Biological Control 99 (2016) 14–18

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Cover cropping reduces the abundance of the banana weevil *Cosmopolites sordidus* but does not reduce its damage to the banana plants

Dominique Carval [a,*,1], Rémi Resmond [a,1], Raphaël Achard [a,1], Philippe Tixier [b,c,1]

[a] CIRAD, UPR GECO, F-97285 Le Lamentin, Martinique
[b] CIRAD, UPR GECO, F-34398 Montpellier, France
[c] Departamento de Agricultura y Agroforesteria, CATIE, CR-30501 Turrialba, Costa Rica

HIGHLIGHTS

- The cover crop *Paspalum notatum* reduced the abundance of adult weevils.
- The proportion of newly emerged adults was increased by the cover crop.
- The proportion of newly emerged adults was negatively correlated with earwig number.
- Corm damage was higher in cover crop plots than in bare soil plots.
- Fruit biomass was lower in cover crop plots than in bare soil plots.

ARTICLE INFO

Article history:
Received 14 December 2015
Revised 1 April 2016
Accepted 10 April 2016
Available online 20 April 2016

Keywords:
Biological control
Banana weevil
Earwig
Ecosystem services
Crop damages

ABSTRACT

Diversification of cropping systems raises new questions in the functioning of arthropod communities and biological control of pests. In banana cropping systems, the addition of a cover crop can increase biodiversity in general and the diversity and abundance of arthropod generalist predators in particular. We measured the abundance of a major pest of bananas, the banana weevil *Cosmopolites sordidus*, in plots with a cover crop, *Paspalum notatum*, and in plots with bare soil; all plots had banana plants. We also measured the effect of the cover crop on the damage done to corms by weevil larvae and on banana fruit biomass. The addition of the cover crop reduced numbers of mature *C. sordidus* adults but failed to reduce damage to corms. The proportion of young adults, which reflects survival of eggs and larvae, was higher in cover crop plots than in bare soil plots and was negatively correlated with the abundance of the earwig *Euborellia caraibea*. Fruit biomass was lower in cover crop plots, perhaps because of competition between the banana crop and the cover crop.

1. Introduction

The banana weevil *Cosmopolites sordidus* (Germar) is a major pest of banana crops (Cuillé, 1950; Gold et al., 2001). *C. sordidus* adults are nocturnal and disperse by walking, usually for short distances (Carval et al., 2015; Gold et al., 2001; Vinatier et al., 2010) although Rannestad et al. (2011) showed that the migration potential of *C. sordidus* may be greater in unsuitable environment. The females chew small cavities in the banana corm and pseudostem, where they deposit eggs (Cuillé, 1950). Once the eggs hatch, the larvae bore galleries as they feed on the corm and pseudostem tissues (Cuillé, 1950). The resulting damage can cause yield losses as high as 100% if the damaged banana plants topple before harvest (Gold et al., 2001).

To manage *C. sordidus*, growers apply pesticides, use clean planting material, practice crop sanitation, and trap the adults (Budenberg et al., 1993; Duyck et al., 2012; Gold et al., 2001; Rhino et al., 2010). Since the beginning of the 20th century, however, researchers have studied natural enemies of *C. sordidus*, especially in Indonesia, which is the putative area of origin of this pest (Froggatt, 1924; Jepson, 1914). In a recent survey in Java and Sumatra, Abera-Kalibata et al. (2006) identified several potential predators of the banana weevil. Three of these consumed eggs

* Corresponding author at: Campus Agroenvironnemental Caraibes, CIRAD, UPR GECO, Petit Morne, F-97285 Le Lamentin, Martinique.
E-mail address: dominique.carval@cirad.fr (D. Carval).

[1] The authors contributed equally to this work.

http://dx.doi.org/10.1016/j.biocontrol.2016.04.004
1049-9644/

and larvae in a laboratory experiment. However, indigenous natural enemies have been proven to be efficient in pest regulation (Letourneau et al., 2009; Offenberg, 2015) and should be favored over the introduction of predators from the pest's area of origin. Endemic, potential natural enemies of *C. sordidus* have been identified in Africa, Asia, and Latin America (Dassou et al., 2015; Gold et al., 2001) and also in the Caribbean (Mollot et al., 2014, 2012), but little information is available concerning their ability to suppress *C. sordidus* numbers. In Uganda, Koppenhöfer et al. (1992) identified the earwig *Euborellia annulipes* (Lucas) as a predator of the eggs and of the four first instars of larvae of *C. sordidus*. In a controlled experiment, Koppenhöfer (1993) found that *E. annulipes* reduced the number of *C. sordidus* eggs and first instars by 28%. Moreover, this earwig occurs in the same habitat as *C. sordidus*, i.e., on corms, pseudostems, and stumps of banana plants (Koppenhöfer, 1993; Koppenhöfer et al., 1992). Using a metabarcoding approach, Mollot et al. (2014) recently proved that the earwig *Euborellia caraibea* (Hebard) feeds on *C. sordidus* in the French West Indies.

Diversification of cropping systems will likely alter arthropod communities and the biological control of arthropod pests. Scherber et al. (2010) showed that the abundance of all trophic groups except pests and invaders increases with plant diversity. Diversification of cropping systems generally enhances pest regulation (Letourneau et al., 2011; Symondson et al., 2002) but may reduce yield (Letourneau et al., 2011). In banana cropping systems, the addition of a cover crop alters the trophic position of predators, leading to a decrease in intraguild predation and potentially to an increase in pest regulation by generalist predators (Duyck et al., 2011; Tixier et al., 2013). The abundance of the fire ant *Solenopsis geminata* and its predation on bait eggs of *C. sordidus* were greater in banana plots with a cover crop than with bare soil (Mollot et al., 2012).

Although valuable, these previous studies did not measure the effect of the cover crop on *C. sordidus* abundance, or on the damage that this pest causes to the banana crop. To be economically efficient, biological control by generalist predators should reduce pest abundance and pest damage and maintain crop yield. Here, we studied how the introduction of a cover crop, *Paspalum notatum* (Poaceae), affects the abundances of the earwig *E. caraibea* and *C. sordidus*, corm damage, and the weight of banana bunches. We tested the following hypothesis regarding the effects of the added cover crop: (i) the abundance of *C. sordidus* will be smaller because the new basal resource will support a diverse herbivore community that provides alternative prey to generalist predators; (ii) the abundance of *E. caraibea* will be greater because of increase in alternative prey and because of a decrease in intraguild predation; (iii) damage caused by *C. sordidus* to the banana crop will be reduced; and (iv) the banana bunches will have reduced mass because of competition with the cover crop.

2. Materials and methods

2.1. Study site and experimental design

The experiment was conducted in Martinique (French West Indies) between January 2014 and April 2015 on an experimental farm in Rivière-Lézarde (14°39′45.04″N; 60°59′59.08″W) in an area initially free from weevil. Six plots were established, each with an area of 361 m^2 and with 49 banana plants (Cavendish Grande Naine cultivar). The banana plants were planted on 24 July 2012. The cover crop *Paspalum notatum* was planted in three of the plots on 11 June 2012, while the other three plots were maintained with bare soil. The plots with the cover crop and with bare soil are hereafter referred to as CCP and BSP, respectively. The plots were arranged as presented in Fig. 1. On 30 October 2012, 70 banana weevils (sex ratio 1:1) were added to each plot. Each month, banana plants were uniformly fertilized, the cover crop was cut back and weeds were controlled with herbicide (glyphosate) in BSP.

2.2. Sampling of banana weevils and earwigs

Banana weevil and earwig abundances were estimated with pseudostem traps once each month in April, June, August, and November of 2014 and in April of 2015. The pseudostem traps, which were 30 cm long, were deposited at the bottom of each banana plant (new traps were deployed for each of the five sampling dates), and weevils and earwigs found in the traps 1 week later were counted (Dassou et al., 2016; Gold et al., 2001; Koppenhöfer et al., 1992). We discriminated between newly emerged adult weevils (hereafter called teneral adults) and older weevils (hereafter called mature adults) based on exoskeleton color (Gold et al., 2001).

2.3. Corm damage caused by C. sordidus

Banana cropping systems can be maintained multiple cycles. A cycle consists in four steps: vegetative growth, flowering, sucker appearance and harvest of the bunch. Data presented here were issued from the second and the third cycles of culture. For each cycle and for each banana plant, at the harvest, bunch was weighed and damage was assessed by removing 2 cm of the corm surface from 10 cm above to 10 cm below the soil surface over the entire circumference of the corm. A 0–100 scale was used to score the damage on each corm (Vilardebo, 1973): 0 = no damage; 5 = 1 or 2 galleries; and 10, 30, 40, 60, and 100 = 10, 25, 50, 75, and 100%, respectively, of the corm circumference damaged. This method

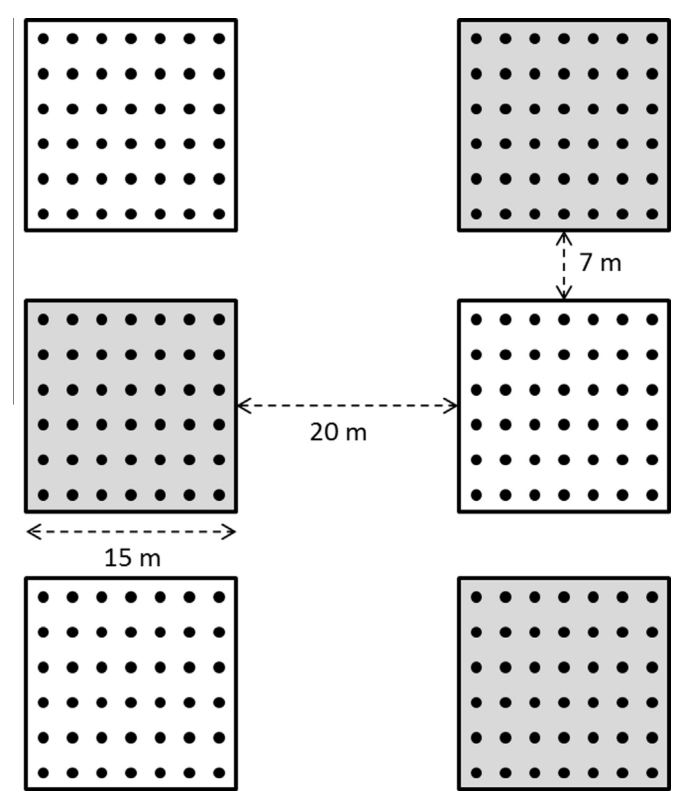

Fig. 1. Spatial arrangement of the experimental plots. White squares: bare soil plots. Gray squares: cover crop plots. Black points: banana plants.