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Full Length Research Paper

Environmental education and ecotourism using termitaria research findings: A case study of Pendjari reserve, Benin

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Findings are available on termitaria and their vegetation in the Pendjari Biosphere Reserve and other Sudanian regions in West Africa, but research without dissemination and impacts on communities seems not to be useful. This work aims at providing non-governmental organization (NGOs) and forestry advisers with useful data for environmental education projects and taking termitaria and their vegetation into account for ecotourism in Pendjari Reserve. This article on termitaria and termitaria-related vegetation summarizes data useful for two purposes. Traditional knowledge on termitaria is useful for education; termitaria plants are used as medicine. Mushrooms growing on termitaria and small mammals living in dead and abandoned mounds are consumed in the reserve. There is a need to train kids and students on termitaria and their vegetation conservation. The panoramic view of mounds and their vegetation is really attractive to tourists. Vegetation on termitaria differs between management types of an area and is dominated by woody species belonging mostly to Combretaceae botanical group. Cappareae species seem restricted to termitaria. The three major ethnic groups in the Reserve hold a diversity of ethnological knowledge on termitaria and their vegetation. These can serve for ecotourism development towards termitaria to lower poverty probability of small households in the Reserve.

Key words: Conservation, ecotourism, environmental education, reserve, termitaria.

INTRODUCTION

The United Nations Educational, Scientific and Cultural Organization (UNESCO) states that environmental education is vital in imparting an inherent aspect for nature amongst society, which enhances public environmental awareness. UNESCO (2014) emphasizes the role of environmental education in safeguarding

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future global developments of societal quality of life (QOL), through protection of the environment, eradication of poverty, minimization of inequalities and insurance of sustainable development.

Education for Sustainable Development (ESD) is the most used term worldwide, by the United Nations. Agenda 21 was the first international document, which identified education as an essential tool for achieving sustainable development in highlighted areas of action for education (McKeown, 2002). Environmental education towards kids has positive impact on natural resources conservation, since in the present day children are disconnected from nature and they have to be trained to become environmental stewards.

All this shows that, environmental education is quite important for sustainable management of natural resources especially in protected areas. Like environmental education, ecotourism and its effects on rural people welfare received several attentions worldwide. For instance, a well-planned tourism provides economic and political incentives for management and conservation, which may bring additional benefits to local communities and regional economies (Tundi Agardy, 1993).

The sum of effects for ecotourism in city is bioclimatic comfort as well as particular matter and CO_2. Ecotourism is very important for plants which affect CO_2 in the environment (Cetin and Sevik, 2016b; Cetin, 2015b; Cetin, 2015c). Rural and urban areas have rich ecotourism potential for protection, used by rural people. GIS (Geographic Information System) is used to determine suitable ecotourism area. Management and planning of ecotourism is very important for the protection of ecotourism areas (Cetin, 2015d; Cetin, 2015e; Cetin, 2016b; Cetin, 2016c; Cetin and Sevik, 2016c; Cetin and Sevik, 2016d). Cavendish and Campbell (2008) emphasized that, environmental income lowers the poverty probability of small households and those with young heads. Many years ago, Goodwin (1996) found that ecotourism is expected by the tourism industry and academics to grow rapidly over the next 20 years. Later, Scheyvens (1999) stated that, ecotourism ventures should only be considered 'successful' if local communities have some measures of control over them and share equitably in the benefits emerging from ecotourism activities. In a review article on the social impacts of protected areas on people, West et al. (2006) focused on social, economic, scientific, and political changes in places where there are protected areas and in the urban centers that control these areas.

In addition, Lindberg (2001) mentioned two related and distinct economic concepts in ecotourism: economic impact and economic value. Similarly, Naughton-Treves et al. (2005) reported that many initiatives aim to link protected areas to local socioeconomic development. They added that, some of these initiatives have been successful, but general expectations are to be tampered with, regarding the capacity of protected areas to alleviate poverty. Termitaria like many biodiversity hotspots in Sub-Saharan Africa and all over the world have received several research attentions in past years. In fact, research activities carried out on termitaria in West African savannahs mostly focused on the behavioral ecology of mounds, the ecology and patterns of termitaria-related vegetation, the medicinal uses of plant species associated with termitaria and other ethnological knowledge related to them. Exclusively, it has been stated on termitaria that, they maintain tree and herbaceous plant species diversity in West African Savannahs (Dossou-Yovo et al., 2016; Dossou-Yovo et al., 2009; Traoré et al., 2008; Mahamane and Mahamane, 2005, Konaté et al., 1999; Grouzis, 1988).

The termitaria vegetations around Pendjari National Park are dominated by woody species which mostly belong to Combretaceae botanical group. Plant species associated with termitaria in fields and fallows are mostly used as medicine by indigenous people surrounding the Pendjari National Park (Dossou-Yovo et al., 2014). These authors also mentioned various traditional beliefs towards termitaria such as, consideration of termitaria as places where ancestral spirits dwell, the medicinal efficiency of termitaria-associated plants recognized by healers in addition to the maintenance of mounds in agricultural lands for fertilization. Sileshi et al. (2009), in their review article, stated how far ethno-ecological and scientific knowledge on termites can serve for the sustainable termite management and human welfare in Africa. In the field of animal species conservation, termitaria in Sub-saharan savannahs serve as nesting place for wild birds and reptiles habitats (Thompson and Thompson, 2015; Dossou-Yovo and Korb, 2010; Heermans, 2010; Knapp and Owens, 2008).

This study highlights data to be used by any stakeholder or forestry advisers in the Biosphere Reserve to train kids and students, on importance of termitaria or write good ESD programs on termitaria by using existing research outcomes. There is a vast review on available publications about termitaria in the Pendjari Reserve as well as other articles published elsewhere on environmental education and ecotourism; therefore, the aim of this study is to provide information about how termitaria preservation can be used, for environmental education and ecotourism.

MATERIALS AND METHODS

Articles published on termitaria in the Biosphere Reserve of Pendjari, have been reviewed in similar ecological zone of Burkina-Faso which summed up relevant information useful for environmental education and ecotourism purpose in the reserve.

Articles regarding key results or suggestions that serve either for environmental education or ecotourism or both were analyzed. Many other articles related to environmental education and ecotourism have been used. The database used for gathering the manuscripts was Google scholar and University of Laval (Canada), covering a period of the last twenty years. The major key words used were: articles on termitaria in West Africa and articles on termitaria in Pendjari Reserve. Information gathered from each publication was related to biological, ecological and ethnological characteristics of termitaria. Duplicates of articles were eliminated considering their title and general goals; articles were filtered based on the research area and ecological region (sudanian) concerned in this paper. This has led to a total of 46 journal articles as well as articles published by international institutes, having been exploited to write this paper. Some means by which environmental education and ecotourism development on termitaria can be undertaken have been suggested in this article.

RESULTS AND DISCUSSION

Percentage of publications according to the fields on interest

This article diversely focused on ecotourism, environmental education and biodiversity conservation. Among all publications, 50% were related to ecotourism, 13.04% on environmental education while the remaining 36.96% were related to biological diversity. The majority of articles highlighted the positive environmental aspects of ecotourism as well as the contribution of environmental education to the sustainable management of protected areas and environment.

How research findings on termitaria can serve for environmental education in the Pendjari biosphere reserve?

There is much traditional for their welfare. For instance, several plants associated with termitaria can be used as medication. Against dysentery, the reserve dwellers used *Anogeissus leiocarpa*, *Diospyros mespiliformis* medicinal and ethnological knowledge on termitaria that present and future generations should inherit and *Flueggea virosa*. The latter as well as *Crossopteryx febrifuga* and Grewia lasiodiscus were used against headaches. Stomach aches and diarrhea were treated using two species *A. leiocarpa* and *Grewia venusta*, *F. virosa* and *Vitellaria paradoxa* (Dossou-Yovo et al.,2014). Termitaria mushrooms Termitomyces sp. Are consumed as protein by people living in the Biosphere Reserve (Dossou-Yovo and Korb, 2010; Dossou- Yovo, 2007). Traditional hunters frequently use termitaria to hide from wild animals (Dossou-Yovo et al., 2014) in fallows. Dead and abandoned mounds are habitat for small mammals; when hunted they can be used as food (Dossou-Yovo and Korb, 2010). However, this hunting negatively impacts the conservation of the biological diversity of small mammals. People, by looking for these animals, totally break dead mounds. As a result, hunting in these habitats is not to be promoted.

Since 1982, Batisse highlighted that the primary function of Reserves remains the *in situ* long-term conservation of plant and animal genetic resources, together with research on ecosystem management and conservation, monitoring of changes in the biosphere, training of specialists, and environmental education. This proves that many decades ago, environmental education was seen as priority function of biosphere reserve. Bonajuto et al. (2002), investigating local residents' attitudes towards two Italian National Parks, found that people are more involved in ecological and pro-environmental activities, which had more positive attitudes towards natural protected areas as compared to local residents involved in other local economic activities. Vodouhê et al. (2010) stated that Pendjari's local populations' perceptions of biodiversity conservation were strongly related to locally perceived benefits. Therefore, train kids and students on termitaria importance for their life and conservation in the reserve will contribute to stimulate their positive attitudes towards termitaria, now and in the future in order to realize the profits obtained from termitaria.

As a result, training kids and students environmentally on termite mounds helps to reduce pressure on the mounds and the mounds-related vegetation. Research without dissemination appears to have no impact on people's behavior, as indigenous people most times do not have access to published data. Moreover, non-governmental organization (NGOs) which are expected to use research outcomes focus of the majority of their activities, on their own annual work plan. However, we do hope that this summary article will be used by different NGOs and forestry advisers, involved in environment conservation within the reserve. Posters, oral presentations and leaflets in primary and secondary schools, training of community groups, and local environmental educators will serve to disseminate all existing knowledge and information on termitaria, to ensure an ESD.

Similarly to these suggested methods, educational outputs (including posters, stickers, videos, lesson plans, and workshops), primarily linking human needs to the ecosystem services provided by bats, were delivered to schools and community groups while, local environmental educators were trained to further develop the environmental education programs (EEPs), for the conservation of Critically Endangered Fruit Bats in the Western Indian Ocean (Trewhella et al., 2005).

How research findings on termitaria can serve for ecotourism purpose in the Pendjari biosphere reserve?

NGOs and any other agency in charge of tourism development in Benin and elsewhere can use some relevant data on termitaria, in order to write ecotourism projects or take termitaria into account in their touristic activities. With regard to the behavioral ecology of termitaria in Savannah, Korb and Linsenmair (2000) had noticed that during the day, sun heats the air in the peripheral air channels inside the ridges of the mounds above the central nest temperature, which produces a temperature gradient in the peripheral air channels with decreased temperatures at the top of the mound.

In contrast, during the night in Savannah and generally in the forest, the authors recorded air channels lower than those of the central nest with CO2 in mounds. Termitaria and their vegetation have received several attentions in the Pendjari Reserve. In fact, they offer panoramic view in the savannah ecosystem, which can really attract tourists. Traoré et al. (2008) as well as Dossou-Yovo et al. (2016) recorded the genera Capparis and Maerua both Capparaceae, solitary on termitaria and absent in the adjacent vegetation. Twenty-four *Capparaceae* species (Capparis and Maerua genera included) were reported on red list of threatened species, by International Union for Conservation of Nature (IUCN) (2016).

Therefore, termitaria can be seen as important conservation habitats for these threatened species. Plant communities on termitaria were different from agricultural lands (field and fallows) to the National Park (Dossou-Yovo et al., 2016). Fandohan et al. (2012) suggested termitaria as a factor used in controlling the establishment of Tamarindus indica and most of the plant species they host, although the termitaria-tamarind associations may be profitable to both termites and tamarind trees. They added that, termitaria may help to mitigate drought on tamarind trees while the trees in turn may offer food to termites. When conducting touristic visits, all data highlighted above will no doubt be very useful and interesting.

Furthermore, much ethnological knowledge on termitaria and their vegetation is available and there is a diversity of medicinal utilizations of termitaria plant species held by the three (03) major ethnic groups of the Pendjari's populations (Gourmanche, Berba and Wama). In fact, twenty-two (22) medicinal plant species from which twenty-one (21) woody species and one herbaceous species were recorded, as collected on termiatria in fields and fallows in the Reserve (Dossou-Yovo et al., 2014). These plants were used by the three ethnic groups to treat thirty (30) diseases and illnesses. Having the full list of the concerned species as well diseases treated and being able to recognize them during field visits will really interest tourists. All these data are interesting and important for ecotourism. Termitaria in Pendjari Biosphere Reserve serve as nesting place for bird species; they are also habitats for small mammals and reptiles (Dossou-Yovo et al., 2010). These findings increase the probability that tourists observe likely animal species on or inside termitaria.

One benefit of ecotourism is the maintenance of biodiversity as in some areas species and ecosystems are protected primarily to attract tourist (Barnard, 1995). Ecotourism was reported as a potential for sustainable development in three ecotourism lodges in the Southeastern Peruvian Amazon (Torres-Sovero et al., 2012). A common ecotourism goal is the generation of economic benefits, whether there are profits for companies, jobs for communities, or revenues for parks (Okech, 2008). Termitaria and their vegetation have until now been investigated biologically, ecologically and chemically and our article is the first one stating their importance for ecotourism. So its implementation will not only provide sustainable jobs for youths but also revenue for the Pendjari National Park and many companies.

Environmental income to be generated by ecotourism will lower the poverty probability of small households and those with young heads in the Biosphere Reserve (Cavendish and Campbell, 2008), so it will improve the QOL of the reserve dwellers. Wearing and Neil (1999) reported that, the tourists and host population benefit experientially from ecotourism through interactive processes. So visitors will also benefit from this ecotourism development. As suggested for environmental education, posters, oral presentations and leaflets suggested in this article, television and radio panels can also serve to inform and sensitize local populations and tourists on the importance of termitaria.

Technical guides on termitaria for ecotourism development are also necessary for that purpose. This guide can be easily and well developed by using existing data. For a better development of ecotourism in the three ecotourism lodges in the Southeastern Peruvian Amazon, Torres-Sovero et al. (2012) first identified and characterized tourist types, and then they found out variables influencing the level of satisfaction in each tourist type. Finally, these authors highlighted factors influencing the tourists' overall satisfaction. For future projects on ecotourism towards termitaria a similar approach can be adopted.

Conclusion

Termitaria and their vegetation, in addition to the biological and ecological role they play, can also serve for environmental education as well as ecotourism services. The ethnological and medicinal knowledge available on termitaria and their vegetation is quite important to be known by kids and students from primary and secondary school and tourists for a better conservation of termitaria and termitaria-associated vegetation.

The panoramic view of termitaria in savannah, their vegetation as well as the variation of plant communities on mounds according to the management type area is very attractive to tourists. Ethnological and medicinal knowledge on termitaria will serve for ecotourism in the reserve. Posters, oral presentations, TV and radio panels, leaflets and technical guide on termitaria are necessary for environmental education and ecotourism development.

This article by stating the way research findings on termitaria can serve both for environmental education and ecotourism is a way to contribute to biodiversity conservation and poverty alleviation in the biosphere reserve. For its dissemination, we will also make it available to the ecological team in charge of the reserve management as well as any forestry advisers and stakeholders.

CONFLICT OF INTEREST

The authors have not declared any conflict of interest

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Full Length Research Paper

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

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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 Adiopodoumé 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°40N) (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 ferralitic soil (Yessoh, 1973; Anonyme, 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 Koffiyaokro) and two others in the forest zone (near Kouassikro). The spacing was 80 × 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, $H' = -\Sigma\, p_i \times \log_2 (p_i)$. Where pi = 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.

$A = \sum n_i / N$;

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

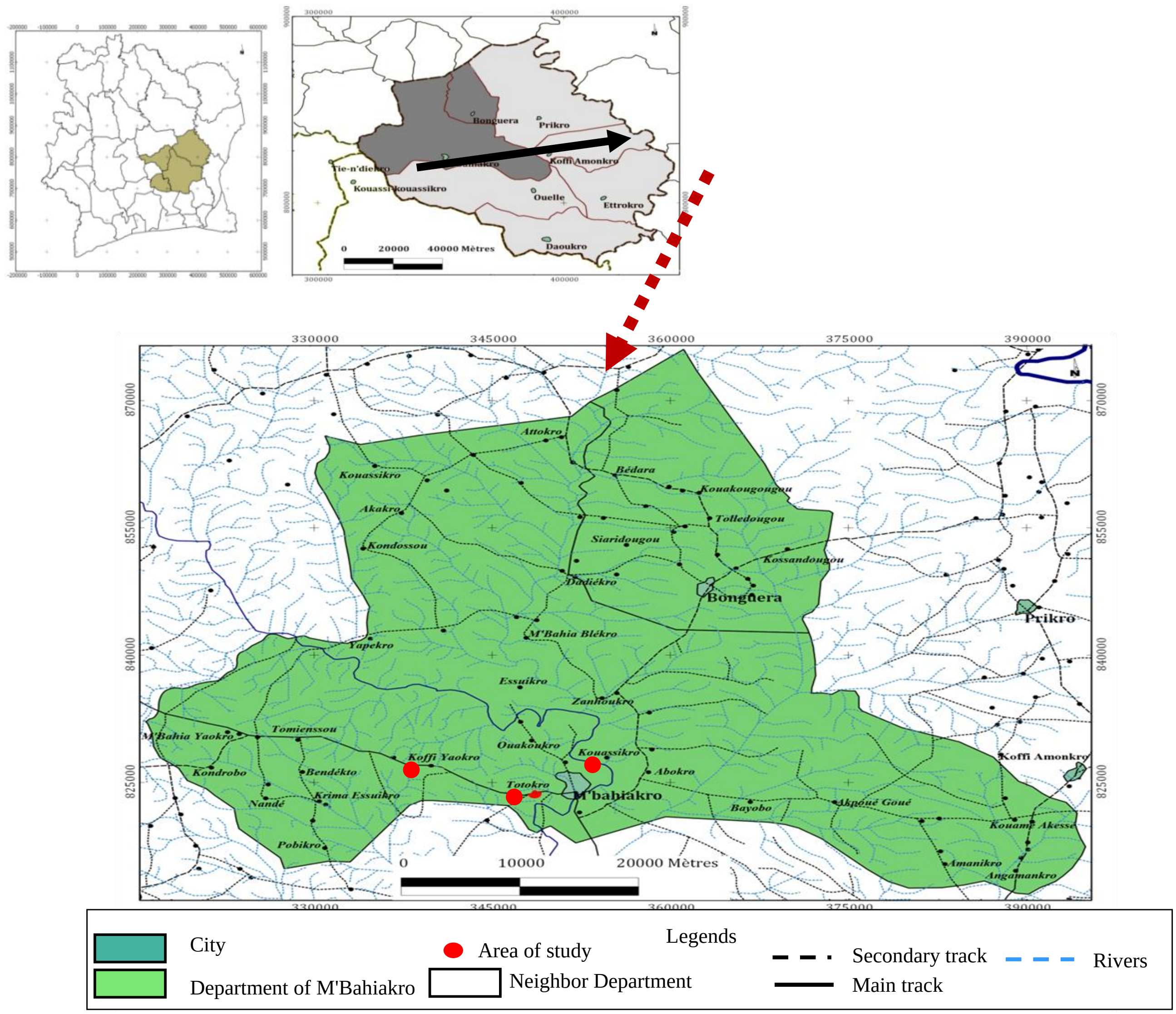

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Figure 1. Presentation of the study area (Source: www.googlemap.ci, 2012).

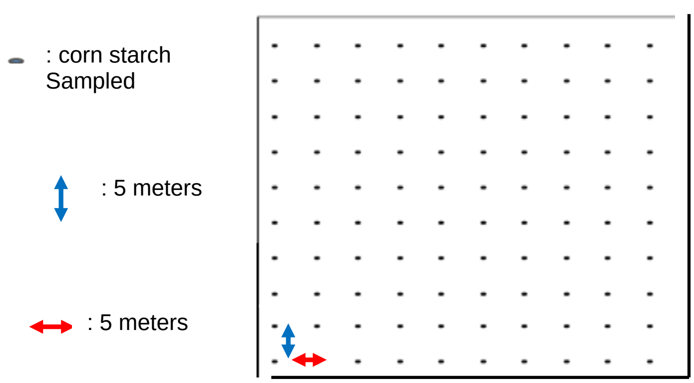

Figure 2. Sampling method: General arrangement of corn plants on the plot. Seed holes: Row spacing (80 cm): Distance between plants (40 cm).

Table 1. Number of insects according to the four phenological stages of corn.

Order of insects	Insect families	Rosette Stage	Elongation stage	Flowering stage	Grain maturation stage	Total number of insects per family	Percentage (%)	Total number of insects per order
Dermoptera	Forficulidae	77	251	262	276	866	4.3	866
Orthoptera	Acrididae	111	463	340	521	1435	7.14	4368
	Pyrgomorphidae	130	502	522	966	2120	10.55	
	Tettigonidae	50	192	178	291	711	3.54	
	Gryllidae	1	28	28	45	102	0.51	
Coleoptera	Attelabidae	3	20	45	31	99	0.49	3885
	coccinelidae	120	430	528	993	2071	10.31	
	Lagriidae	21	97	145	309	572	2.85	
	Chrysomelidae	35	210	273	480	998	4.97	
	Lycidae	0	33	33	79	145	0.72	
Heteroptera	Coreidae	1	150	198	431	780	3.88	6190
	Pyrrhocoridae	59	259	300	620	1238	6.16	
	Lygaeidae	8	51	81	191	331	1.65	
	Reduviidae	60	312	262	480	1114	5.54	
	Cydnidae	0	0	350	1016	1366	6.8	
	pentatomidae	0	0	111	251	362	1.8	
	Rhopalidae	1	110	165	391	667	3.32	
	Enicocephalidae	0	7	9	22	38	0.19	
	Acanthosomatidae	2	38	66	130	236	1.17	
	Cimicidae	0	0	9	49	58	0.29	
Homoptera	Lophopidae	0	71	129	253	453	2.25	2016
	Cercopidae	117	273	321	254	965	4.8	
	Derbidae	0	250	161	187	598	2.98	
Lepidoptera	Noctuidae	0	0	246	1105	1351	6.72	2169
	Pyralidae	0	0	90	728	818	4.07	
Diptera	Asilidae	0	0	14	24	38	0.19	38
Dictyoptera	Blattidae	2	132	128	299	561	2.79	561
Size		**798**	**3879**	**4994**	**10422**	**20093**	**100**	
Average		**199.5**	**969.75**	**1664.67**	**1488.86**			

index with H'=1.72. 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

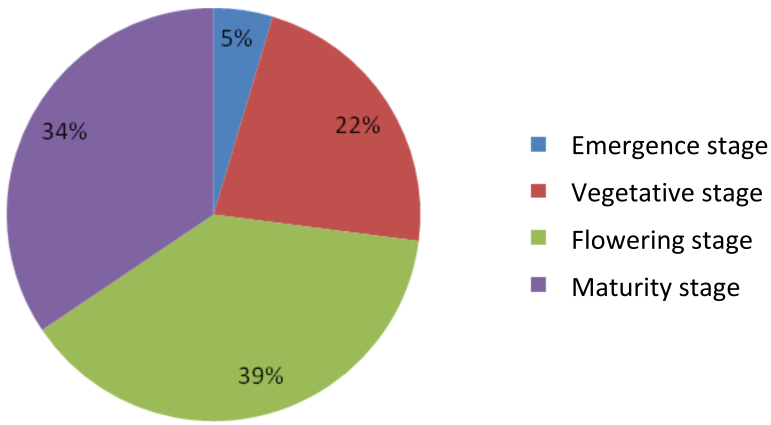

Figure 3. Proportion of insect pests depending on the phenological stages of corn.

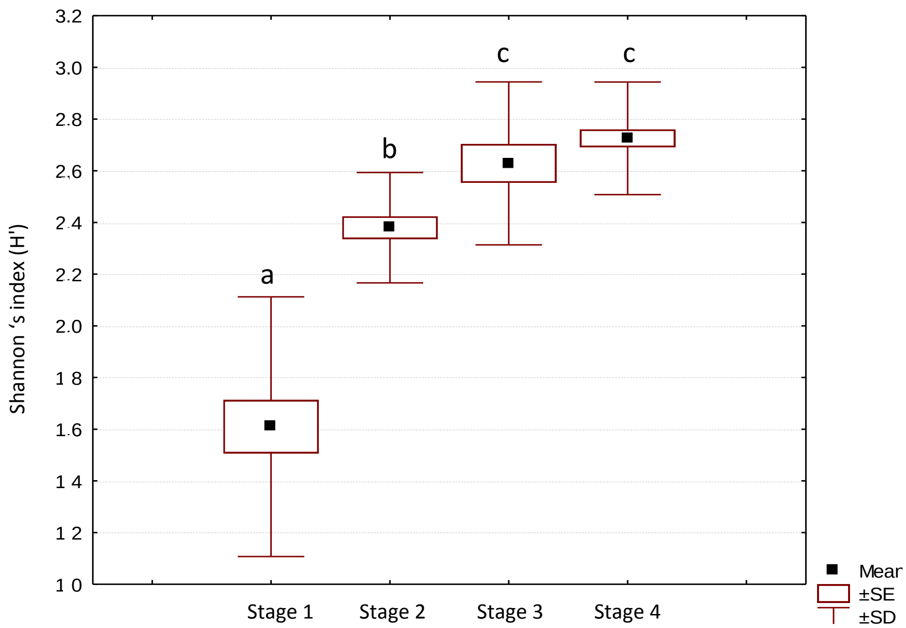

Figure 4. overall diversity of insects.

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

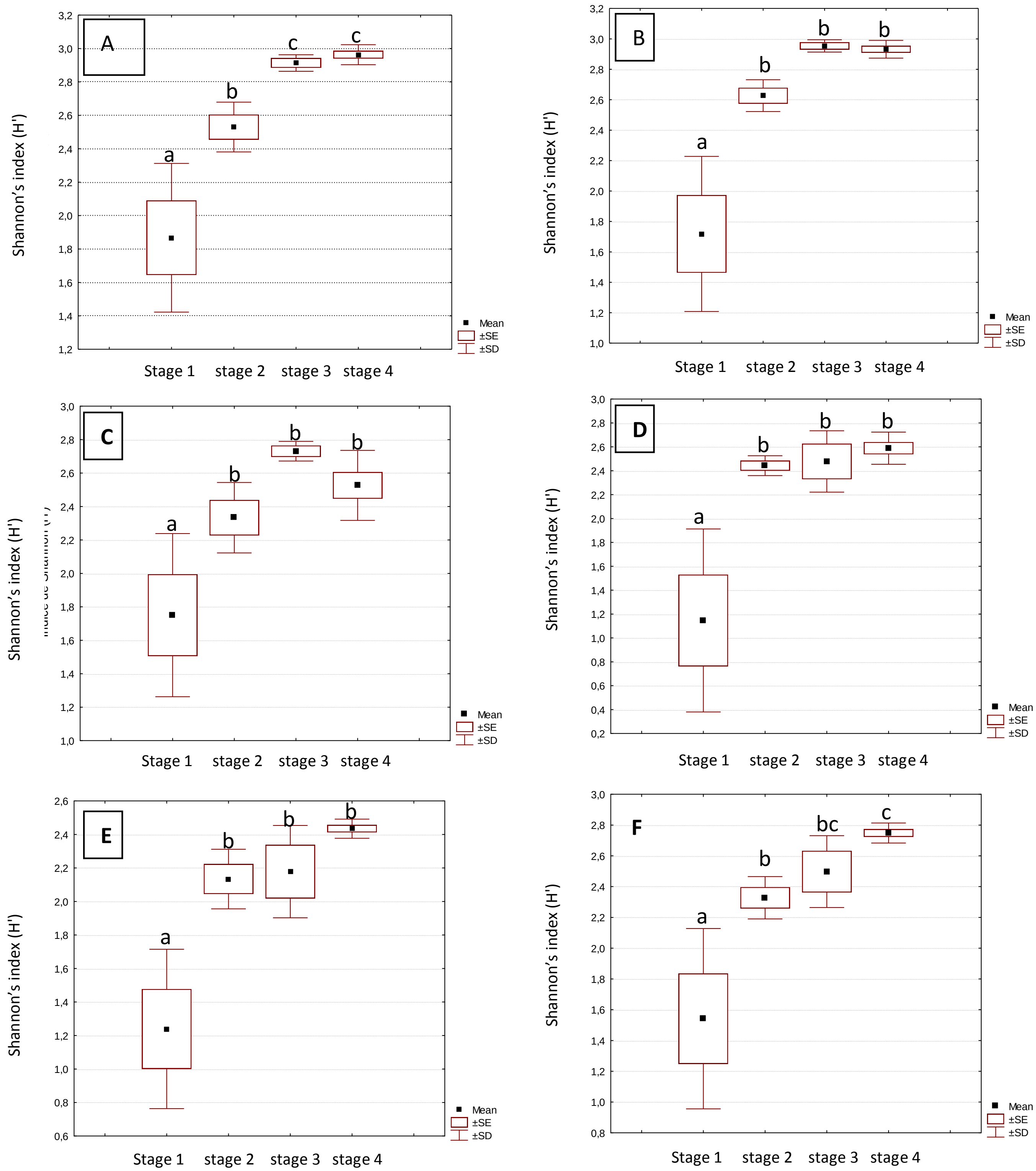

Figure 5. Insect diversity according to plot: **A**: Totokro plot 1. **B**: Totokro plot 2. C: Koffiyaokro plot 1; **D**: Koffiyaokro plot 2. **E**: Kouassikro plot 1. **F**: Kouassikro plot 2. Legends: Stage 1 = Emergence; Stage 2 = vegetative; Stage 3 = flowering; Stage 4 = Maturity.

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.

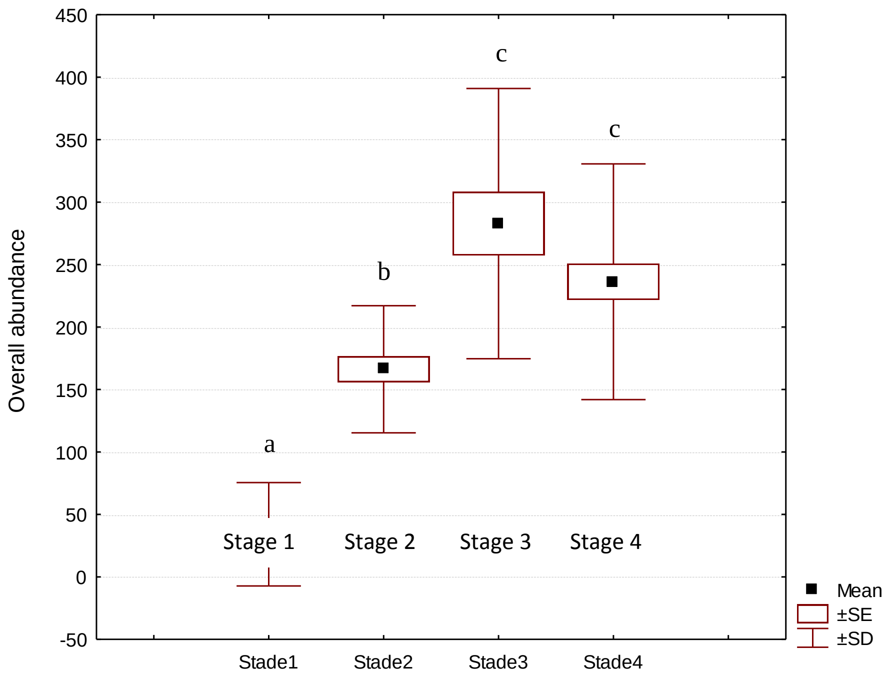

Figure 6. Overall insect abundance.

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

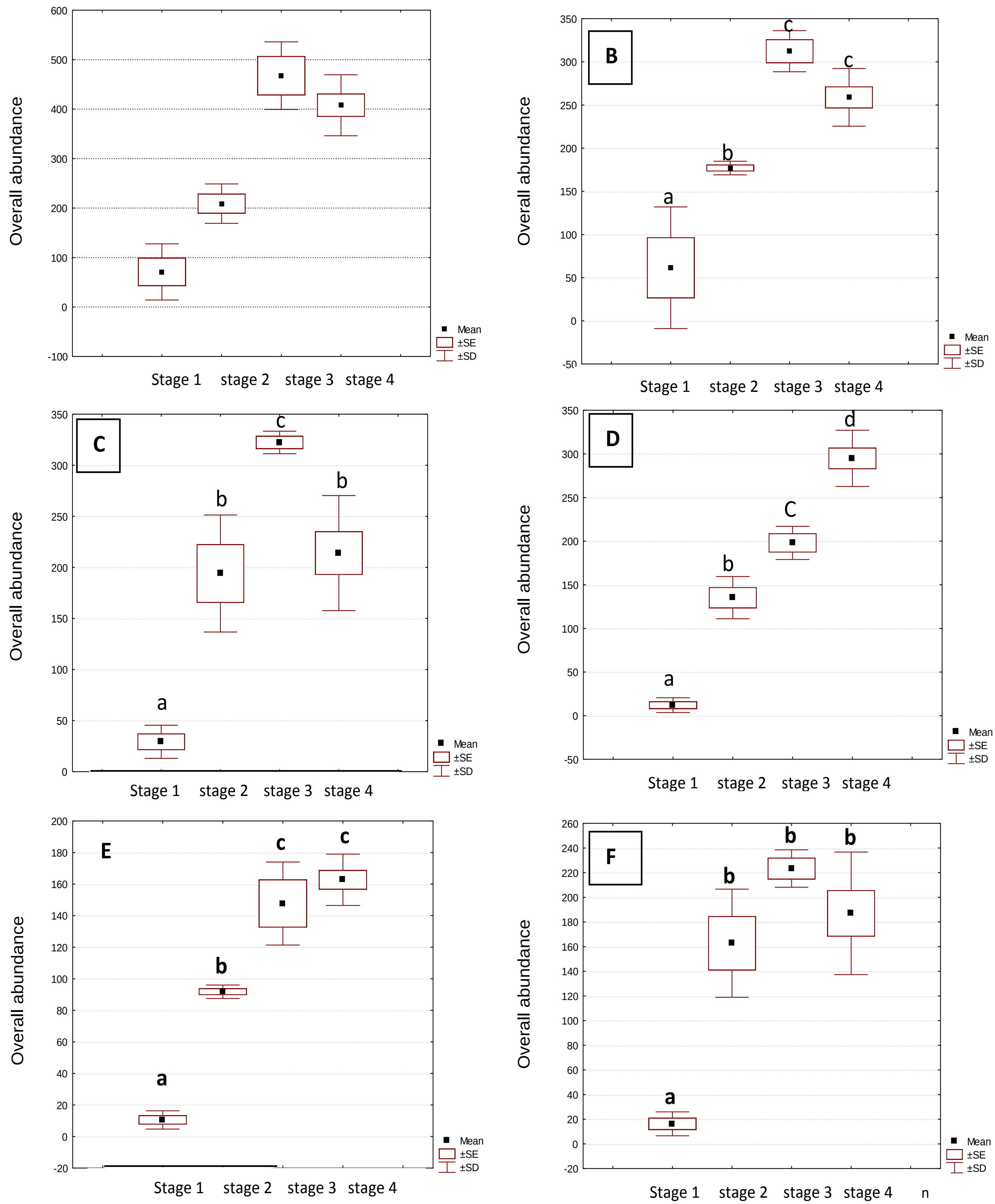

Figure 7. Insect abundance according to plot: A: Totokro 1. B: Totokro 2. C: Koffiyaokro 1.D: Koffiyaokro 2. E: Kouassikro 1. F: Kouassikro 2.

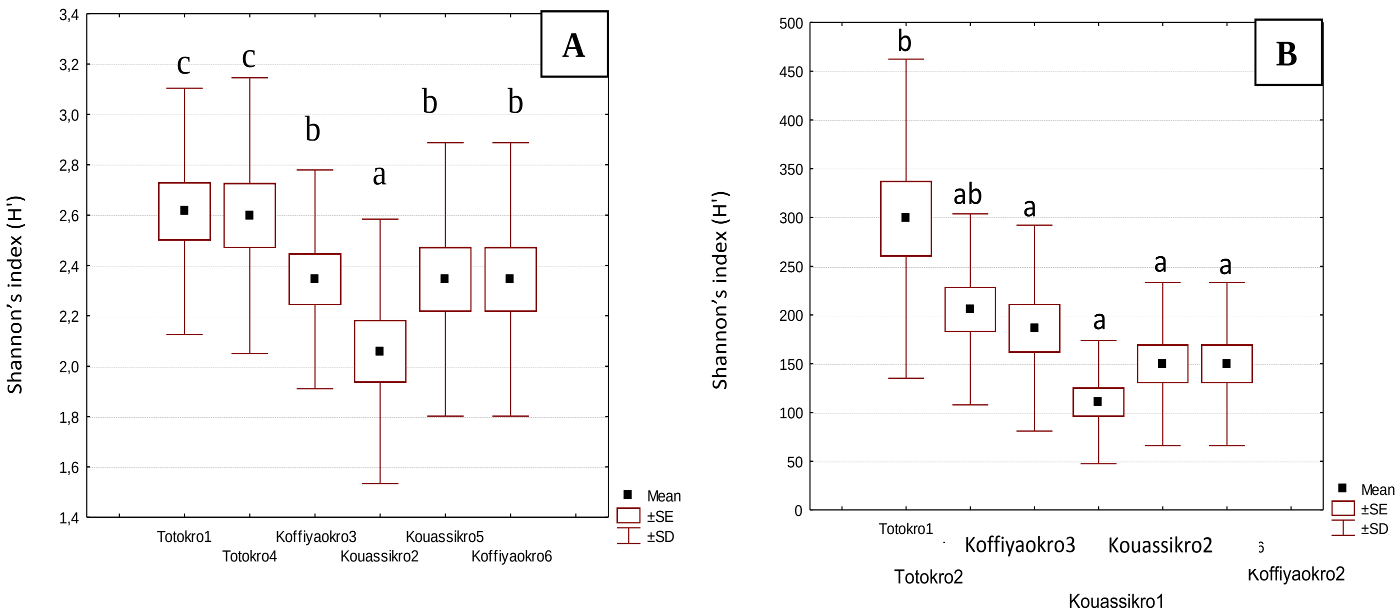

Figure 8. Diversity and abundance of insects according to plot: A: Effect of the environment on biological diversity; B: Effect of the environment on abundance.

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, Cydnidae, 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.

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