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(Research Article)

Abundance of pests of flood recession maize (*Zea mays* L.) in the Senegal River Valley

Mame Diarra KANE [1,*], Adiouma Georges Robert Jacques SARR [1], Mouhamadou Moustapha NDIAYE [2], Abdoul Aziz NIANG [2] and Mbacké SEMBENE [1]

[1] *Department of Animal Biology, Genomics Laboratory, Faculty of Science and Technology, Cheikh Anta Diop, University of Dakar, Senegal.*

[2] *Fundamental Institute of Black Africa, Cheikh Anta Diop (IFAN-CAD)B. P. 206, Dakar, Sénégal.*

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Abstract

Maize, a foodstuff of economic and nutritional importance, is grown in Senegal in four regions such as the Senegal River valley, especially in the cold season. However, maize is subject to many pests. In view of the damage they cause, a knowledge of the entomofauna remains interesting. The abundance of the entomofauna of floodplain maize in the river valley, particularly in Dembancane, was determined. Thus, a population of 590 individuals was collected. Consequently, the absolute and relative abundance and frequency of occurrence or Constance were evaluated. The Kruskall-wallis test was performed followed by the DUNN test. Following this a Fisher test and a Chi-2 test were performed. From the beginning of flowering to the beginning of ripening, the study covered 58 species of insects and 5 species of spiders belonging to eight orders. The absolute abundance of species varies according to the plot and the development phase. In addition, Heteroptera are the most represented with 35.46% followed by Coleoptera and Orthoptera with 26.24%. The contribution of each species in this study area differs as a result of the different values found of relative abundance and Constance.

Keywords: Abundance; Bio-pest; flood recession maize; Parasitoid; Senegal River Valley

1. Introduction

Global cereal production is dominated by three cereals [1], including maize, which ranks first ahead of wheat and rice [2]. Introduced to Africa by Portuguese explorers around the 16th century [3], maize (*Zea mays* L.) represents a staple food for many African countries [4]. In Senegal, this cereal is mainly grown for its grain in four regions: eastern Senegal, Sine-Saloum, Casamance, and the Senegal River Valley. However, according to statistics from the General Directorate for Agricultural Protection (DGAP), maize production in the valley does not exceed 10% of the national total [3]. Thus, due to climatie changes in this environment, farmers generally grow maize in a rotation system with legumes [5] during the flood season to ensure a low but secure yield [6].

In fact, despite its importance for food and industry, the corn plant is often subject to numerous pests, of which insects are the most distinguished. In addition to the climatic factors limiting the production of corn, the intensification of irrigated agriculture has favored a pullulation of pests causing several losses to the corn in culture. These pests belong to lepidopterans, coleopterans, hemipterans and orthopterans. Of course, all parts of the plant are susceptible to attack, but the most noted pests are associated with roots, stalk, cobs and kernels [7]. As a result, damage occurs, disrupting plant development, reducing yields, and rendering the ear unsuitable for the market.

In response to these constraints related to insect attacks, a research project on irrigated maize production in the Senegal River region was initiated in the early 1990s. In addition, Goebel [8], proposed an overview of the main entomological

* Corresponding author: Mame Diarra KANE

constraints encountered in the Senegal River region and to review the various control options in the new context of irrigated cropping systems. More recently, a census of the entomofauna frequenting sweet corn was made by Mbow [9].

Therefore, a better knowledge of the entomofauna of floodplain maize in the river valley would allow us to contribute to the improvement of floodplain maize crop protection. The general objective of this study is to evaluate the abundance of maize pests and their possible natural enemies in order to find means of control to ensure the maintenance of a rate that is below economically acceptable thresholds. Thus, it is specifically to :

- Determine absolute abundance,
- Assess relative abundance,
- Determine the frequency of occurrence of species.

2. Material and methods

2.1. Study framework

Dembancane is a commune since 2008 in the department of Kanel of the region of Matam. Its coordinates are 15° 05 north and 12° 42 west with an altitude of 23m. It is located near the Senegal River and the border with Mauritania and is crossed by the N2 national road that links Bakel and Matam. According to the eco-geographical zones of Matam, it is located in the locality of Walo, otherwise known as "Dande mayo", a flood zone par excellence characterized by flood recession and irrigated cultivation (corn, sweet potato, sorghum...). These crops, intended for self-consumption, use local varieties. Maize in this area is often rotated with cowpeas and sweet potatoes.

Being an agro-ecological zone, Dembancane is marked by a vegetation dominated by *Acacia nilotica* but also presents *Balanites aegyptiaca*, *Piliostigma reticultum*, *Momordica charantia*, *Ziziphus mauritiana*, *Gossypium* sp... It responds to the needs of the production and supply of agricultural and fisheries products [10].

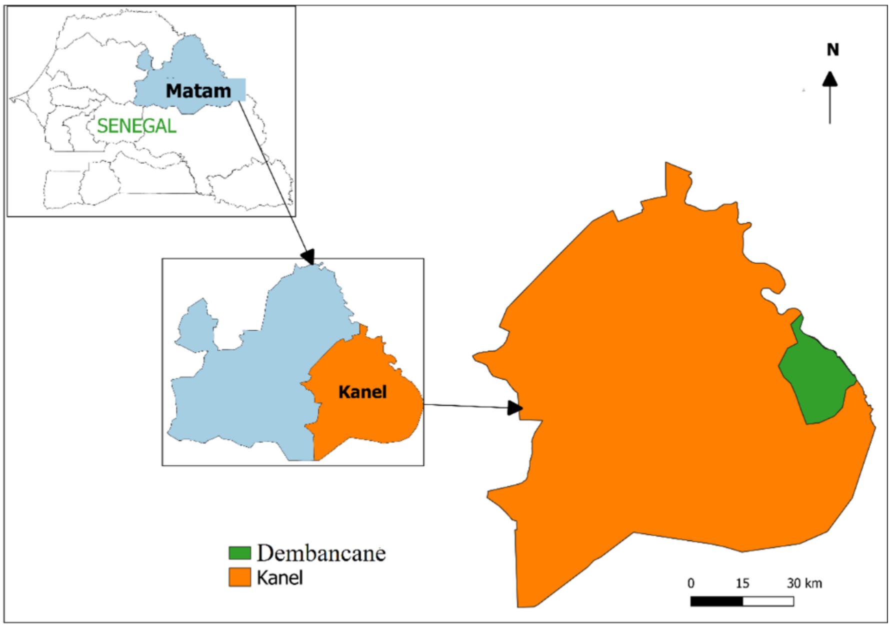


Figure 1 Geographical map of Dembancane

2.2. Sampling, Collection and Breeding of species

For this study, seven fields considered as plots were randomly selected from this area. The first five have a perimeter of 45m wide and 400m long, the sixth has a width of 50m by 400m long and the seventh has a width of 50m by 500m long. The study was carried out from December 25, 2020 until February 2, 2020. Out of seven partials, sampling was conducted at dusk in a random fashion. Although the maize plant has three developmental phases, our research focused on the last two particularly at the early flowering and early maturation stages present in the field.

The collection was carried out during 7 days. Thus, insects were taken directly from the plant with insect forceps or captured in the surrounding area with a net. Indeed, these species were trapped because they are generally found in the seedling's cones. However, others to count spiders were found on the leaves, the folds of the leaves, in the spike and on the stem.

Figure 2 Types of traps used (A) the net and (B) the pincer at dusk (C)

Then, they were put in labeled tubes containing 70° alcohol to avoid putrefaction. In addition, the rearing of the collected larvae was started, providing them with corn leaves (Figure 3a) to continue their development cycle (Figure 3b).

Figure 3 Insect rearing (a=larva, b= pupa)

2.3. Identification of the species encountered

The identification of these species was carried out thanks to the collection of the IFAN (Institut Fondamental d'Afrique Noire). Indeed, their morphological recognition is carried out with the help of magnifying glass by comparing their morphological characteristics with those of the collection. The collected species are distributed and classified taxonomically.

Figure 4 Morphological recognition of collected species

2.4. Abundance

2.4.1. Absolute abundance

Absolute abundance (Aa) is the total number of individuals caught of a species [11].

2.4.2. Relative frequency or relative abundance

Relative frequency (f) is the percentage of individuals of a species relative to the total number of individuals of all species [12].

$$f = ni*100 /N \quad \text{or} \quad Ar\ \% = Aa*100/At$$

ni : Number of individuals of a given species
N : Total number of individuals of all species combined

According to Faurie *et al*. [11], relative abundance values are ranked 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

2.5. Frequency of occurrence or Consistency

Frequency of occurrence is the ratio of the number of surveys where species i occurs to the total number of surveys multiplied by one hundred [9].

$$Fo\% = Pi*100/P$$

Pi : number of surveys where species i is present
P : total number of surveys

According to Dajoy, based on Fo values, we have several categories of species:

Rare species if Fo < 5%

Accidental species if 5% < Fo < 25%.
Accessory species if 25% < Fo < 50%.
Regular species if 50% < Fo < 75%.
Constant species if 75% < Fo < 100
Ubiquitous species if Fo = 100% [11].

2.6. Statistical analysis

Data analysis was conducted using Excel and Python version 3.8 from Python Software Foundation [13] for graphing and R studio version 4.0.3 from R Core Team [14] for statistical testing. The Kruskall-wallis test (non-parametric) is performed for a multiple comparison of the mean ranks of the corresponding variable. Thus, each mean is assigned to a letter. According to the statistics, means assigned to the same letters or having at least one letter in common do not differ significantly. However, two averages differ if they have no letters in common. Dunn's test is performed to test the significance of the mean ranks per pair of plots. A Fisher test is performed to test if the distribution of the orders of the collected species is distinct or not. In addition, the Chi-2 test of independence is performed to test the linkage of certain species.

3. Results

3.1. Inventory of species encountered

A total of 585 insects and 5 spiders belonging to eight orders were collected in the Dembancane site. The Fisher test gives a p-value of 1. The insects consisted of 58 species distributed in 24 families and 7 orders (Heteroptera, Coleoptera, Orthoptera, Homoptera, Thysanoptera, Lepidoptera, Neuroptera). On the other hand, spiders are composed of five (5) species belonging to the order Araneae.

3.2. Abundance of species encountered

Heteroptera were the most abundant with 35.71%, followed by Coleoptera with 26.43% and Orthoptera with 25.00%. In contrast to these orders, Homoptera, Thysanoptera, Lepidoptera, Araneae and Neuroptera are the least represented (Figure 5).

The absolute abundance of species by plot (A to G) is shown in Figure 6. Thus, it varies according to the plot and the phase of development of the corn.

The analysis in Table 1 shows a comparison of the mean of the species of the different plots in a two-to-one way following the Kruskall-wallis test. Thus, the significance of the differences is shown by Dunn's test.

The relative abundance of these species is shown in Figure 7. We have one common species (*Piezodorus* sp.), five rare species (*Rhaphidopalpa* sp., *Eysarcoris inconspicuus*, *Geocoris amabilis*, *Spodoptera frugiperda*, and *Pyrgomorpha cognata*), and very rare species.

The calculation of the constancy of these species shows that some species are accidental. This is the case of *Caryedon serratus*, others are accessory (*Naphius* sp., *Paederus* sp., *Tribolium castaneum* and *Spermophagus* sp.). Thus the group of other species consists of regular, constant and ubiquitous species (Figure 8). Only one species (*Anthicus* sp.) is constant with Fo = 85, 71%. Four are found regular including *Rhaphidopalpa* sp., *Thrips* sp., *Calidea nana* and *Leptocoris* sp. Five species are omnipresent: *E. inconspicuus*, *Dimorphopterus sp*., *G. amabilis*, *Piezodorus* sp., *P. cognata* and *Oecanthus pellucens* with a frequency of 100%. Thus, following a Chi-2 test of independence, the P-value found is 0.99, greater than 0.05.

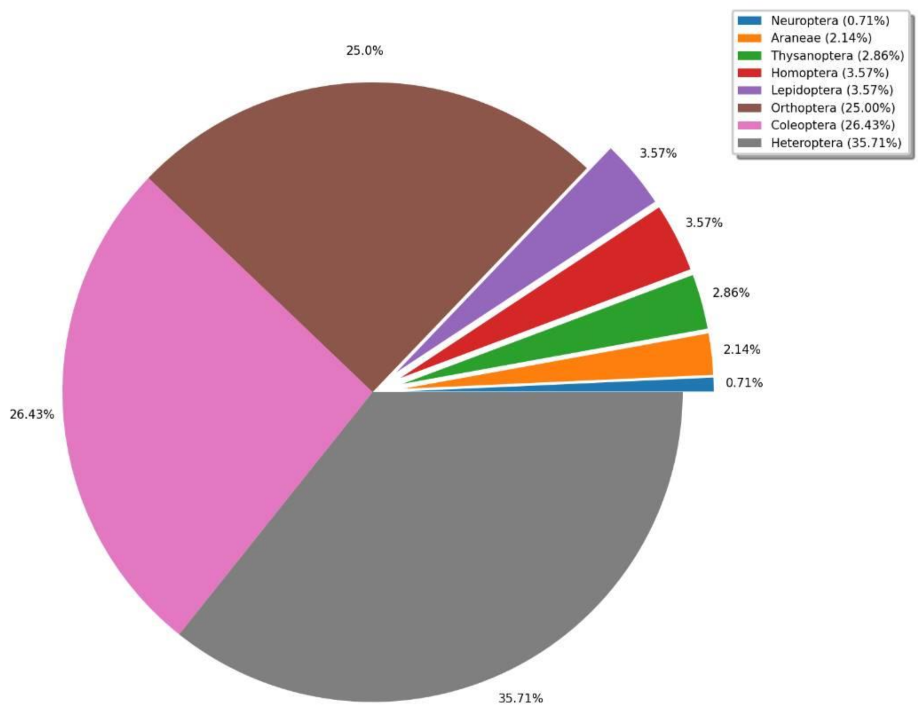
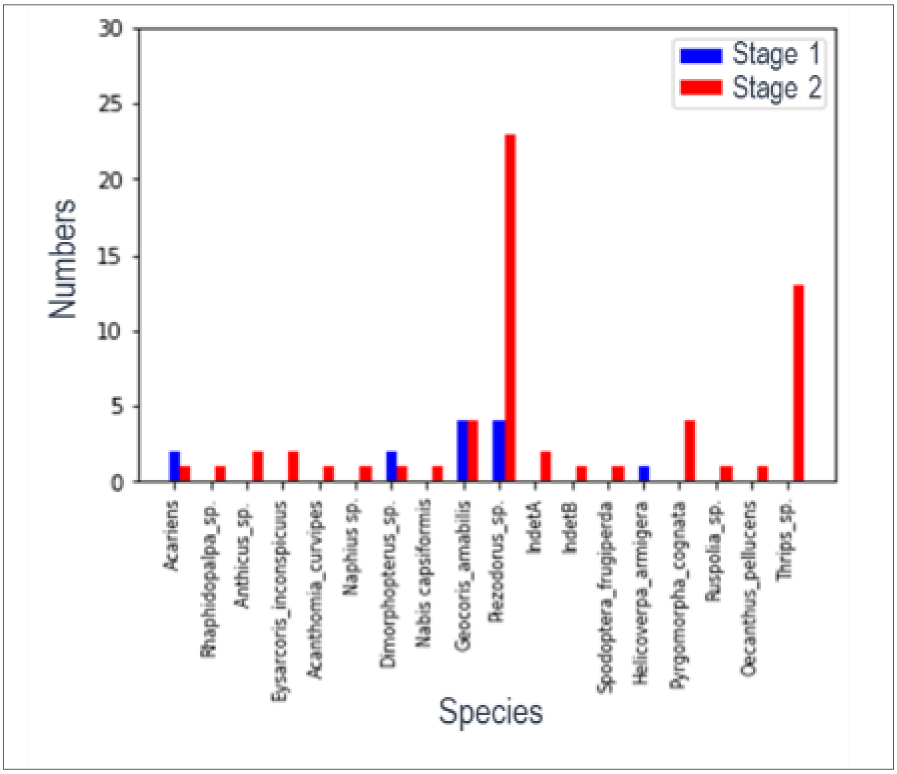
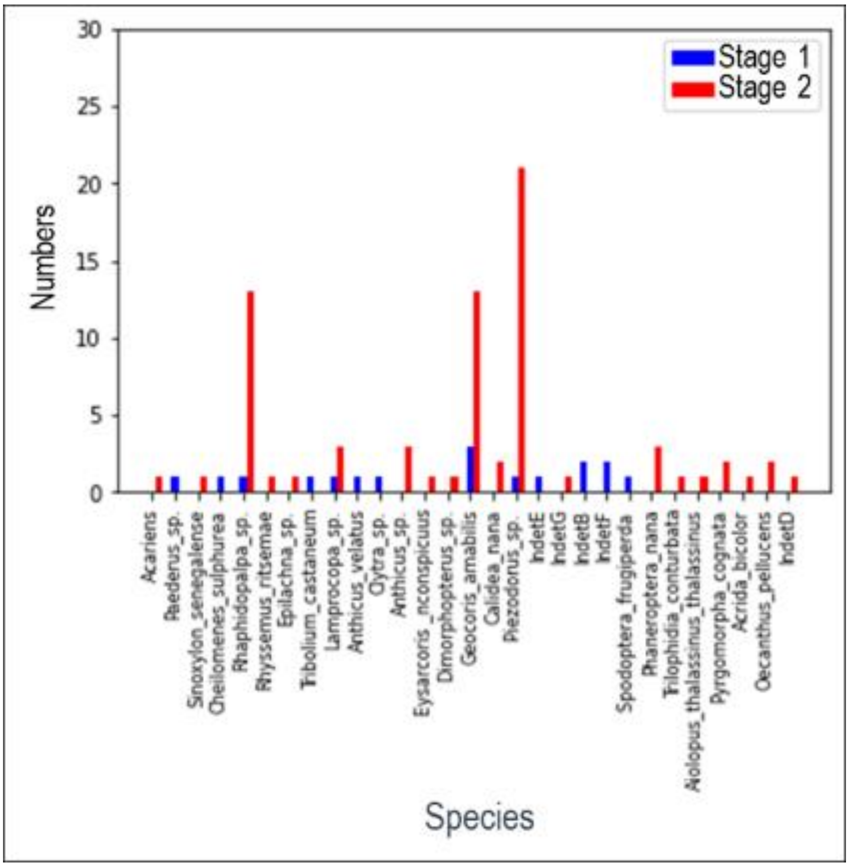


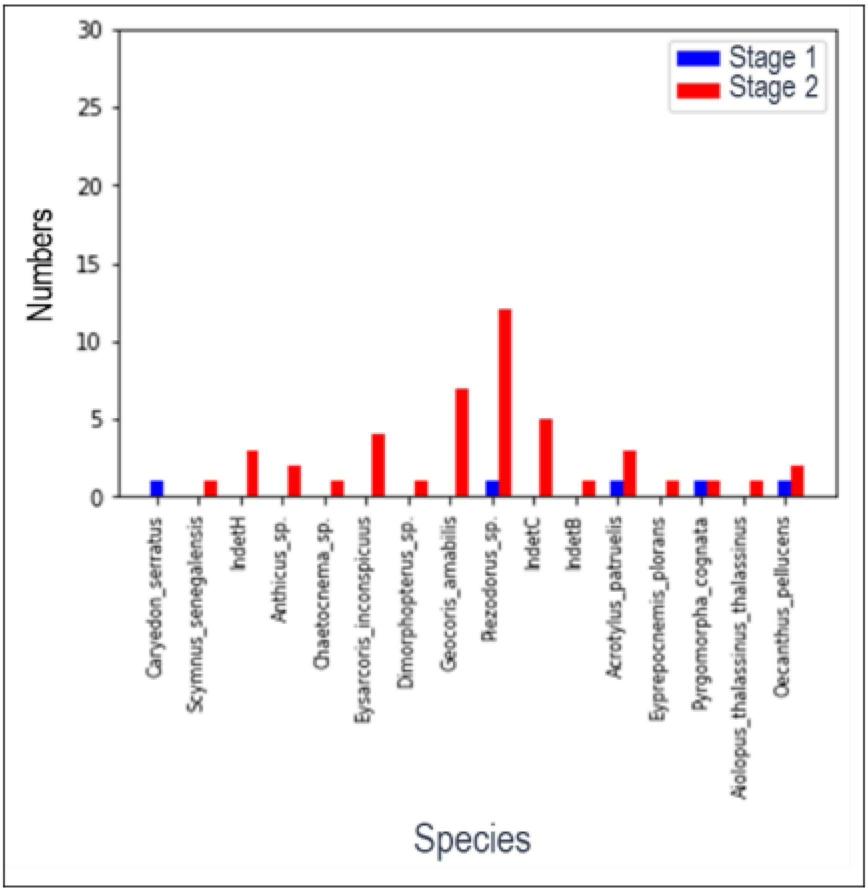
Figure 5 Percentages of the different insect orders and the spider order



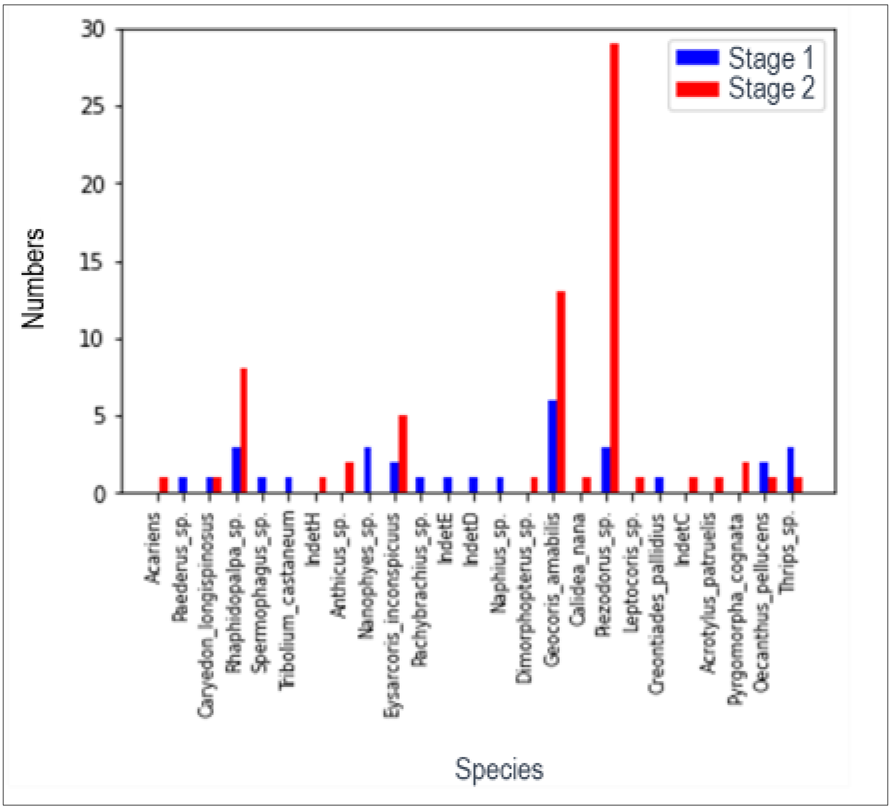
A


Stage 1
Stage 2
Numbers
30
25
20
15
10
5
0
Acariens
Paederus_sp.
Sinoxylon_senegalense
Cheilomenes_sulphurea
Rhaphidopalpa_sp.
Rhyssemus_ritsemae
Epilachna_sp.
Tribolium_castaneum
Lamprocopa_sp.
Anthicus_velatus
Oytra_sp.
Anthicus_sp.
Eysarcoris_nconspicuus
Dimorphopterus_sp.
Geocoris_amabilis
Calidea_nana
Piezodorus_sp.
IndetE
IndetG
IndetB
IndetF
Spodoptera_frugiperda
Phaneroptera_nana
Trilophidia_conturbata
Aiolopus_thalassinus_thalassinus
Pyrgomorpha_cognata
Acrida_bicolor
Oecanthus_pellucens
IndetD
Species

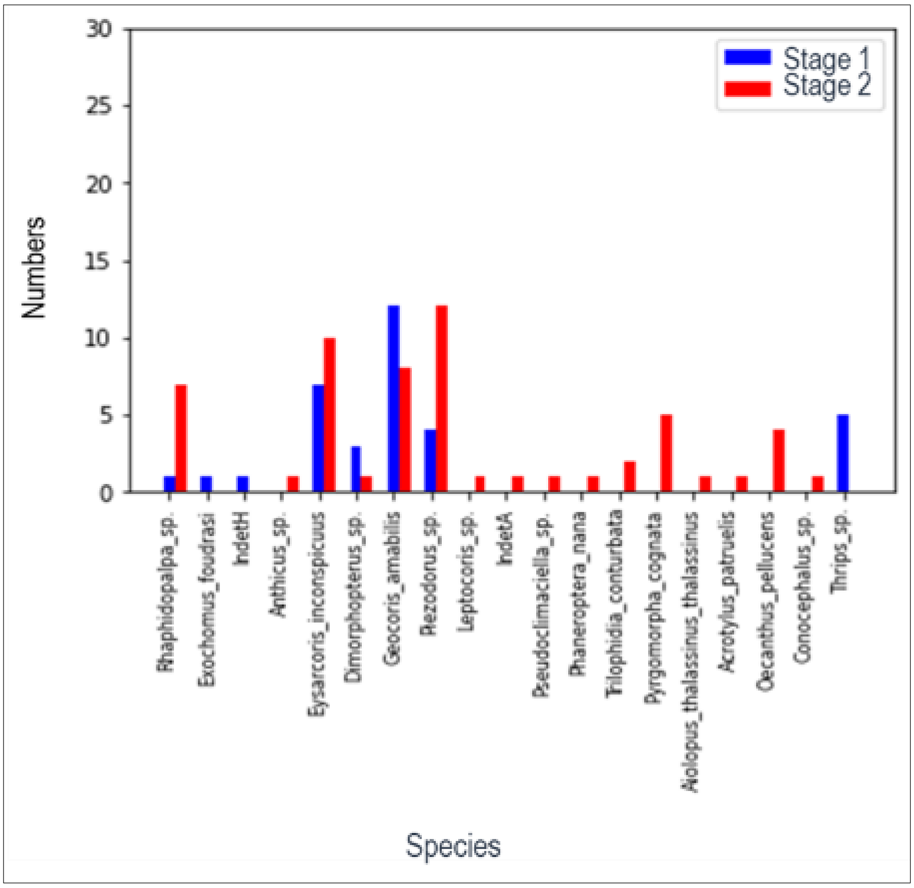
B


Stage 1
Stage 2
Numbers
30
25
20
15
10
5
0
Caryedon_serratus
Scymnus_senegalensis
IndetH
Anthicus_sp.
Chaetocnema_sp.
Eysarcoris_inconspicuus
Dimorphopterus_sp.
Geocoris_amabilis
Piezodorus_sp.
IndetC
IndetB
Acrotylus_patruelis
Eyprepocnemis_plorans
Pyrgomorpha_cognata
Aiolopus_thalassinus_thalassinus
Oecanthus_pellucens
Species

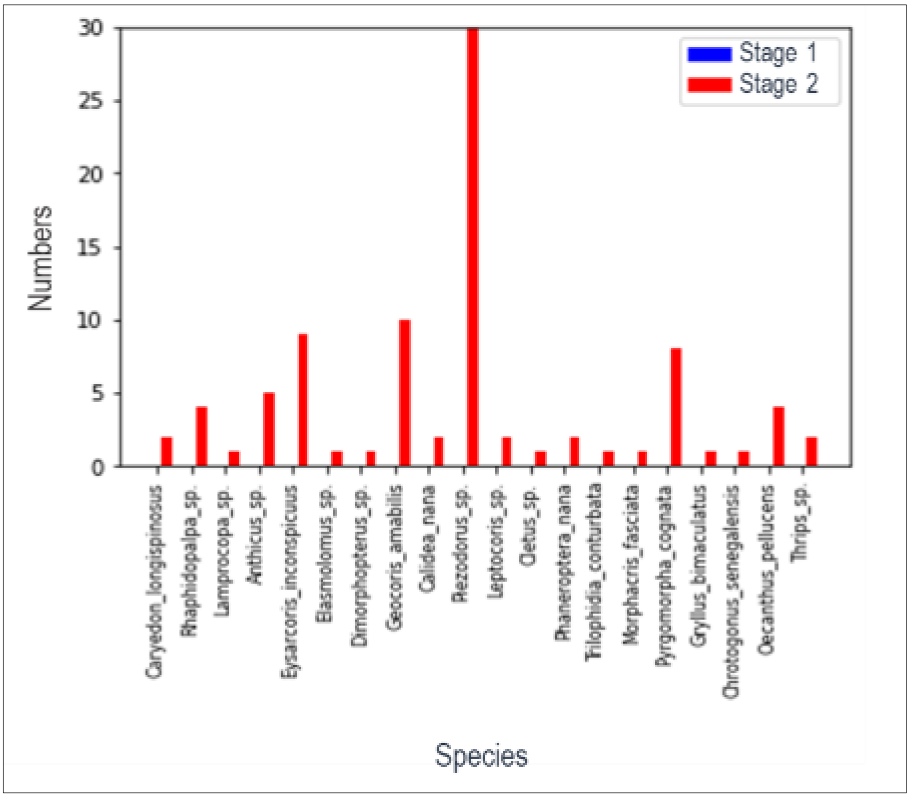
C


Stage 1
Stage 2
Numbers
Species
30
25
20
15
10
5
0
Acariens
Paederus_sp.
Caryedon_longispinosus
Rhaphidopalpa_sp.
Spermophagus_sp.
Tribolium_castaneum
IndetH
Anthicus_sp.
Nanophyes_sp.
Eysarcoris_inconspicuus
Pachybrachius_sp.
IndetE
IndetD
Naphius_sp.
Dimorphopterus_sp.
Geocoris_amabilis
Calidea_nana
Piezodorus_sp.
Leptocoris_sp.
Creontiades_pallidus
IndetC
Acrotylus_patruelis
Pyrgomorpha_cognata
Oecanthus_pellucens
Thrips_sp.

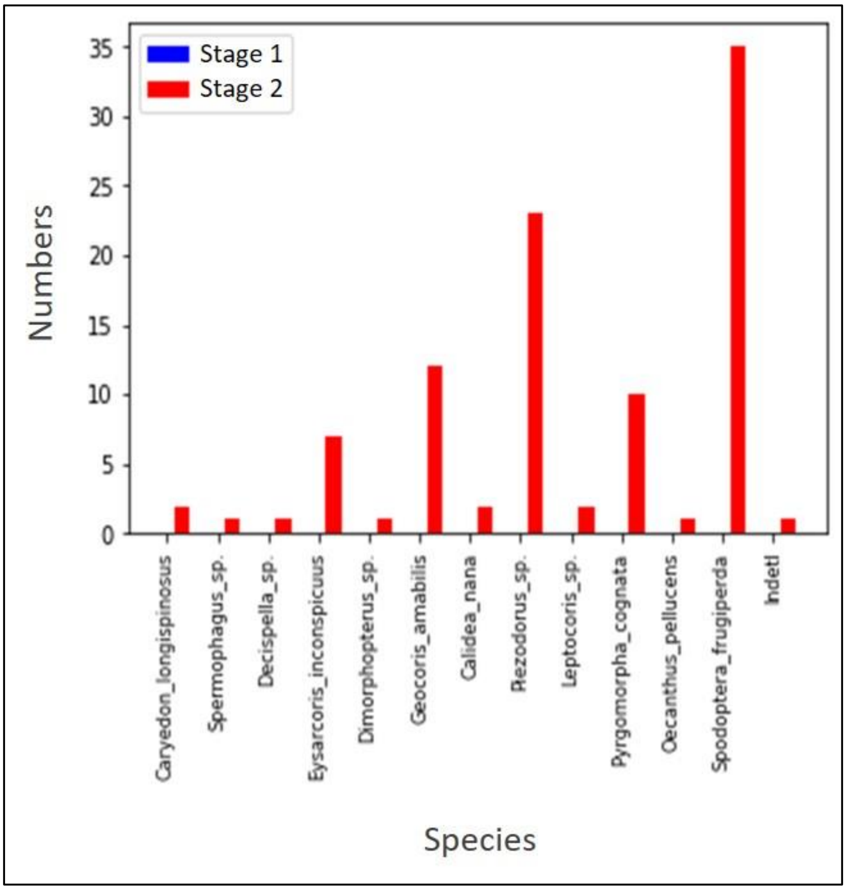
D


Stage 1
Stage 2
Numbers
Species
30
25
20
15
10
5
0
Rhaphidopalpa_sp.
Exochomus_foudrasi
IndetH
Anthicus_sp.
Eysarcoris_inconspicuus
Dimorphopterus_sp.
Geocoris_amabilis
Piezodorus_sp.
Leptocoris_sp.
IndetA
Pseudoclimaciella_sp.
Phaneroptera_nana
Trilophidia_conturbata
Pyrgomorpha_cognata
Aiolopus_thalassinus
Acrotylus_patruelis
Oecanthus_pellucens
Conocephalus_sp.
Thrips_sp.

E



F



G

Figure 6 Absolute abundance of species by plot (A to G) at early flowering and early ripening stages

Table 1 Average species on the different plots

Stage1								
		Plot A	**Plot B**	**Plot C**	**Plot D**	**Plot E**	**Plot F**	**Plot G**
	Mean	0.722^{a}	0.586^{a}	0.312^{a}	1.24^{b}	1.789^{ab}	0	0
	Standard error	0.321	0.144	0.119	0.29	0.735	0	0
Stage2								
		Plot A	Plot B	Plot C	Plot D	Plot E	Plot F	Plot G
	Mean	3.333^{ab}	2.517^{a}	2.812^{b}	2.76^{a}	3^{ab}	4.4^{b}	7.534^{b}
	Standard error	1.323	0.891	0.764	1.242	0.837	1.489	2.914

Values are means followed by standard deviation. Means assigned to the same letters or having at least one letter in common have no significant differences. However, two averages differ if they have no common letter

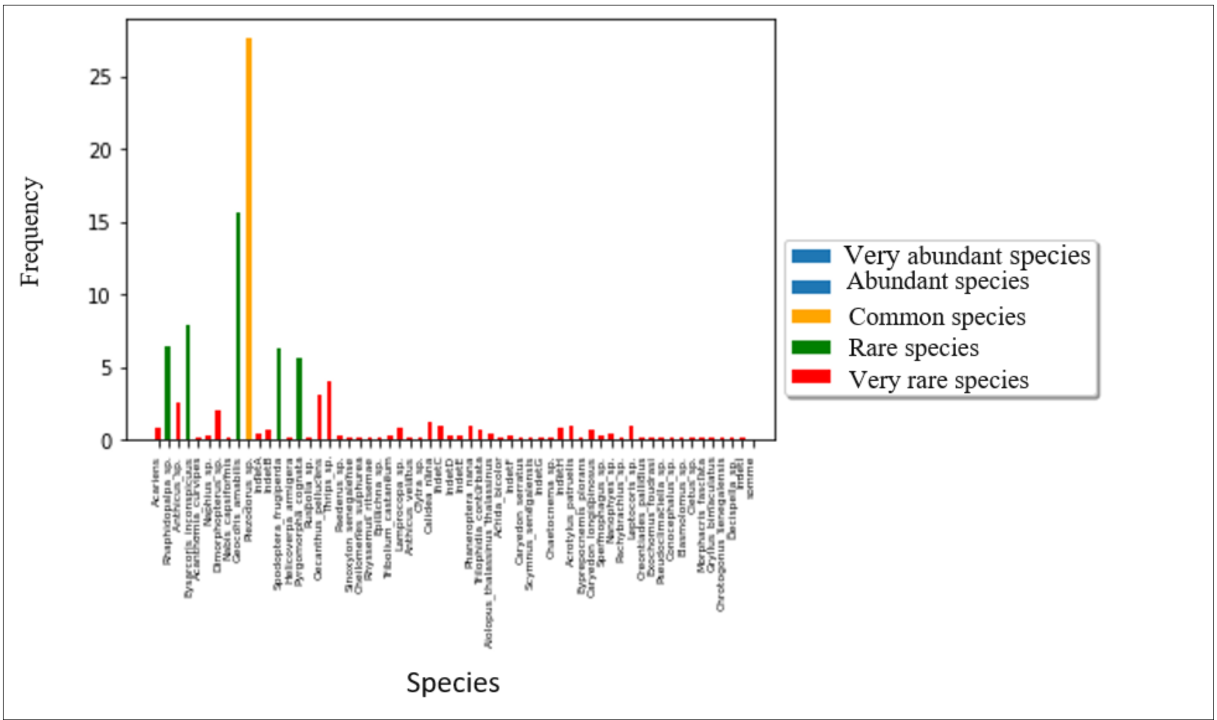


Figure 7 Relative abundance of species in the study area

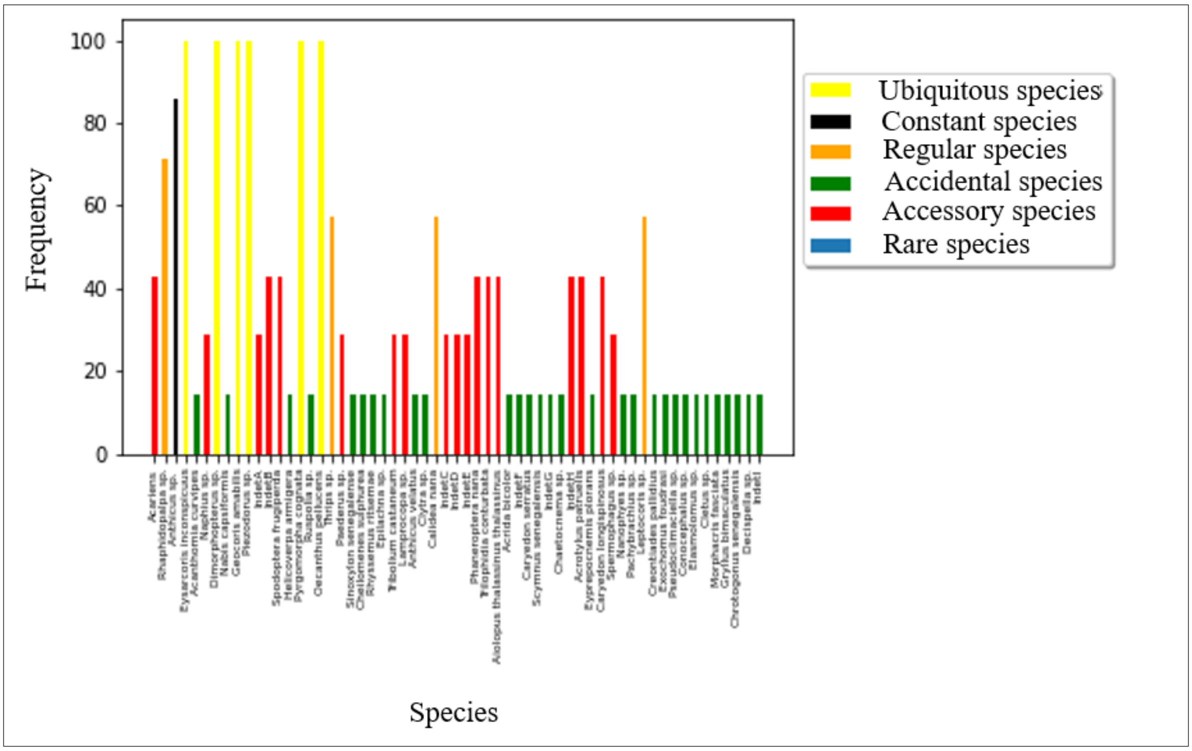


Figure 8 Frequency of occurrence or constancy of species in the study area

4. Discussion

Our study was carried out on 58 species of insects including 585 individuals and five species of spiders, collected at the beginning of flowering and beginning of maturation. Thus, following the Fisher test, a difference in the distribution of the orders of the species is noted. Indeed, the species are distributed in eight orders (Heteroptera, Coleoptera, Orthoptera, Homoptera, Thysanoptera, Lepidoptera, Araneae and Neuroptera). In contrast, Mbow [9] found insects infested with sweet corn in Senegal in ten orders (Coleoptera, Lepidoptera, Heteroptera, Homoptera, Orthoptera, Diptera, Geophilomorpha, Hemiptera, Hymenoptera and Dermoptera). Indeed, this dissimilarity would be due to the climate characterized by rainy season and dry season.

Heteroptera were the most common in the study area (35.71%). However, these results are different from those of Mbow [9] and Aderolu *et al*. [15] who found beetles being the most abundant in their study areas. This could be explained by the fact that heteropterans appreciate maize better in the dry season.

In contrast, Djidjonri *et al*. [16] showed Lepidoptera to be the most abundant order in their study. This could be the result of the effect of crop rotation with cowpea against this group of insects. This result is consistent with those of Djidjonri *et al.* [17] who showed that intercropping cowpea with maize reduces pest density.

The representation of these different orders shows that corn harbors a large number of insects. However, the frequency of these orders, pushes us to determine the abundance and frequency of occurrence of each species.

Species are most abundant at the early maturation stage in all plots. However, this abundance is higher in plot E at the early flowering stage and in plot G at the early maturation stage. This proves that the species inventoried do appreciate corn at the early maturation stage. However, *Piezodorus* sp. is the most represented species in the environment. This could be due to the lack of encounter with its natural enemies. The abundance of these species is justified by Table 2, which shows differences in the average species on some plots. Indeed, plot E at the early flowering stage and plot G at the early ripening stage have the highest mean absolute values.

The determination of relative abundance allowed us to find very rare, rare and common species in the environment. Indeed, *Piezodorus* sp. is the common species in the environment. Pentatomids of the genus *Piezodorus* are phytophagous and predatory heteropterans [18]. According to the work of Buchori *et al.* [19], *Piezodorus* sp. is a maize pest whose eggs are often parasitized by parasitoids of the Trichogramma family. Thus in our study, these

Trichogramma are not encountered at either stage. The absence of these species could lead to the abundant presence of this pest in all plots.

Spodoptera frugiperda is rare in the area except for plot G where it is abundant. This unevenness in its distribution could be explained by the fact that it is an invasive species. Indeed, it was first introduced in Africa in 2016 [20]. However, Djidjonri *et al*. [16] found *Spodoptera frugiperda* to be the most represented in Cameroon.

Helicoverpa armigera, which is very rare in this environment, belongs to the order Lepidoptera and has a wide host range that allows it to expand geographically. This pest causes severe damage along its range on maize, cotton, tomato and even vegetable crops [21]. Its rarity could be explained by the intercropping of cowpea, sweet potato in the study area. Thus, according to EPPO [21], its impact could be reduced to an economic threshold through crop rotation. But also, *H. armigera* has a lower fecundity rate on maize compared to cowpea. Indeed, it seems that maize possesses enzyme inhibitors acting on the digestion of the larvae of this pest [22]. Indeed, this commodity contains molecules capable of acting on certain natural enemies [7]. For example, studies have shown that 2,4-dihydroxy-7 methoxy-1,4-benzoxazin-3-one (DIMBOA) is an inhibitor that causes a reduction in the digestion capacity of *H. armigera* larvae, while 6-methoxybenzoxazolinin-3-one (MBOA) reduces the conversion efficiency of digested food [23].

Through the frequency of occurrence values, species are found incidental in this area in the case of *Caryedon serratus* (the peanut bruchid), *Cheilomenes sulphurea*, *Scymnus senegalensis* and *Exochomus foudrasi*. Indeed, the presence of *C. serratus* would be due to the existence of its host plant *Piliostigma reticulatum* [24] found around the plots. However, ladybugs would be present in this area due to the existence of *Gossipium* sp. near the plots. According to Miranda *et al*. [25], these small ladybugs are numerous in cotton crops.

Accessory species are encountered (*Naphius* sp., *Paederus* sp., *Tribolium castaneum* and *Spermophagus* sp.). Of these, *Spermophagus* sp. represents a primary stock pest. However, its presence could be explained by the fact that its infestation starts in the field. Indeed, it belongs to the bruchidae family. These bruchids mainly attack legumes but they are also associated with the convolvulaceae family [26] such as sweet potato in this area.

Anthicus sp. the only constant species in the environment, is a predator of *Thrips* [27]. Thus, its presence could be justified by the regularity of its prey. *Thrips* sp. attacks both cowpea [28] and the maize plant, which becomes dry, stunted, yellowed and its deformed leaves curl up on itself [29].

Then, *Rhaphidopalpa* sp. is found regular in the environment. Indeed, *Rhaphidopalpa* sp. is a pest of Cucurbitaceae. However, corn is often put for trap in these crops knowing that it is a resting medium for this species [30]. Therefore, its presence would be due to the existence of *Momordica charantia* and the impact of corn on its ecology.

Finally, six species are omnipresent. This is because all these species namely *Eysarcoris inconspicuus*, *Dimorphopterus* sp., *G. amabilis*, *Piezodorus* sp., *Pyrgomorpha cognata* and *Oecanthus pellucens* are present in all surveys. Thus, these obtained results disagree with those of Mbow [9] where only one species was found ubiquitous. These species are found unrelated with a significant P-value equal to 0.99. This could be explained by the fact that some are generalist predators and others are phytophagous. The genus *Oecanthus* are predators of insects, particularly soft-bodied insects [31].

The different abundance and constancy values show the importance of each species in the environment. However, a species in abundance or a species represented by a single individual does not make the same contribution to the ecosystem [9].

5. Conclusion

This study focuses on the entomofauna of flood recession maize in the Senegal River valley, consisting of 590 individuals, including 585 insects and 5 spiders, divided into eight orders (Heteroptera, Coleoptera, Orthoptera, Homoptera, Thysanoptera, Lepidoptera, Neuroptera and Araneae). Thus, their absolute abundance varies according to the plot and the development phase of the corn. Despite the different values of relative abundance and Constance of species, Heteroptera are the most represented.

Additional studies are needed to better understand the entomofauna of maize. Thus, it would be interesting to broaden the sampling on the different phases of development of flood recession maize, to extend our research to other study stations but also to broaden this work by extending our studies to other crops, namely rice, millet and sorghum.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest of this research work.

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