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Effects of strip-tilled cover cropping on the population density of thrips and predatory insects in a cucurbit agroecosystem

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ABSTRACT

Strip-till cover cropping provides a structurally complex habitat (both diverse above ground vegetation and modified soil surface environment) in subsequent crops, which can contribute to suppressing herbivores in the cash crop, through either enhancing conservation biological control or altering herbivore behavior to the complex habitat. Two field trials (spring and autumn) were conducted to examine effects of strip-tilled cover crops (sunn hemp and marigold) on population densities of thrips (primarily, *Frankliniella occidentalis* and *Thrips palmi*) and generalist predators (*Orius* spp. and ground beetles, *Aephnidius* spp.) in cucurbit plantings. The results showed that strip-tilled cover crop treatments reduced thrips densities on cucurbit crops compared to the conventional monoculture. The strip-tilled treatments suppressed thrips densities more consistently in the autumn than in the spring trial. The reduced densities of thrips in strip-tilled cover crop plots were not attributable to the enhanced activity of predatory insects, but were most likely due to the disruption of host locating ability of thrips. Our study showed that the strip-till cover cropping could be an effective pest management technique for sustainable cucurbit production.

Introduction

The tropical climate of Hawaii allows farmers to grow sequential vegetable crops, resulting in an environment that can be highly disturbed and can become inhospitable for many organisms, including herbivore natural enemies. Thus, growers of high-value vegetable crops increasingly seek alternative production systems that conserve natural enemies, soil and water resources (Altieri, 1999; Hartwig and Ammon, 2002; Roger-Estrade et al., 2010), and minimize the use of pesticides (Epstein and Bassein, 2003). One potential option for addressing these environmental and economic goals may be through the use of cover crops in combination with conservation tillage (e.g., strip-till cover cropping). These practices reduce soil disturbances; increase the abundance of soil organisms higher in the soil food web hierarchy; and result in improved soil health (DuPont et al., 2009; Wang et al., 2011). In addition, strip-till cover cropping creates a structurally complex habitat by providing a modified soil surface environment as well as diverse above ground vegetation. Such habitats are known to offer food (prey and alternative plant resources such as nectar and pollen) and shelter for natural enemies (primarily, predators), thereby increasing their abundance in the entire crop field (Bickerton and Hamilton, 2012; Lundgren et al., 2009; Xu et al., 2015). Thus, increased abundance of predators (both plant dwellers and epigaeic) in a structurally complex habitat can potentially contribute to suppress herbivores in the cash crop (Landis et al., 2000; Zehnder et al., 2007). A structurally complex habitat can also alter herbivore behaviors through changes in visual or/and olfactory cues that are used to locate host plants (Finch and Collier, 2000), and reduce their abundance in the cash crop (Finch et al., 2003; Morley et al., 2005). A better understanding of how strip-till cover cropping systems impact herbivore and natural enemy populations may generate a generalized system approach for sustainable pest management in vegetable crops.

Thrips (Thysanoptera: Thripidae) are an important pest of cucurbit crops (Cucurbitaceae) and usually occur in an assemblage of mixed species. For example, the western flower thrips, ***Frankliniella occidentalis*** (Peregande) was the most abundant species followed by the melon thrips, ***Thrips palmi*** Karny in cucumber plants (Rosenheim et al., 1990; Welter et al., 1990). Although both species of thrips occurred concurrently, the abundance of *F. occidentalis* was found to be greater in the flowers, while *T. palmi* was more abundant on the leaves of cucumber plants (Rosenheim et al., 1990). Feeding by mixed species of thrips on vegetative plant parts causes indirect damage, whereas feeding on developing fruits cause direct damage. The direct damage generates silvery or streak-like scars on the developing fruits, which may be

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accompanied by fruit malformation (Rosenheim et al., 1990; Welter et al., 1990). Both scarring and malformation result in downgrading of fruits at harvest. A 10% reduction in cucumber yield was observed at peak densities of mixed-species of thrips that indicated along with the cosmetic damage (direct), thrips can also reduce the mass of fruit produced (indirect) (Welter et al., 1990). The use of insecticides is the primary strategy for controlling populations of *F. occidentalis*, however this pest has a great propensity of developing resistance because of its biological attributes, and cases of resistance to most classes of insecticides have been detected (Bielza, 2008; Li et al., 2016). The challenges in insecticide resistance for *F. occidentalis* management triggered the development of integrated approaches that consists host-plant resistant, and cultural and biological control methods (Gao et al., 2012).

A significant proportion of field mortality of thrips has been typically attributable to the omnivorous predator, *Orius* spp. (Hemiptera: Anthocoridae) (Funderburk et al., 2000; Shirk et al., 2012). Plant diversity that provides both pollen and prey resources optimize fitness of *Orius* spp. (Lundgren et al., 2009; Pumariño and Alomar, 2012), and enhance biological control of thrips (Letourneau and Altieri, 1983; Manandhar and Wright, 2015, 2016). Furthermore, complex soil surface habitats achieved through either tilling or surface mulching of cover crop residues have shown to increase the abundance of epigaeic arthropods (e.g., ground beetles, spiders, and ants) (Bryant et al., 2013; Hummel et al., 2002; Pullaro et al., 2006) that may provide biological control services in agroecosystems. Ground beetles (Coleoptera: Carabidae) are important natural enemies of many crop pests (Lang et al., 1999; Xu et al., 2015). Owing to the fact that thrips complete a stage of their life cycle in the soil as pre-pupae, the increased abundance of ground beetles in the modified soil environment may contribute to regulation of thrips populations in the primary crop (Berndt et al., 2004).

Host-plant selection by *F. occidentalis* involves orientation behavior to olfactory and visual cues (Teulon et al., 1999; Davidson et al., 2012). In some cases, plants constitute essential oils that produce unique odors and have been used to suppress pests either by spraying extracts, or intercropping for their repellant or host-odor masking action (e.g., whitefly pests, Togni et al., 2010; Zhao et al., 2014). Although plant essential oils that repel or attract thrips have been tested to develop a "push-pull" strategy (Egger et al., 2014; van Tol et al., 2007), the use of such plants in a habitat management scheme has not been reported for thrips management. Studies have shown that the crops grown with living mulches (Theunissen and Schelling, 1996, 1998) and with killed or organic mulches (Larentzaki et al., 2008; Summers et al., 2010; Quintanilla-Tornel et al., 2016) have shown to suppress populations of thrips in vegetables. A structurally complex habitat resulting from strip-tilled cover cropping could interfere with thrips ability to locate host plants and reduce their densities in cucurbit crops.

Two cover crops, sunn hemp, *Crotalaria juncea* L. (Fabaceae) and marigold, *Tagetes patula* (Asteraceae) were chosen considering their general capabilities to release allelopathic compounds that enhance a nematode suppressive soil environment (Hooks et al., 2010; Wang et al., 2002), to determine if these plants provide any further benefit in terms of reducing above-ground pests. Sunn hemp is a rapid growing tall legume plant that is mainly used for green manure in tropics (Rotar and Joy, 1983). The floral resources provided by sunn hemp intercropped with corn were found to support populations of *Trichogramma* spp. and *Orius* spp. resulting in enhanced biological control of key pests in the intercropping system (Manandhar and Wright, 2015, 2016). Previous studies have also shown that the architectural complexity of sunn hemp effectively reduced whitefly (*Bemisia argentifollii* Bellow and Perring) mediated squash silverleaf disorder and aphid (*Aphis gossypii* Glover) transmitted non-persistent viruses on zucchini plants (Manandhar et al., 2009; Manandhar and Hooks, 2011). Further assessment of sunn hemp in strip-till cover cropping systems may provide its potential for suppressing multiple pest species, including thrips in a cucurbit agroecosystem. Marigold is a comparatively short-stature plant and produces less biomass than sunn hemp (Wang et al., 2011) and strips of marigold producing flowers within crop plots have been shown to be attractive for predators and parasitoids (Silveira et al., 2009). The marigold plants constitute volatile essential oils that produce a unique odor (Ogunwande and Olawore, 2006; Babu and Kaul, 2007) and have insecticidal properties (Vasudevan et al., 1997). For this reason, marigold could interfere with olfactory as well visual cues of thrips, as opposed to only visual interference of cues with sunn hemp in a strip-till system. In this study, we examined the effects of strip-till cover cropping on the population densities of mixed species of thrips (primarily, *F. occidentalis* and *T. tabaci*) and generalist predators (*Orius* spp. and ground beetles) in cucurbit plantings. In this system, we hypothesize that a variety of mechanisms, either enhanced biological control services, or obstruction in host plant finding behavior, or combination of both will play a role in altering thrips populations on cucurbit crops.

Methods

Two field trials were conducted to examine the effects of strip-tilled cover cropping on the population densities of mixed species of thrips and generalist predators. The field sites are located on the island of Oahu in Hawaii, United States. The first field trial was conducted at the Khamphout Farms (Kunia), a vegetable farm owned by an immigrant farm family, in the spring 2008 season. The second field trial was conducted at the Poamoho Research Station (Waialua), a University of Hawaii at Manoa experiment station, in the autumn 2008 season. A cash crop, bitter melon (*Momordica charantia* L.) (trailer type) was chosen for the Khamphout Farms (spring season), as it is an important vegetable crop in their existing farm production system. Bitter melon was replaced by cucumber (*Cucumis sativus* L.) (bush type) at the Poamoho Research Station (autumn season), for its simpler cultivation requirements, and to avoid high melon fly, *Bactocera cucurbitae* Coquillett (Diptera: Tephritidae) infestations such as those that occurred in bitter melon at the Khamphout Farms.

Field layout

Trials were set up in a randomized complete block design with each treatment replicated four times. Treatment plots were 11 m by 11 m, separated by 6 m within a block, and each block was separated by 11 m from other blocks. Treatments within blocks included two strip-tilled cover crop (strip-tilled) plots and a conventional monoculture (control) plot. The two strip-tilled treatments were (1) strip-tilled marigold and (2) strip-tilled sunn hemp.

The entire field plot was tilled prior to each trial. Cover crop seeds, Marigold (variety: Single Gold) and sunn hemp (variety: Tropic Sun) were sown at the rate of 2 kg/ha and 40 kg/ha in the strip-tilled marigold and sunn hemp plots, respectively. A total of 19 rows of cover crops at an inter-row spacing of 61 cm were grown for approximately 3 months in each treatment plot. In the spring trial, sunn hemp plants were mowed just below knee height level (~30 cm) using a flail mower, whereas alternate rows of marigold plants were mowed at the base using a weed whacker. Each alternate row of mowed plants along with its residues (both sunn hemp and marigold) was tilled in a 61 cm wide strip using a FRC tiller (Honda Motor Co., Ltd., Japan). In the autumn trial, alternate rows of sunn hemp and marigold were mowed at the base using a Weed Whacker and the mowed plants along with its residues were tilled in the soil using the FRC tiller. Additionally, remaining rows of sunn hemp were clipped to a height of 1 m just before the cucumber planting and the clipped portions were used as a surface mulch. Approximately one-month old green house grown bitter melon (variety: Local, Fukuda Seeds, Honolulu, HI, USA) and cucumber (variety: Sweet Slice, Seed Lab, University of Hawaii at Manoa, Honolulu, HI, USA) seedlings were transplanted on previously tilled strips in the strip-tilled plots, whereas in the previously tilled fallow soil in the control plots. The seedlings were transplanted in nine rows at an