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# Effects of mulching on above and below ground pests and beneficials in a green onion agroecosystem

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ABSTRACT

In 2013 and 2014, different mulching systems were investigated for their potential to suppress above and below ground pests, and enhance beneficial arthropods and soil health in green onion (*Allium cepa*) plantings. Three types of mulch systems (organic, living and solarization mulch) were evaluated and compared. Green onions were grown in four pre-plant treatments: (1) organic mulch generated by flail mowing a sunn hemp (*Crotalaria juncea*) cover crop (SH) followed by a no-till cropping system, (2) soil solarization (Sol), (3) sunn hemp-solarization mulch in which the sunn hemp was incorporated into the soil followed by soil solarization (SHSol), and (4) bare ground with insecticides (BG). Sol, SHSol and BG were practiced in conventional tilled system. SH (in 2013 and 2014) and SHSol (in 2014) treatments included strips of buckwheat and cowpea along the crop border to serve as living mulch or insectary plants. Green onion plants in SH had lower thrips and leaf miners damage than other treatments in both study years. When insectary borders were added to SHSol in 2014, thrips and leaf miners damages were also reduced in SHSol compared to Sol and BG. Incidence of purple blotch was reduced in SH and SHSol treatments in 2014. The SH treatment contained an increased abundance and richness of detritivores, predatory arthropods, parasitoids and beneficial free-living nematodes (particularly bacterivores and fungivores). Although weeds and initial populations of plant-parasitic nematodes were lower in solarization (Sol, SHSol) than other treatments, green onion yield was greatest in SH organic mulch systems in both study years. Overall, the integration of surface organic, living and solarization mulches into a green onion agroecosystem provided multiple ecosystem services including suppression of above and below ground pest organisms.

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## 1. Introduction

In light of soil degradation problems caused by continuous tillage (Reeves, 1997) and its negative impact on soil health (Magdoff, 2001; Roger-Estrade et al., 2010), reduced tillage, cover cropping, mulching and other management tactics that reduces organic producers reliance on tillage have received greater research attention in recent years (Hartwig and Ammon, 2002; Pittelkow et al., 2015; Roger-Estrade et al., 2010). Mulching can be the addition of inorganic or organic material such as plastic, straw, cover crop residue or live plant to the soil surface to provide one or several ecosystem services such as enriching or protecting the soil, preventing pest establishment or enhancing crop yield. Mulching in the form of cover crops and practicing reduce tillage have some ecological advantages over conventional land preparation tasks such as plowing and disking the entire field as they are generally less disrupted to the soil environment.

Cover crop mulch that remains on the soil surface can be used to add soil organic matter (Dabney et al., 2001), prevent soil erosion (Saxton et al., 2000), increase soil water retention (McIntyre, 1958; Dabney, 1998), improve soil health (Wang et al., 2011a), and suppress arthropod and weed pests as well as diseases (Altieri 1999; Creamer et al., 1996; Gonzalez-Martin et al., 2014). Organic mulch associated with no-till farming is well-known for its soil health benefits (Doran, 2002; Parr et al., 1992). Many researchers have used nematode community indices as soil health indicators and found that no-till farming and organic mulches can enhance nematode diversity, soil food web structure of free-living nematodes and crop yields (Bongers, 1990; Ferris et al., 2012a,b; Hoyt, 1999; Sieriebriennikov et al., 2014). Nematodes are good soil health indicators because they play important roles in soil nutrient cycling (Ferris et al., 2012a,b). Organic mulches have been shown also to increase spider abundance (Sunderland and Samu, 2000) and subsequently enhance biological control. Despite vast

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ecosystem services that can be provided by mulching, limited effort has been devoted to integrating different mulching practices to concurrently manage above and below ground pest complexes.

Cover crops may be used as insectary plants to enhance the activity of beneficial arthropods by providing them nectar and pollen (Cowgill et al., 1993; Lavandero et al., 2005; Hogg et al., 2011) or augmenting their prey (Taylor and Pfannenstiel, 2008). Insectary plants have been shown to attract beneficial arthropods such as Coccinellid beetles, spiders and Chalcidoid wasps (Rodriguez-Saona et al., 2012). However, insectary plants may differ in their attractiveness to beneficial arthropods. For example, buckwheat (*Fagopyrum esculentum*) is quick to flower and its floral resources can attract a diverse range of beneficial insects (Platt et al., 1999; Ambrosino et al., 2006; Tavares et al., 2015); whereas cowpea (*Vigna unguiculata*) has extra-floral nectaries (Pate et al., 1985) which attract beneficial arthropods. However, insectary plants may need to be used in conjunction with other pest management tactics to have a perceptible impact on pests being targeted and cash crop yield.

Cover crops may be used also to prevent weed establishment. If used alone as surface residue, they may not provide satisfactory weed control unless there is sufficient biomass which allows the residue to persist for a lengthy period of time. In the U.S.A., farmers spend $6 billion a year on herbicides, tillage, and cultivation for weed control (Chandler, 1991); and weeds are still the number one production constraint for many crop producers (Turner et al., 2007). Synthetic mulches have been studied for their ability to suppress weed establishment by acting as physical barriers, trapping solar heat or both (Stapleton, 2000). Soil solarization involves covering the soil with a transparent polyethylene film to reach temperatures detrimental to soil-borne pests (Gamliel and Katan, 2012; McGovern and McSorley, 1997). Soil solarization has been used consistently to suppress weeds (Marahatta et al., 2012), but its effect on plant-parasitic nematodes has been variable or provided short-term suppression (Wang et al., 2011b). In addition, soil solarization can temporarily reduce soil health conditions (Wang et al., 2006). However, negative effects of soil solarization on soil health can be negated by integrating cover crops into the system. For example, a combination of cover cropping and soil solarization reduced plant-parasitic nematodes and weeds more effectively than either tactic alone, and soil health as indicated by the abundance of free-living nematodes was enhanced significantly by the combination compared to using soil solarization alone (Marahatta et al., 2012).

Green onion (*Allium cepa*) is a short-term vegetable crop that has low tolerance to weeds (Smith et al., 2010). In addition, green onion production in Hawaii is challenging due to thrips (Thysanoptera: Thripidae) which can transmit Iris yellow spot virus (IYSV, *Toposvirus*: Bunyaviridae) (Bag et al., 2015), leaf miners (*Liriomyza* spp.) (Diptera: Agromyzidae) (Herr and Johnson, 1992), and purple blotch caused by foliar infection of *Alternaria porri* (Ellis). Incidence of purple blotch can be intensified by thrips damage (Diaz-Montano et al., 2011; Thind and Jhooty, 1982), causing up to 59% yield reduction in bulb onions (Gupta and Pathak, 1988). Covering the soil with organic mulch has been reported to reduce thrips infestations on onions and other crops (Larentzaki et al., 2008; Diaz-Montano et al., 2011). Thus, green onion production can benefit from a mulching system that provides multiple ecosystem services including pest suppression.

The overall goal of this study was to evaluate the effect of integrating multiple mulching tactics on above and below ground pests and beneficial organisms, weed suppression and marketable yield within a green onion cropping system. It is hypothesized that an organic mulch will enhance above and below ground beneficial organisms and subsequently improve soil health; living mulch (insectary borders) will attract natural enemies of arthropod pests; and a solarization mulch will reduce weed establishment and abundance of plant-parasitic nematodes within the upper soil layer prior to crop planting. As such, it is postulated that integrating several mulching practices within the same field will provide greater ecosystem services including the suppression of multiple pest complexes.

## 2. Materials and methods

### 2.1. Field experimental layout

A field experiment was conducted at the University of Hawaii at Manoa Poamoho Experiment Station (21°53′N, 158°8′W) on Oahu, HI in 2013 and 2014. The soil type at the site is Wahiawa silty clay in the Oxisol order with Tropptic Eutrustox, clayey, kaolinitic, isohyperthermic properties, containing 18.6% sand, 37.7% silt, and 43.7% clay in the top 25-cm soil. Soil organic matter was approximately 2% with pH of 6.5. The experiment consisted of four treatments: (1) organic mulch generated by flail mowing a sunn hemp (Crotalaria juncea 'Tropic Sun') cover crop (SH) followed by a no-till cropping system, (2) soil solarization (Sol), (3) SH green manure (soil incorporation) followed by soil solarization (SHSol), and (4) bare ground (BG) with insecticide sprays. SH (in 2013 and 2014) and SHSol (in 2014) treatments included strips of buckwheat and cowpea along the crop border. SH treatment plots were managed without tillage (No-till), whereas SHSol, Sol, and BG plots were tilled prior to green onion planting. Each treatment was replicated four times in $9.2 \times 2.4\text{-m}^2$ plots, and arranged in a randomized complete block design. Individual plots were separated by a minimum 6-m of bare-ground. The experiment was repeated in the same field and treatment plots to evaluate the cumulative effect over two field plantings.

Sunn hemp was seeded at a rate of 33 kg/ha and grown for 3.5 months in the SH treatment, the soil was solarized for 3.5 months in the Sol treatment, and sunn hemp was grown for two months prior to soil incorporation and afterwards the soil was solarized for six weeks in the SHSol treatment. A flail mower was used to terminate the SH, leaving SH residues as an organic surface mulch in SH plots. Solarization involved covering the soil after tillage with 1.2-m wide, 25-μm thick, uv stabilized, low density transparent polyethylene mulch (ISO Poly Firms, Inc., Gary Court, SC). Temperature probes (WatchDog B-series button data logger, Spectrum® Technologies, Aurora, IL) were placed at 5- and 15-cm soil depth in Sol and SHSol plots to monitor soil temperature hourly. BG treatment was initially tilled, left fallow with weeds during SH growing or soil solarization period, and tilled again prior to crop planting. Strips of buckwheat (60 cm × 2.4 m) and cowpea (60 cm × 9.2 m) were seeded at rates of 63.8 kg/ha and 55 kg/ha, respectively along the borders of SH plots 30 cm away from the onion crop in 2013, and SH and SHSol in 2014 to serve as insectary plants.

In 2013, green onions were planted on July 1, and harvested on October 4 from 100 randomly selected plants per plot. In 2014, green onions were planted on July 3, and harvested on two dates (September 9 and December 4) from 50 randomly selected plants per plot on each harvest date. Green onion vegetative propagules were planted in eight rows within each plot at 30-cm intra- and inter- row spacing. Plants were drip irrigated and fertilized with turkey manure fertilizer (Sustane 5-2-4, Sustane Naturally Fertilizer Inc., Cannon Falls, MN) at 66 kg N/ha over two applications. Green onion in the control plots (BG) received insecticides spray of spinosad (Entrust®, Dow Agrosciences, Indianapolis, IN) and pyrethrins (Pyganic® EC 5.0II, MGK, Minneapolis, MN) applied in rotation every two weeks or as needed to manage thrips. Weeds were managed manually or sprayed with herbicides (Roundup®, Monsanto, St. Louis, MO, or Fusilade®, Syngenta, Greensboro, NC) in all plots as required.