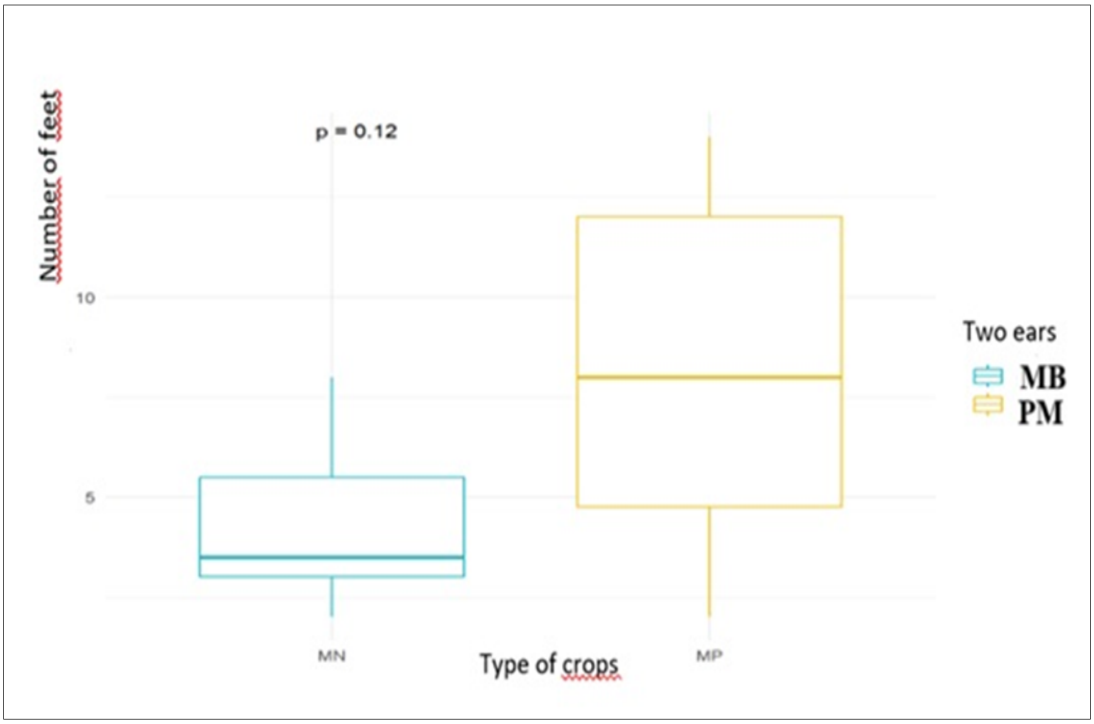


Fig 6: Maize stalks producing two corncobs in MB and PM

Fig 7 shows the number of corn stalks without cobs in the different MB and PM treatments. The number of earless corn plants was higher in the control plots (CP) than in the associated plots. The parametric test carried out shows that the p-value is significantly higher than 0.05 and is equal to 0.82.

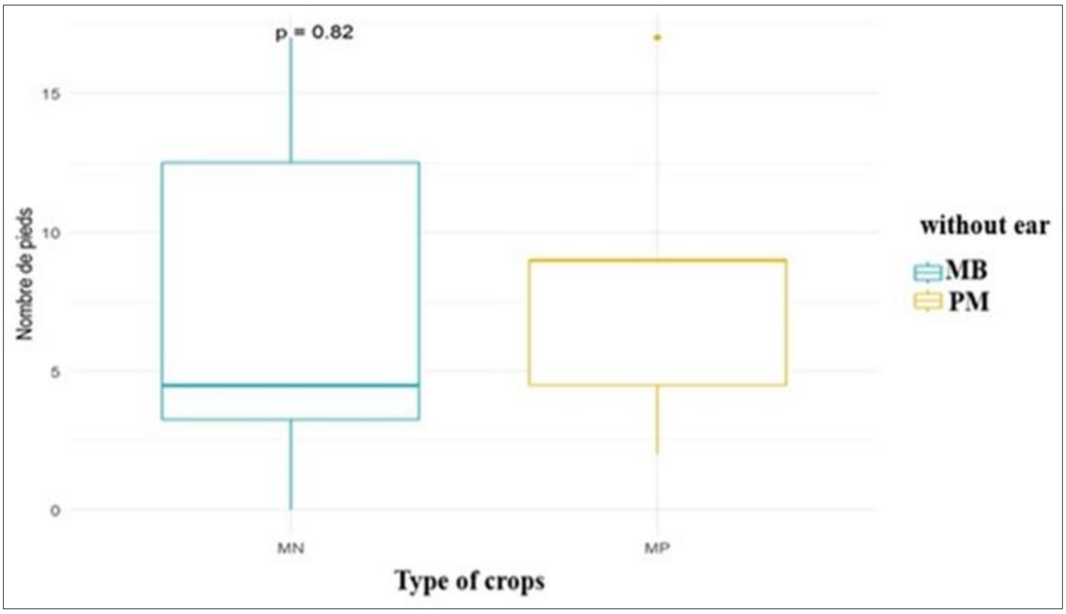


Fig 7: Corn stalks without cobs in MB and PM

Discussion

This study aimed to determine the effect of crop association in the control of *S. frugiperda*, *S. littoralis*, *H. armigera*, and *C. chalcites* caterpillars in the Senegalese agricultural basin to maintain these pests at a rate below economically acceptable threshold. Indeed, it appeared that the analysis of the frequency of occurrence shows that *S. frugiperda*, *H. armigera*, and *C. chalcites* are accidental in both types of crops. Only *S. littoralis* is constant with a relative abundance of 43.22% in non-associated plots and 56.77% in associated plots. The low population of *S. frugiperda* could be explained by the fact that these species practice interspecific cannibalism. These results corroborate those of Ortega (1988) [34] stating that during the second or third larval stage, *S. frugiperda* species devour each other. The low abundance of H. armigera could be explained by the fact that they are in competition with *S. frugiperda* populations and that the former dominates. This could explain the absence of *S. frugiperda* in pure maize plots. The *C. chalcites* population occurs with a higher frequency of occurrence in maize-cowpea than in pure maize. This difference could be explained by the fact that in the maize-cowpea association, the populations of *S. frugiperda* and those of *H. armigera* are in low abundance, which reduces competition for resources. This could favor the establishment of *C. chalcites* populations in these plots. Work by Thomson *et al*. (2010) [45] confirmed that some insects can become major pests when they invade new areas where they have no natural predators or parasites to control their population. This could explain the preponderance of *S. littoralis* in this site. The results of the analysis of the evolution of the dynamics of *S. littoralis* populations showed the absence of this species at the beginning and at the end of the surveys in both types of culture. Indeed, the start of the survey corresponded to the beginning of the wintering period; the lack of rain would have led to a scarcity of food resources, which could prevent the development of this species. The favorable climatic conditions during the wintering period allowed sufficient access to food, thus favoring the proliferation of *S. littoralis*. These results are in line with those of Geurts *et al*. (2012) [19] who stated that factors such as rain and food directly influence the abundance and dynamics of its population. The abundance and frequency of *S. littoralis* were much higher in plots consisting of pure maize than in those consisting of maize-cowpea. Indeed, cowpea could have had a repellent action against *S. littoralis*, thus contributing to a decrease in this population in plots where it is grown in association with maize. Growing maize with cowpea protected maize against *S. littoralis*, making this association beneficial for maize cultivation. Our results corroborate those of Corre-hellou *et al.* (2014) [11] stating that the crop association complicates the canopy structure, increases botanical diversity and can thus induce both visual and olfactory confusion in certain pests. In addition, weeds likely to compete with maize could be slowed down by the maize-cowpea association. This result is close to that of Garba (2007) [18] who showed that the association of two crops (cereal and legume) produces advantages in terms of weed control, soil cover and soil protection against erosion. In our study, the number of plants without an ear, with one ear and those with two ears was also considered depending on the types of cultivation. Indeed, the number of plants with one or two ears and without an ear was higher in plots consisting of pure corn than in those consisting of corn-cowpea but the difference was not significant. This shows that the association does not influence the production of ears in all types of cultivation. In all cases, this association remains largely profitable and beneficial for improving and stabilizing productivity compared to pure corn cultivation while preserving the environment.

Conclusion

This study was conducted to determine the effectiveness of the corn-cowpea crop association in the control of caterpillars in the Senegalese agricultural basin. It revealed a low frequency of the species *S. frugiperda*, *H. armigera* and *C. chalcites*. Only *S. littoralis* is constant with its higher abundance in pure corn than in corn-cowpea. The crop association helps reduce the population of *S. littoralis* but has no effect on the production of the number of plants. In terms of recommendations, it would be interesting to support farmers in the adoption of the corn-cowpea association in the control of the caterpillars of *S. frugiperda*, *H. armigera* and *C. chalcites*, to encourage agricultural policies favoring agro-ecology by trying to carry out early sowing for better control of *S. littoralis* populations. In terms of prospects, it would be interesting to evaluate the effectiveness of cowpea leaf extracts on different species of noctuids, to determine the molecules contained in cowpea leaves acting as repellents, to set up trials in real conditions in different agricultural areas of Senegal to better evaluate the performance of this association.

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