Influence of the Cultivated Plant Diversity on the Abundance of Arthropod Trophic Groups and *Helicoverpa armigera* Biological Control in Tomato Cropping Systems in Benin

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Abstract

With the aim of optimizing pest management, a study was carried out to determine the effect of cultivated plant diversity on arthropod communities and Helicoverpaarmigera regulation in tomato cropping systems. Therefore, the diversity of cultivated plants and arthropod communities were assessed within and around tomato fields from 30 farmer's fields randomly selected in South of Benin. In each tomato field, an experimental plot (or elementary plot) (20x20m) in the center of each tomato field was delimited. Each experimental plot was subdivided into a 4 m by 4 m quadrats in which all cropped plants were identified and counted. In the center of each quadrat, one Pitfall trap with soapy water leading to 25 Pitfall traps per field was placed and uplifted after 72 hours to capture the soil and littermacrofauna. The study showed that at the field scale, the abundances of omnivore predators, generalist predators and herbivores were greater in mixed cropping systems than in monocropping systems while the abundance of Helicoverpaarmigera was lower in the mixed cropping systems than in monocropping systems. Multiple intercropped plant species increased the abundance of generalist and omnivore predators. This study allowed better understanding how plant diversity associated to tomato field structures arthropod food webs to finally enhance the ecological management of H. armigera.

Keywords:
Tomato, Helicoverpaarmigera, arthropods, predators, pest management

Introduction

Cultivating plant mixtures is expected to provide a higher overall productivity, a better control of pests and diseases , and enhanced ecological services . Mixed cropping systems are often seen as a strategy to reduce the risk of pest incidence through ecological processes as diverse as barrier, dilution and trophic effects (Ratnadass *et al.,* 2012). Increasing natural regulations constitutes an important component of more sustainable cropping systems. The management of animals and plants communities in the agroecosystems represents one of most important levers to improve these regulations. Understanding trophic interactions between different species in agroecosystems is essential to develop more efficient pest control strategies based on ecological regulation processes.

In Benin, tomatoes are grown in cropping systems ranging from monoculture to intercropping with diverse food crops including maize, roots, tubers and vegetables. These un-mechanized cropping systems rely on family labor and receive very little chemical inputs. The cultivation of tomato is very important for the economy of many countries and contributes to the food security of populations . The tomato fruit is involved in several daily dishes and is a source of minerals and vitamins that can help reduce micronutrient and vitamin deficiencies .

Pests and diseases greatly reduce the yield and the market value of the tomato fruits. The main tomato pest is *Helicoverpaarmigera* which feed on tomato fruits. *Helicoverpaarmigera* is polyphagous and also causes massive damages to the tomato fruit, thus greatly reducing tomato yield. Several studies showed that the generalist predators are important predator groups and can improve pest control in cropping systems . Generally, arthropod biodiversity declines with cropping intensification, yet little is known about the mechanisms for predator declines and how the fall in diversity may affect the role of the generalist predators. Few studies showed the role of associated crops on generalist predator abundance increases and on pest regulations. The crop diversity is expected to change the structure of arthropod trophic groups in tomato cropping systems and *in fine* should modify the control of *H. armigera* by predators.

The management of plant diversity in tomato fields is the primary pest management practice that farmers can do. It is thus important to understand how cultivated plant diversity in these systems influences the structure of arthropod food webs and the control of *H. armigera*. In this study, we studied 30 tomato fields (in monocropping or in mixcropping) to investigate how the cultivated plants mixed with tomato plants affects the abundance of generalist predators and of *H. armigera*. Our goal was to identify the plants intercropped with tomatoes that participate to improve the control of *H. armigera* and to reduce the postharvest damages.

Materials and Methods

Study sites

The study was realized at the southern part of Benin in the regions of Atlantic, Mono and Couffo. The tomato fields were located in the small villages of Allada, Kpomassè, Sèhouè, Ouègbo, Grand-popo, Azovè, Djakotomey and Aplahoué, in areas where tomato is a major production. The climate is humid tropical with, an average temperature of 28 ° C and rainfall up to 1400 mm per year. The soil is sandy clay soil. All fields contained the tomato plants and a diverse array of other annual (e.g. maize, groundnut and vegetable crops) and perennial crops (e.g. palms and pineapples).

Measurement of plant diversity and arthropod communities in tomato cropping systems

In 30 fields covering a gradient of situations ranging from 1 to 10 associated crops, we characterized the vegetation structure (species composition) at the field scales. In each tomato field, an experimental plot (or elementary plot) (20x20m) in the center of each tomato field was delimited. Each experimental plot was subdivided into a 4 m by 4 m quadrats in which all cropped plants were identified and counted. In the center of each quadrat, one Pitfall trap with soapy water leading to 25 Pitfall traps per field was placed and uplifted after 72 hours to capture the soil and litter macrofauna. At total 25 pitfall traps were used per field in order to maximize the trapping. Additionally, all flying insects were captured with an entomological net and the others were collected directly on the plants using a mouth aspirator. All arthropod individuals collected with the traps, nets and aspirator were identified up to the genus or to the species and counted. The same measurements were realized between 8 to 12 AM in two periods: 3 months in the long rainy season (May, June and July) and 3 months in the short rainy season (August, September and October). The identification of arthropod taxa collected in the fields was completed at Entomological Museum of IITA – Benin. Each taxon was associated to a trophic group (herbivore, predator…) according to the literature.

Data analysis

The cultivated plant diversity was evaluated with Shannon Index which was calculated with the diversity function of the vegan package version 2.2-1 . Poisson Generalized Linear Models (GLMs) was used to analyze the effect of cultivated plant diversity on the abundance of arthropod trophic groups. The student test was used to test the difference between pluricrops and monocrops of tomato with respect to the abundance of each arthropod trophic group. Statistical analyses were performed with R 2.15.0 at a significant level of 5% (alpha=0.05).

Results

Abundance of the arthropod species in tomato agroecosystems

As a whole, 3351 individual arthropods from 12 orders were collected inside tomatoes fields. The most abundant orders were Hymenoptera with 1937 individuals followed by Orthoptera with 391 individuals, Araneae with 384 individuals, Coleoptera with 353 individuals. On the literature basis, 5 arthropod trophic groups were constituted as follows: omnivores (1905 individuals), herbivores (940 individuals), generalist predators (467 individuals), detritivores (30 individuals) and parasitoids (7 individuals). We retained for further analyses the arthropods for which the trophic group abundances were > 400 individuals. The arthropod species the most abundant and for which the occurrence was > 50 in tomatoagroecosystemswere*Paltothyreustarsatus, Pheidole*spp., *Gonocephalum simplex*, *Araneus*sp., *Aiolopussimulatrix, Erigone*sp., *Zonocerusvariegatus, Helicoverpaarmigera, Camponotus*sp.

Difference of *Helicoverpaarmigera* abundance between monocrop and multi-crops in tomato agro-ecosystems

The abundances of *Helicoverpaarmigera*weresignificantly lower in the mixed crop fieldsthan in monocropwhile the abundances of the predators were significantly higher in the mixed crop fieldsthan in monocropfields (Figure 1). While the abundances of herbivores and omnivores were not correlatedwith the crop type (Table 1). All the diversity indices such as arthropod abundance, arthropod diversity, arthropod richness and arthropod evenness were significantly higher in the mixed crop fieldsthan in monocropfields (Figure 2 & Table 2).

Table 1. **Kruskal-Wallis tests on abundance according to the crop type. ns : no significant**

Species/Trophic group	Chi²	p value	Significance level
Helicoverpaarmigera	33.50176	< 0.001	****
Predator	46.66613	< 0.001	****
Omnivore	3.696173	0.054	ns
Herbivore	2.990399	0.084	ns

Table 2. **Kruskal-Wallis tests on arthropod community indices according to the crop type**

Community index	Chi²	p value	Significancelevel
Abundance	19.32724	1.101238e-05	****
Richness	11.46436	7.094359e-04	***
Diversity	6.31877	1.194665e-02	*
Evenness	8.507922	3.536036e-03	**

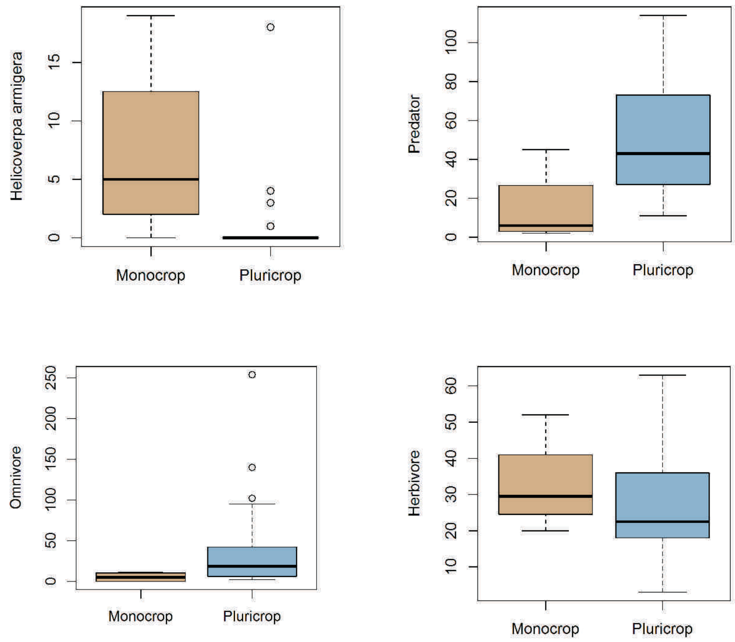

Figure 1. **Abundance of *Helicoverpaarmigera* and of 3 trophic groups according to the crop type**

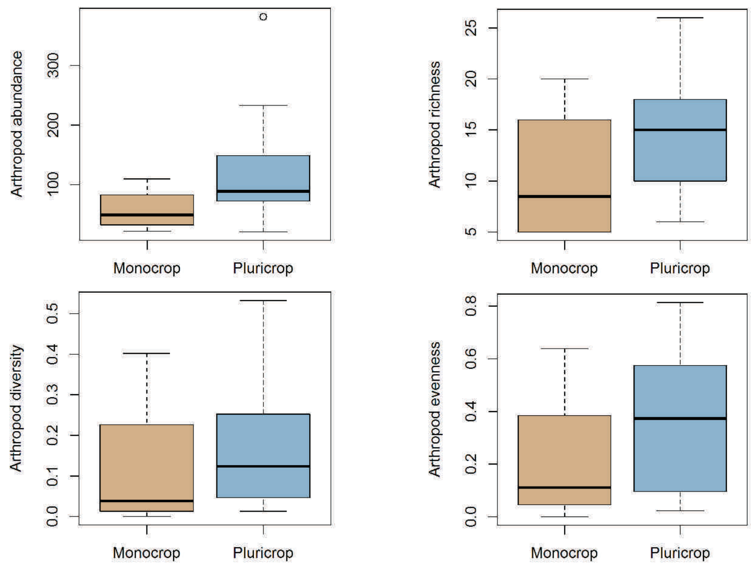

Figure 2. **Arthropod community indices according to the crop type**