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Efficacy of two traps and three different pheromone-based attractants to control the banana weevil adults *Cosmopolites sordidus* (Coleoptera: Curculionidae) in banana orchards on Terceira Island, Azores

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Abstract: The banana borer weevil, *Cosmopolites sordidus* (German) (Coleoptera: Curculionidae), is considered an important pest of bananas. It is extremely specific to Musaceae (Musaceae: *Musa* species). The efficacy of the different combination of traps and attractants on the banana weevil is important to been investigated to identify the best combination to use in banana orchards on Terceira Island (Azores). For that purpose, an essay was conducted during two years (2021 and 2022) to determine the efficiency of two traps (Cosmotrack and Stopweevil) and three attractants containing sordidin pheromone (Cosmogel NovAgrica, CosmoPlus Scyll'Agro and EcoSordidina 90K Ecobertura) to monitor *C. sordidus* populations in two banana orchards. The trap contents were collected every 15 days in 2021 for all the year (January to December). In 2022 the same two traps (Cosmotrack and Stopweevil) and only two different attractants (Cosmogel NovAgrica and CosmoPlus Scyll'Agro) were tested for 5 months (from January to May). The results from both essays suggest that Cosmotrack with Cosmoplus is the more suitable best combination trap and attractant for the control of *C. sordidus*. We also found significant differences in the banana weevil adult captures between the two traps and the three attractants considered in two orchards. Significant difference was found between Cosmotrack with Cosmoplus and Cosmotrack with Cosmogel, and when between Cosmotrack with Cosmoplus regarding all the other trap and attractant combinations tested.

Key words: Attractants, Traps, *Cosmopolites sordidus*, Banana borer weevil, Banana orchards, Azores.

Introduction

The banana (*Musa acuminata* Colla) production is the second most important agricultural crop in area in Azores and the production reached 5.053 tons in 2018 (PRDF, 2019). The majority of the orchards are generally located on southern part of the islands. There are several pests that affect the banana orchards the most important are thrips, snails, mites and banana borer weevil. This pest *Cosmopolites sordidus* (Germar, 1824) (Coleoptera: Curculionidae) belongs to the Curculionidae family is one of the most diverse groups of beetles with more than 50,000 species

feeding on plants, flowers in any terrestrial or freshwater habitat, on plant tissue from roots to seeds thus becoming economically important. *C. sordidus* is considered among the most serious pests of banana (Jayaraman et al., 1997). It is likely to be originated from the Indo-Malaysian region, which is also the origin and major centre of diversity of the genus *Musa* to which the pest is specific (Koppenhofer et al., 1992). Although it is now spread worldwide (Ndiege et al., 1996). This pest was detected in the Azorean Archipelago only in 2003 (Lopes et al., 2006). *C. sordidus* larvae cause great damage to banana plants, primarily by burrowing and tunnelling into the interior plant corm, which weakens the plant affecting nutrient transport and stem growth (de Graaf, 2007). Moreover, the toppling of the corm or secondary pathogen infections are also facilitated (Gettman, 1992; Reddy et al., 2008; Tresson, 2021). To determine this pest population trends monitoring is an effective and important method and parapheromone-based trapping has been proven to be an important monitoring tool for insects and for many pests (Tewari et al., 2014). Trapping systems are also important because they could reduce pest populations and insecticide application (Ndiege et al., 1996; Tinzaara et al., 1999). The advantages of using parapheromone traps for monitoring are many and consist of lower costs, specificity, ease of use, high sensitivity (Tewari et al., 2014), safety and durability (Tinzaara et al., 2020) and affordability to farmers. Beauhaire et al. (1995) refers the isolation, identification and synthesis of the male-produced aggregation pheromone emitted by *C. sordidus* and lately, an efficient synthesis of a lures containing a quaternary mixture of diastereisomers of sordidin has been developed (Jayaraman et al., 1997). This mixtures to which females and males both respond, confirmed its function as an aggregation pheromone and made field-testing possible (Reddy et al., 2008). Different traps with various characteristics (colour, type and shading) have been also studied to enhance efficacy to *C. sordidus* (Fu et al., 2019). Among different kind of traps, pitfall traps with an aggregation pheromone have been used with success in the past three decades in integrated pest management (IPM) strategies (Tresson et al., 2021) and proved to be very powerful in banana weevil trapping (Reddy et al., 2009; Tinzaara et al., 1999). In this study, one set of two different trapping systems containing different aggregation pheromone-based lures was tested to evaluate in the field the efficiency of attracting *C. sordidus* adults. Similar studies regarding efficacy of different lures were also tested in recent years on Terceira Island (Ventura et al., 2012), as well as on Canary Islands (Delgado et al., 2019).

Materials and methods

Study sites

This study took place in the Azores Archipelago (Portugal) on Terceira Island for two years in two banana orchards that were chosen in the city of Angra do Heroísmo. Both sites are smaller than 10.000 m^2. The first site in São Pedro (38° 39’ 29.28’’ N – 27° 13’ 46.04” W; 36 m.a.s.l.), around 10.000 m^2 and the second site in São Bento (38° 39’ 42.77” N – 27° 12’ 35.56” W; 66 m.a.s.l.) covered 7.500 m^2. *Musa acuminata* Dwarf Cavendish plants were observed in this study and samples were collected from May to September 2021 and from January to May 2022.

Both sites were protected by windbreaks of *Pittosporum undulatum* Vent and each orchard also produces vegetable garden plants (greenbeans, peppers and *Colocasia* spp.) climbing plants (maracuja, beans) and vineyards around the edges, growing on the stone walls bordering the properties in São Pedro and coffee and some citrus fruit trees. Crop sanitation and agronomic practices were carried out in both sites as needed,. In both sites, fertilizer and ph correction applications were carried out once a year, normally at the beginning of spring.

Traps and lures

In this study, two different types of traps were used: CosmoTrack and Stopweevil traps (Figure 1). CosmoTrack (Figure 1) is a yellow pitfall trap which consists of two cylindrical containers (radius:15 cm; height:14 cm) separated through a central opening of 1.5 cm. The lower half is buried into the soil and the upper half emerge from the ground and insects can enter the trap through the central opening. The StopWeevil (Figure 1) trap is a triangular ground trap, created by the La Laguna University in Tenerife Island (Spain), with lateral triangular shaped ramps and openings on each side and a receptacle in the inner part protected by a dome to avoid accumulation of leaves and soil and prevent water flooding.

In 2021 four parapheromone-based lures (Figure 2) were tested: CosmoPlus (Scyll'Agro), Cosmogel (NovAgrica), Cosmolure (Chemtica Internacional S. A) and EcoSordidina 90-K (Ecobertura).

In 2022 only three pheromone-based lures (Figure 2) were tested: CosmoPlus (Scyll'Agro), Cosmogel (NovAgrica) and Cosmolure (Chemtica Internacional S. A).

CosmoPlus has a gel formulation with 45 mg of sordidin wrapped in a plastic bag (Figure 2). Cosmogel has also a gel formulation enclosed in a plastic package that contains 90 mg of pheromone and banana tree volatiles (Figure 2). And Cosmolure with 6.94 g/l de product of sordidin enclosed in a plastic package. Ecosordidina 90-K consists of a 4 cm cylindrical diffuser containing a liquid formulation charged with 90 mg of aggregation pheromone produced by the La Laguna University in Tenerife (Spain).

Cosmoplus lure wrapping was just cut on the top and placed inside the lower part of the Cosmotrack trap. Cosmogel and Cosmolure diffuser was suspended with wires at 20 cm in the upper part of the StopWeevil trap.

Each lure packs were replaced every 90 days and all traps' bottoms were filled with soapy water to prevent banana borer weevils from escaping from inside the trap.

Figure 1. The two trap types studied (right Cosmotrack and left Stopweevil).

Figure 2. The parapheromone-based lures tested: CosmoPlus (top left), Cosmolure (left), Cosmogel (middle right) and Ecosordidina 90-K (top right).

Experimental design

In 2021 were tested two-trapping systems with the four attractants: Cosmotrack + Cosmoplus; Cosmotrack+ Cosmogel; Stopweevil + Sordidin and Stopweevil + Cosmolure. In 2022 were also tested the two trap types but with only three attractants (Cosmotrack+ Cosmoplus; Stopweevil+ Cosmolure and Stopweevil + Cosmogel).

Each combination has constituted a set. Three repetitions of each set were placed in each of the two experimental sites: São Bento and São Pedro (3 traps of each combination per site) and those were randomly moved every fifteen days on the soil surface from May until September 2021 and from January to May in 2022. Reddy (2009) and Ventura (2012) works were used as references to evaluate the minimum distance between traps in each repetition and, because of the small size of each plot, we chose to maintain at least 2 m of distance separating each trap and given the opportunity of the adults to choose which combination of trap and attractant is the most efficient in capturing this pest. The content was removed every 15 days when each trap was rinsed and refilled with soapy water.

Statistical analyses

All the data were analysed using SPSS statistical program (Levine, 2013), firstly verifying the existence of a normal or non-normal distribution of the sample data and after verifying its non-normality through the Kolmogorov-Smirnov test, a non-parametric test was used for independent samples, the Kruskal-Wallis test, and comparisons were made between the different modalities tested through the Pairwise method.

Results and discussion

Cosmopolites sordidus abundance

In 2021 from January to December in the two sites were captured 16540 *C. sordidus* adults. São Pedro registered 66.3 % adults captured (10956) and in São Bento 33.7 % (5584) what gave an average of 913 adults per month.

In 2022 from January to May in the two sites were captured 3505 adults. São Pedro registered 68 % adults (2385) and in São Bento 32 % (1120) what gives until May an average of 701 adults per month (Table 1).

Table 1. Total of *C. sordidus* adults captured in the different trap/ttractant's combination tested in 2021 and 2022 for each location.

Year	Location	Cosmotrack + Cosmoplus	Cosmotrack + Cosmogel	StopWeevil + Ecosordidin	StopWeevil+ Cosmolure
2021	São Pedro	5732	2788	1218	1218
	São Bento	3373	1377	508	326
Year	Location	Cosmotrack + Cosmoplus	StopWeevil + Cosmolure	StopWeevil+ Cosmogel	
2022	São Pedro	16238	7523	2944	
	São Bento	32105	14861	5888	

These results shown that weevil abundance was significantly greater in São Pedro banana orchard (Table 1) and this most likely due to the lack of proper cultural practices. In this orchard the amount of unremoved organic and plant material is big and for that is an important source for atraction and also a focus of infestation because corms of bananas and plants are attractive to banana borer weevils more than any other crop residues (Okolle et al., 2020). The accumulation of crop trash and toppled plants on the soil surface offers additional sheltered areas where *C. sordidus* individual can hide and allow accessible oviposition areas (de Graaf et al., 2007). Another adverse consequence of poor cultural management could cause the accumulation of material in the lateral openings of the ground trap Stop Weevil transported by the wind which can be also a way of prevent banana borer weevils from entering this trap.

The captures in the Stopweevil trap were in 2021 less around 24.6 % (3270 adults) when compared with those on the Cosmotrack trap (13270 adults) and in 2022 where greater reaching 64.6 % (31216 adults) but much less than those in Cosmotrack (48343 adults).

From the results obtained it seems that the trapping system which combine a pheromone lure with a surface ground trap is not suitable in Terceira banana plantation, aspect consequently confirmed by the low catches recorded in all the combinations using the Stop Weevil trap (Table 1).

Pitfall traps like Cosmotrack trap are very recommended for banana orchards in Terceira Island because little vegetal material, mostly soil matter, was found in pitfall openings and because of the smaller size which cause less hindrance to farmers during agronomic practices. In this study adult's from banana borer weevils attracted to the aggregation pheromone bait inside Cosmotrack traps were unable to get out of that type of trap.

Attractant efficacy of different traps and attractants combination on C. sordidus

In this study, on the two years the different pheromone-based trapping systems set were compared to determine their efficacy in terms of the attractivity to *Cosmopolites sordidus* adults. Results showed that Cosmotrack + Cosmoplus was the most effective combination in the trapping of *C. sordidus* in both sites (Table 1) and in both years of this study. These results were like those obtain by Ventura et al. (2012) and Delgado et al. (2019).

Even Cosmotrack + Cosmogel is more effective than all the combinations in the Stop Weevil trap in both 2021 and 2022 results (Table 1).

The total number of *C. sordidus* caught in traps was significantly different among trapping systems (Table 1). In 2021 and 2022 the catches of *C. sordidus* adults in Cosmotrack trap with Cosmoplus were significantly greater than on all the other ($p < 0.05$).

In 2021 regarding the adult's caughts in the Stop Weevil traps with ecosordinin ($p = 0.001$) were registered signifficant differences but not with this trap with Cosmolure ($p = 0.916$). In the comparision between two atractants (Cosmoplus and Cosmolure) in the same trap type (Cosmotrack) the results show that the atractant Cosmoplus registered significant differences regarding the Cosmogel ($p = 0.023$).

In 2022 there were not significant differences bewteen the two different attractants in the Stop Weevil trap ($p = 0.076$) but the Cosmotrack trap regsitered the greater adult's captures and significant differences between this trap and the other tested ($p = 0.003$).

In conclusion, this study has highlighted that trapping systems are very important to know the pest densities and their fluctuations in time and monitoring with Sordidin-baited trapping systems including pitfall traps like the Cosmotrack and the attractant Cosmoplus had the best results in the capturing *C. sordidus* adults. The surface ground traps like Stop Weevil trap are not recommended because of its low effiency in capturing *C. sordidus* on banana orchards in Terceira Island. Further investigation of the natural predators of the banana borer weevil weevil is also needed in order to enhance biological control actions on this important banana pest.

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