GfÖ Ecological Society of Germany, Austria and Switzerland

Basic and Applied Ecology 17 (2016) 11–20

Basic and Applied Ecology

www.elsevier.com/locate/baae

# Contrasting effects of plant diversity across arthropod trophic groups in plantain-based agroecosystems

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Received 15 December 2014; accepted 9 September 2015
Available online 25 September 2015

## Abstract

Previous biodiversity studies have shown that plant diversity increases the complexity of arthropod food webs. However, only a few studies have addressed this issue in tropical ecosystems, in which the small annual variations allow the community to approach a steady state. With the goal of optimizing pest management, we studied the effect of plant diversity on the arthropod community in 20 plantain-based fields in Cameroon. Plantain-based agroecosystems are especially useful for studying the effects of plant diversity because they contain few to many non-plantain crop plants and are treated with few or no pesticides or fertilizers. We measured the diversity of cropped plants and the abundance of ground-dwelling arthropods. Five trophic groups of arthropods were identified based on stable isotopic signatures ($\delta^{13}C$ and $\delta^{15}N$). At the field scale, predator abundance was positively correlated with plant diversity while herbivore abundance displayed the opposite pattern. These strong and inverse effects of plant diversity on predator and herbivore abundances suggest that top-down forces and resource concentration structure the arthropod community in plantain fields. Our findings are consistent with other studies that showed a reduction of interaction and interference between predators in more structured habitats. These findings will help in the design of plantain agroecosystems that enhance pest control.

## Zusammenfassung

Frühere Untersuchungen zur Biodiversität haben gezeigt, dass die Pflanzendiversität die Komplexität von Arthropoden-Nahrungsnetzen erhöht. Indessen haben sich nur wenige Studien mit dieser Fragestellung in tropischen Ökosystemen befasst, in denen geringe saisonale Umweltveränderungen der Gemeinschaft erlauben, einen Gleichgewichtszustand zu erreichen. Mit dem Ziel einer optimierten Schädlingskontrolle untersuchten wir den Effekt der Pflanzendiversität auf die Arthropodengemeinschaften von 20 Kochbananenfeldern in Kamerun. Diese Felder sind besonders gut für solche Untersuchungen geeignet, weil zusammen mit der Kochbanane einige bis viele andere Nutzpflanzen angebaut werden und weil Pestizide oder Dünger kaum oder gar nicht eingesetzt werden. Wir maßen die Diversität der angebauten Pflanzen und die Abundanz von bodenbewohnenden Arthropoden. Fünf trophische Gruppen wurden anhand der Signaturen von stabilen Isotopen (<delta>13 C and <delta>15 N)

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http://dx.doi.org/10.1016/j.baae.2015.09.003

identifiziert. Auf der Felds kalawar die Abundanz der Räuber positiv mit der Pflanzendiversität korreliert, während die Abundanz der Herbivoren einen entgegengesetzten Trend zeigte. Diese starken gegenläufigen Effekte legen nahe, dass top-down-Kontrolle und Ressourcen-Konzentration die Arthropodengemeinschaften von Kochbananenfeldern strukturieren. Unsere Befunde stimmen mit anderen Untersuchungen überein, die einen Rückgang von Interaktion und Interferenz zwischen Räubern in stärker strukturierten Habitaten gezeigt hatten. Diese Ergebnisse werden sich bei der Gestaltung von Kochbananen-Agrosystemen, die die Schädlingskontrolle verbessern, als nützlich erweisen.


***Keywords:*** Arthropod food webs; Field scale; Multitrophic interactions; Habitat structure; Cameroon; *Musa* spp. AAB group

## Introduction

High functional diversity in agroecosystems provides and promotes important services to human society such as biological control, pollination, and nutrient cycling (Cardinale et al. 2012). The effect of biodiversity on ecosystem characteristics, including belowground biomass, pollination, and predation and parasitism of pests, is mediated by the heterogeneity of resources and their spatial organization (Tylianakis et al. 2008). Currently, there is a critical need to better understand the effect of plant diversity on the functioning of agroecosystems so as to enhance production and ecosystem services.

Plant diversity determines the structure of food webs (Eisenhauer et al. 2013; Haddad, Crutsinger, Gross, Haarstad, & Tilman 2011) and affects the abundance, diversity, and functioning of species at higher trophic levels (Ebeling, Klein, Weisser, & Tscharntke 2012; Loranger et al. 2014; Unsicker et al. 2006). Scherber et al. (2010) documented a positive effect of plant diversity on the abundance and diversity of most trophic groups (except invasive groups), and this effect decreased with increasing trophic height. Plant diversification of agroecosystems is currently receiving considerable attention from agroecologists (Fahrig et al. 2011; Isbell 2015). More specifically, ecosystems with higher plant diversity are expected to support increased levels of pest regulation (Letourneau et al. 2011; Quijas, Schmid, & Balvanera 2010). Plant diversity helps sustain arthropod populations, including increased abundances of natural enemies (Tylianakis, Tscharntke, & Lewis 2007), and often supports increased levels of pest predation (Landis, Menalled, Costamagna, & Wilkinson 2005). Pests can be controlled by both bottom-up effects from plants and by top-down effects by natural enemies (Rosenheim 1998). Theory suggests that plant diversity enhances pest control by stabilizing natural enemy communities (Tylianakis & Romo 2010) and by providing resources that have indirect effects on higher trophic levels through bottom-up trophic cascades (Power 1992). Diversified systems, however, do not always exhibit decreases in pest numbers and damage (Letourneau et al. 2011). Indeed, in diversified agroecosystems, the predators may feed on more abundant alternative prey, thus decreasing their control of pests (Holt 1977). The connectivity (i.e., consumption intensity) between trophic groups is thus crucial in the provision of pest control. Here, we investigated the effect of plant diversity on the abundance of trophic groups, and we assumed that their connections ranged from strong to weak. Based on the response of each trophic group and of the studied taxa in terms of abundance, we assessed the relative effects of bottom-up vs. top-down forces in structuring the food web.

The use of stable isotopes of C and N can be useful for identifying homogeneous trophic groups and for generating hypotheses about their linkages. Because values of $\delta^{13}C$ (see "Materials and methods" section for details on the δ notation) are relatively conserved along trophic chains, $\delta^{13}C$ is a good marker of the resources consumed by a given organism (DeNiro & Epstein 1978). Basal resources have contrasting values of $\delta^{13}C$, ranging from −30‰ to −5‰ for C3 and C4 plants, respectively (Swap, Aranibar, Dowty, Gilhooly, & Macko 2004; Yakir & Israeli 1995); this enables researchers to separate primary consumer taxa that feed on different basal resources. At the same time, the regular enrichment of $^{15}N$ along trophic chains allows researchers to use $\delta^{15}N$ values to estimate the trophic level of organisms (Minagawa & Wada 1984; Ponsard & Arditi 2000). Taxa with similar values of $\delta^{13}C$ and $\delta^{15}N$ are thus in the same trophic niche and constitute a relatively homogeneous group (Newsome, Martinez del Rio, Bearhop, & Phillips 2007).

In the humid tropics of Africa, plantains (cooking bananas with *Musa* AAB genome) are cropped in association with annual crops (roots, tubers, and vegetable crops) and perennial crops (cocoa, coffee, palm, and others). Plantain fields may be planted with >20 kinds of other crop plants and are mainly managed with few or no inputs of fertilizer or pesticide. In most banana and plantain production areas, the most important pest is the banana weevil, *Cosmopolites sordidus* (Coleoptera, Curculionidae) (Germar., 1825) (Gold, Pena, & Karamura 2001). In a simple banana agroecosystem, previous studies have shown that the addition of a primary resource (a cover crop) altered the structure of the arthropod community (Duyck et al. 2011), increased the abundance of a potential predator of *C. sordidus* (*Solenopsis geminata*, Myrmicinae), and increased *S. geminata* predation of *C. sordidus* eggs that were artificially placed in the fields (Mollot, Tixier, Lescourret, Quilici, & Duyck 2012). We expect that the presence of multiple crops may also change the structure of arthropod food webs in plantain systems and should