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A sown grass cover enriched with wild forb plants improves the biological control of aphids in citrus

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Abstract

There is increasing interest in the use of sown ground covers in agriculture to provide alternative resources to predators and parasitoids as part of conservation biological control. Nevertheless, there is limited evidence that this approach is effective in commercial orchards, where a wild complex of plants co-occur with the sown plant species. In citrus orchards, ground covers with grasses (Poaceae) were originally promoted to prevent soil erosion. Herein, we analyzed the effect of this sown ground cover on the biological control of *Aphis spiraecola* Patch (Hemiptera: Aphididae), the main aphid pest on citrus. We therefore first described the ground cover plant composition and their inhabiting aphids in four commercial citrus orchards. Second, we compared the presence of *A. spiraecola* and its natural enemies between these and four other commercial orchards with bare soil. While grasses represented ∼66% of the ground cover, the rest of the cover comprised mainly *Malva* sp. (13%), *Oxalis* sp. (5%) and *Sonchus* sp. (2%). Poaceae plants and *Oxalis* sp. harbored stenophagous aphids and *Macrosiphum euphorbiae* Thomas (Hemiptera: Aphididae), respectively, which appeared sooner in the system than citrus aphids. These aphids may serve as alternative prey or hosts for natural enemies, and thus could enhance the biocontrol of *A. spiraecola*. By contrast, *Malva* sp. and *Sonchus* sp. harbored the potential citrus pest *Aphis gossypii* Glover and other aphids that appear simultaneously with *A. spiraecola*. Therefore, by attracting them to the cover, this latter group could relieve the attack of natural enemies on *A. spiraecola* in the canopy. Although these wild plants may act as reservoirs for *A. spiraecola* as well as other aphid species that can disrupt the biocontrol services of natural enemies, overall, the sown cover was effective in terms of biological control of *A. spiraecola* in the citrus canopy. It promoted the early presence of predators in citrus canopies but did not promote the early presence of parasitoids. Predators attacked *A. spiraecola* colonies before their exponential increase. These attacks resulted in satisfactory aphid control, as citrus orchards with ground cover never exceeded the aphid economic threshold.

Zusammenfassung

Gegenwärtig gibt es in der Landwirtschaft ein zunehmendes Interesse an eingesäter Bodenbedeckung, um Räubern und Parasitoiden als Teil der biologischen Schädlingsbekämpfung alternative Ressourcen anzubieten. Es gibt aber nur eingeschränkte Belege für die Effektivität dieses Ansatzes in kommerziellen Obstplantagen, wo ein Komplex von Wildpflanzen mit den eingesäten Arten vergesellschaftet auftritt. In Zitrusplantagen wurde die Bodenbedeckung mit Gräsern (Poaceae) ursprünglich gefördert, um der Bodenerosion entgegenzuwirken. Wir untersuchten die Auswirkungen dieser Bodenbedeckung auf die biologische Bekämpfung von *Aphis spiraecola* Patch (Hemiptera: Aphididae), der wichtigsten schädlichen Blattlaus an Zitrusfrüchten. Wir beschrieben zuerst die Zusammensetzung der Bodenbedeckung und der darauf vorkommenden Blattläuse in vier

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kommerziellen Zitrusplantagen. Dann verglichen wir das Auftreten von *A. spiraecola* und ihrer natürlichen Feinde in diesen Plantagen mit vier weiteren Plantagen ohne Bodenvegetation. Gräser stellten etwa 66% der Bodenvegetation, während der Rest hauptsächlich aus *Malva* sp. (13%), *Oxalis* sp. (5%) und *Sonchus* sp. (2%) bestand. Gräser und *Oxalis* sp. beherbergten stenophage Blattläuse bzw. *Macrosiphum euphorbiae* Thomas (Hemiptera: Aphididae), die zeitiger als die Zitrusblattläuse im System auftraten. Diese Blattläuse könnten als alternative Beute bzw. Wirte für natürliche Gegenspieler fungieren und somit die biologische Kontrolle von *A. spiraecola* verstärken. Im Gegensatz dazu beherbergten *Malva* sp. und *Sonchus* sp. den potentiellen Zitrusschädling *Aphis gossypii* Glover und andere Blattläuse, die gleichzeitig mit *A. spiraecola* erscheinen. Indem sie natürliche Feinde aus der Kronenschicht in die Bodenvegetation locken, könnte die letztgenannte Gruppe den Feinddruck auf *A. spiraecola* mindern. Auch wenn diese Wildpflanzen als Reservoire von *A. spiraecola* und anderen Blattläusen dienen können, war die eingesäte Bodenbedeckung in Form biologischer Schädlingskontrolle in den Zitrusplantagen insgesamt effektiv. Bodenvegetation förderte die frühe Anwesenheit von Räubern in den Zitrusbäumen, nicht aber die der Parasitoiden. Räuber attackierten die Kolonien von *A. spiraecola* bevor das exponentielle Wachstum einsetzte. Der Räuberdruck ergab eine befriedigende Blattlauskontrolle, da in Zitrus-Plantagen mit Bodenvegetation in keinem Fall die wirtschaftliche Schadensschwelle überschritten wurde.

Keywords: *Aphis spiraecola*; *Aphis gossypii*; Conservation biological control; Habitat management; Clementines

Introduction

The aim of habitat management in conservation biological control is to create a suitable ecological infrastructure to favor natural enemies and to enhance biological control in agricultural systems (Landis, Wratten, & Gurr, 2000; Fiedler, Landis, & Wratten, 2008). In monoculture agroecosystems, natural enemies suffer from a lack of food for adults, alternative prey or hosts, and shelter against adverse conditions (Landis et al., 2000). In the absence of these vital resources, colonization of crops by predators and parasitoids is often much lower than colonization by herbivores (Thies & Tscharntke, 1999). An extensively researched form of habitat management that favors natural enemies in tree crops is the use of ground covers (Bugg & Waddington, 1994; Landis et al., 2000; Silva, Franco, Vasconcelos, & Branco, 2010). In the last ten years, grass covers have been cultivated with citrus trees both for agronomic reasons (Aucejo, 2005) and because it facilitates the management of the two-spotted spider mite *Tetranychus urticae* Koch (Prostigmata: Tetranychidae), a key pest in clementines, by both bottom-up and top-down regulation (Aguilar-Fenollosa, Ibañez-Gual, Pascual-Ruiz, Hurtado, & Jacas, 2011a,b). In addition, ground cover management could also enhance the presence of generalist ground-dwelling predators, which can prey on citrus pests inhabiting or pupating on the soil such as the Mediterranean fruit fly *Ceratitis capitata* Wiedemann (Diptera: Tephritidae) (Monzo, Molla, Castanera, & Urbaneja, 2009).

Aphis spiraecola Patch (Hemiptera: Aphididae) is a key pest of Clementine mandarins, *Citrus clementina* Hort. ex Tan. (Geraniales: Rutaceae), in the Mediterranean basin (Hermoso de Mendoza, Arouni, Belliure, Carbonell, & Perez-Panades, 2006; Tena & Garcia-Marí, 2011; Vacante & Gerson, 2012). This polyphagous aphid colonizes young, tender clementine shoots in spring and causes economic losses because it sucks sap, serves as a vector for *Citrus tristeza* virus, excretes large amounts of honeydew and curls developing leaves while the colony population is growing (Hermoso de Mendoza et al., 2006). To improve the management of aphids in clementines, Hermoso de Mendoza et al. (2006) established intervention thresholds based on the percentage of shoots infested by aphids within a 0.25 m^2 ring throw on the outer canopy of trees. An insecticide application is justified when more than 25% of the shoots are infested. Hereinafter, we refer to the time period during which the percentage of infested shoots reaches approximately 20 to 25%, as the critical period for the management of *A. spiraecola* on clementines.

Citrus, as a permanent and perennial crop, provides an environment in which numerous predators and parasitoids of *A. spiraecola* readily develop in the spring (Romeu-Dalmau, Espadaler, & Pinol, 2012; Vacante & Gerson, 2012; Gómez-Marco, Tena, Jacas, & Urbaneja, 2015a; Gómez-Marco et al., 2015b). Despite this abundant and diverse complex of natural enemies, biological control of *A. spiraecola* is generally insufficient because of the asynchrony of predators with aphid population growth (Gómez-Marco et al., 2015a) and the lack of effective parasitoids (Gómez-Marco et al., 2015b). Recently, it has been demonstrated that predators can maintain aphid densities under the economic threshold if they arrive early in the season, from seven to ten days after *A. spiraecola* colonizes the spring shoots (Gómez-Marco et al., 2015a). Therefore, we hypothesize that a ground cover that promotes the early establishment of natural enemies, prior to the exponential increase of the aphid (Gómez-Marco et al., 2015a), might facilitate the biological control of *A. spiraecola* in citrus orchards.

To advance the presence of the natural enemies of *A. spiraecola* in citrus canopies, a ground cover based on grass plants must possess certain key features. For example, the cover should harbor alternative prey or host species, such