Diversity and abundance of insect pests of corn (*Zea mays* Poaceae) grown in a rural environment in the city of M’Bahiakro (East Central Côte d’Ivoire)

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Knowledge of the distribution of insect pests of corn at different stages of the plant is essential for the development of appropriate control strategies. This work was carried out in a rural environment in M’Bahiakro, in East Central Côte d’Ivoire. The study of dynamics, biodiversity and insect abundance on each plot was carried out. For this purpose, six plots, of which two were in the forest zone and four in the savanna zone, were visited from September 2012 to January 2014. The analysis of results showed that the flowering stage had the largest number of insect populations and the most diverse ones (1665 insects on average distributed over 27 families). The distribution of insect pest populations appears to be influenced by environmental characteristics. In the savanna, diversity and abundance indices of insect pests appeared to be higher than those in the forest (Shannon diversity index H’=2.57 in the savannah against H’=2.15 in the forest; Abundance index A’=200 in the savannah against A’=130 in the forest).

Key words: *Zea mays*, phenological stages, insect pests, M’Bahiakro, Côte d’Ivoire.

INTRODUCTION

Corn (*Zea mays* Poaceae, Linné 1753) occupies an important place among food crops. It is grown in 150 countries. Corn is the most widely grown cereal in the world, with grain yield slightly ahead of rice and wheat (Gay, 1999; FAO, 2004). However, the yields in developing countries remain very low (FAO, 2000). In Côte d’Ivoire, average yields in rural environment are in the order of 0.8 tons per hectare compared to 2 to 5 tons...
per hectare in controlled environments (CNRA, 2006). Unfortunately, this crop is confronted by numerous constraints, including a strong attack by insect at all developmental stages (Pollet, 1975; Moyal, 1988; Foua-Bi, 1989; Camara et al., 1990). Insects affect the plant either directly by feeding on the organs (roots, stems, leaves, flowers or fruits) or indirectly by transmitting pathogenic microorganisms to the plant, causing diseases and consequently loss of fruit nutritional or market quality (Ochou, 1996). In West Africa, especially in Côte d’Ivoire the pests and diseases of this crop remain little known and the knowledge of them are not recent. Therefore, they need to be updated. Postharvest losses due to insects are one of the major concerns of smallholders (Ochou, 1996).

In Côte d’Ivoire, the entomological works on corn are few and mostly concentrated in the north and central part of the country (CNRA, 2006). The only entomological works related to the phenological stages of corn were carried out by Pollet (1975) on Adlopodoumé in the southern part of the country. Knowledge of the distribution of these insect pests at different developmental stages of corn is essential for working out appropriate control strategies. This study was carried out to assess the effect of environmental characteristics (savanna and forest) on the diversity and abundance of insects pests.

**Study site**

The study area was located in M'Bahiakro, in East Central Côte d’Ivoire (longitude 4°9’W and latitude 7°40’N) (Figure 1). The average temperature recorded was 25.8°C and a total rainfall of 1024 mm. The vegetation was characterized by semi-deciduous forests and savannas (Mangenot, 1955) on ferrallitic soil (Yessoh, 1973; Anonymous, 2010).

**MATERIALS AND METHODS**

The corn variety used was the early variety PR91331-SR. The grains were dentate and yellow in color. The duration of the development cycle was 90 days (CNRA, 2006). The four phenological stages were identified according to the methodology described by Pollet (1974). The observations were carried out according to the four development stages: the “rosette stage”, the “elongation stage”, the “flowering stage” and the “grain maturation stage”.

The technical equipment consisted of the tools for capturing, sorting, preserving and identifying the insects.

**Plot selection**

The study was conducted in a rural environment. Overall, six corn fields of about 7 days of development (“emergence stage”) were selected: Four plots in the savanna zone (2 near Totokro village and 2 near Koffiyaakro) and two others in the forest zone (near Kouassikro). The spacing was 80 x 40 cm (Figure 2).

**Insect sampling, collection and identification**

The experimental design used was similar to the one proposed by Pollet (1975). In our study, the six plots were monitored throughout the corn cycle. Each plot was visited once a week from sampling and collection took place on-farm from September 2011 to January 2012. Observations continued until the ears dried season.

Each week and for each plot, 10 rows of corn, 5 m apart, were chosen, and on each selected row 10 plants 5 meters apart were also chosen. A total of 100 plants were selected for each plot each week throughout the development cycle. Insects were picked up by hand or captured with sweep nets and stored in 70% alcohol-containing pillboxes.

In the laboratory, the insects were observed using the CETI Belgium binocular microscope and the ZEISS Germany microscope and identified using the identification keys (Appert and Deuse, 1988; Jean and Boisclair, 2009).

**Statistical analysis**

The diversity indices of each phenological stage of corn per plot were determined using software R version 2.8. This index accounts for both the species richness and the abundance of the different species. The Shannon-Weaver index \( H' \) is independent of sample size, \( H' = - \sum n_i \log_2 n_i \). Where \( n_i = \) probability of encounter of species \( I \); When \( H' \) tends towards 0, diversity is minimal. It is maximum when it tends towards 5.

The relative abundance of insects in the different environments and per phenological stages of the plant was calculated. Thus, the average number of individuals of a sampled species \( I \) was calculated. It was based on the incidence (presence = 1 and absence = 0) of the species in question.

\[ A = \frac{\sum n_i}{N}; \]

Where \( n_i = \) incidence of the individual of species \( I \), and \( N = \) total number of insects of the phenological stage or of the plot.

Then, based on the abundances of collected taxa, the environments were classified using the Ward method (similarity of environments) using Statistica software version 6.0. An analysis of variance (ANOVA) helped compare the diversity and abundance of populations of insect pests of corn in savanna and forest plots in the city of M’Bahiakro. This was done using Statistica software version 6.0 at 5% level.

**RESULTS**

**Phenology and entomofauna of corn variety PR91331-SR**

The development cycle of variety PR91331-SR lasted 96 days on average. The emergence stage lasted 24 days on average. The vegetative stage lasted 19 days on average. The “flowering stage” lasted 14 days. The grain maturation stage lasted 39 days.

The main insects sampled in corn fields belonged to 8 orders distributed in 27 families (Table 1). The “flowering” stage had the highest number of insects and families (Figure 3).

**Overall diversity**

The “emergence” stage had the lowest biological diversity
Figure 1. Presentation of the study area (Source: www.googlemap.ci, 2012).

Figure 2. Sampling method: General arrangement of corn plants on the plot. Seed holes: Row spacing (80 cm): Distance between plants (40 cm).
Table 1. Number of insects according to the four phenological stages of corn.

<table>
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<tr>
<th>Order of insects</th>
<th>Insect families</th>
<th>Rosette Stage</th>
<th>Elongation stage</th>
<th>Flowering stage</th>
<th>Grain maturation stage</th>
<th>Total number of insects per family</th>
<th>Percentage (%)</th>
<th>Total number of insects per order</th>
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<td>20093</td>
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Average: 199.5 969.75 1664.67 1488.86

The “flowering” and “grain maturation” stages were the most diversified with diversity indices of $H'$=2.67 and $H'$=2.74 respectively. At the “vegetative” stage the diversity index had a value of $H'$=2.40. There was no significant difference in diversity between
flowering and maturation stages of the grains (Figure 4).

**Diversity of insects according to plots**

Concerning the Totokro plots (Figure 5A and B), savanna zones, the lowest value of the diversity index observed at the emergence stage was between $H'=1.7$ and $H'=1.9$ (Anova, $p<0.05$). The flowering and grain maturation stages showed the greatest diversities with indices ranging between 2.8 and 3. The analysis showed that there was no significant difference in diversity indices between the flowering and grain maturation stages for the first plot and vegetative, flowering and grain maturation for the second plot.

Concerning the plots of Koffiyaokro (Figure 5C and D), savanna zones, the lowest diversity value recorded at the emergence stage was $H'=1.75$ for the first plot and $H'=1.14$ for the second plot (Anova, $p=0.05$). The highest diversity values observed at vegetative, flowering and grain maturation stages ranged between 2.3 and 2.8 for the first plot and between 2.4 and 2.7 for the second plot. There was no significant difference in diversity between these three stages on both plots.

As for the plots of Kouassikro (Figure 5E and F), forest zone, the lowest diversity noted at the emergence stage was less than 1.6. The highest diversity values were recorded at vegetative, flowering and grain maturation
Figure 5. Insect diversity according to plot: A: Totokro plot 1. B: Totokro plot 2. C: Koffiyaokro plot 1; D: Koffiyaokro plot 2. E: Kouassikro plot 1. F: Kouassikro plot 2. Legends: Stage 1 = Emergence; Stage 2 = vegetative; Stage 3 = flowering; Stage 4 = Maturity.

stages with $2.1 < H' < 2.5$ for the first plot and $2.3 < H' < 2.8$ for the second plot. There was no significant difference in the diversity between vegetative, flowering and grain maturation stages on the first plot.
Overall abundance

The high abundance values were observed at the flowering and maturation stages of grains, respectively 282.77 and 236.23 individuals. They were followed by vegetative stages with 166.20 individuals and emergence with 34.12 individuals (Figure 6). The statistical analysis of the results did not reveal statistically significant differences in insect abundance between and grain maturation stages (Anova, p = 0.05).

Abundance according to plots

On the Totokro 1, Totokro 2, Koffiyaokro 1 and Kouassikro 2 plots, the highest abundance was observed at the “flowering” stage (Figure 7A, B, C and F). It was followed by that of “grain maturation” stage. The emergence stage was the one which had the lowest abundance. There was no significant difference in abundances between the “flowering” and “grain maturation” stages on both Totokro plots. There was also no significant difference in abundance between the vegetative and grain maturation stages on the Koffiyaokro 1 plot. On the Kouassikro 2 plot, there was no significant difference in abundance between the vegetative, flowering and grain maturation stages. On the Koffiyaokro 2 and Kouassikro 1 plots, the abundance of insect pests of corn increased with plant development stage (Figures 7D and E). The highest abundances were observed at the flowering and grain maturation stages. There was no significant difference in abundance between these two development stages. The lowest abundance was observed at the emergence stage.

Effect of the environment on biological diversity

The results showed that savanna plots were the most diverse with 2.43<H'<2.71 unlike forest plots with H'<2.45. However, most of the families observed in the savanna zone were also observed in the forest zone, except for the Derbidae family observed only in the savanna.

The analysis of the results revealed that both Totokro plots located in the savanna zone were the most diverse with H'=2.71 and H'=2.70 respectively. They were followed by the Kouassikro 2 and Koffiyaokro 2 plots with H'=2.45 and H'=2.43, respectively. The lowest value of this index was observed in the Kouassikro 1 plot (H'=2.14) (Figure 8A). These values were statistically homogeneous between environments (Anova p > 0.05).

Effect of the environment on the abundance of insect populations

The highest abundance was recorded on Totokro 1 plot (208.77 individuals). It was followed by the neighboring plot Totokro 2 (205.72 individuals). The other 4 plots had the lowest abundances between 110.01 and 186.55 individuals. These values were statistically homogeneous.
between the 4 plots (Figure 8B).

**DISCUSSION**

The diversity and abundance of insect pests are closely related to the different development stages of corn. These parameters are higher at the flowering and "grain maturation stages. These results are close to those obtained by Pollet (1974). Indeed, of the 18 phytophagous insects and the 4 stem borers assessed by this author during the complete cycle of corn, all are present at the flowering stage except 2 stem borers whereas at the grain maturation stage, the 4 stem borers and 12 phytophagous insects are present. Furthermore, Jean and Boisclair (2009) showed that at the "Flowering" stage, there is a significant difference in diversity of insect pests of cultivated corn. The vast majority of insect pest families identified by these authors during the corn development cycle were also observed at the "flowering" stage. Indeed, in addition to insects that attack corn at the vegetative stage, particularly Acrididae, Pyrgomorphidae, Tettigonidae and some Coleoptera, another group of insects that attack the inflorescences (male and female) and the ears appeared (Appert and Deuse, 1988; Jean and Boisclair, 2009). Male and female inflorescences are specifically attacked by some Hemipter, Coleoptera and larvae of Lepidoptera (Mason et al., 1996; Heinrichs et al., 2000). At these development stages (flowering and grain maturation), the plant has various nutritive resources sufficient for a wide variety of insect pests as food (O’Day and Steffey, 1998; Boisclair and Fournier, 2006). These stages are therefore the most vulnerable (Van Duyn, 2004; Hazzard et al., 2007).

The savanna plots showed overall significant magnitudes of diversity and abundance in relation to forest plots. These results were obtained by Pollet (1974). Indeed, the observations carried out by this author in controlled plots in southern Côte d’Ivoire (forest zone) revealed a low biological diversity. This suggests that plots in savannah zones with a generally warm climate might favor insect activity while wet periods do not favor high activity of insect pests of corn.

**Conclusion**

This study showed that in the rural environment, a great diversity of insect pests colonizes the plots of corn grown in the city of M’Bahiakro. The insect pests of corn grown in this city belong to 27 families of insects distributed within 8 orders. The most common insect orders are the Orthoptera, Coleoptera, Hemiptera and Lepidoptera. The main families stemming from these orders are Acrididae, Pyrgomorphidae, Coccinellidae, Chrysomelidae, Pyrrhocoridae, Reduviidae, Cynidae, Cercopidae, Noctuidae and Pyralidae.

The distribution of insect pest populations is closely related to the development stage of corn. The flowering and maturation of grains are the development stages where the abundance and diversity of insect pests are important. At these development stages (flowering and maturation), the great majority of insect pests are present.
The distribution of insect pest populations is also influenced by environmental characteristics. In the savanna, diversity and abundance indices are higher than those obtained in the forest.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES