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Reduced ultraviolet light transmission increases insecticide longevity in protected culture raspberry production

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HIGHLIGHTS

- Photodegradation of insecticides on raspberries under protected culture is unknown.
- Insecticides have up to 60% greater retention when covered in UV-blocking plastics.
- Residues remain higher for up to 14 days under UV-blocking plastics.
- Efficacy of insecticides was higher under UV-blocking plastics.
- Reduced degradation can optimize pesticide use efficiency.

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ABSTRACT

High tunnels are large protective structures used for season extension of many crops, including raspberries. These structures are often covered in plastic films to reduce and diffuse ultraviolet light transmission for pest and disease control, but this may also affect the photodegradation and efficacy of pesticides applied under these tunnels. We compared the residue levels of ten insecticides under three tunnel plastics with varying levels of UV transmission and open field conditions. Raspberry plants placed in research-scale tunnels were treated with insecticides and residues on fruit and foliage were monitored for one or two weeks in early 2015 and early and late 2016. Plastics that reduce UV transmission resulted in 50% greater residues of some insecticides compared to transparent plastics, and 60% compared to uncovered tunnels. This increased persistence of residues was evident within 1 day and remained consistently higher for up to 14 days. This pattern was demonstrated for multiple insecticides, including bifenthrin, esfenvalerate, imidacloprid, thiamethoxam, and spinosad. In contrast, the insecticide malathion degraded rapidly regardless of the plastic treatment, indicating less sensitivity to photodegradation. Bioassays using insecticide-treated leaves that were under UV-blocking plastic revealed higher mortality of the invasive fruit pest, *Drosophila suzukii*, compared to leaves that were uncovered. This indicates that the activity of pesticides under high tunnels covered in UV-reducing plastics may be prolonged, allowing for fewer insecticide applications and longer intervals between sprays. This information can be used to help optimize pest control in protected culture berry production.

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1. Introduction

Raspberries are an economically important crop that enhance human diets throughout the world (Manganaris et al., 2014; Yang and Kortesniemi, 2015). Raspberry growers are increasingly implementing high tunnels to better control their climatic variability and expand the regions where berry production can be profitable (Kadir et al., 2006; Thompson et al., 2009; Lamont, 2009; Demchak, 2009; Neri et al., 2012). High tunnels are steel structures covered with plastic which enable modification and greater control of the crop environment, extending the growing season into both the spring and the fall (Lamont, 2009; Giacomelli, 2009; Hanson et al., 2011). This approach also protects the plants from rain, which is a frequent concern for producers in many temperate production regions, thereby reducing disease incidence and preventing wash-off of pesticide residues (Demchak, 2009; Hanson et al., 2011; Neri et al., 2012).

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Increasingly, production under these tunnels is being optimized through the manipulation of the plastic covering type. Various plastics can be selected for their specialized features, based on the needs of the crop and region, including light diffusion, manipulation of infrared radiation, and decreased condensation (Espi et al., 2006; Heidenreich et al., 2008; Lamont, 2009). Plastics manufacturers are also developing ways to reduce the transmission of ultraviolet (UV) light. This began primarily for improved plant growth and yield (Kataoka et al., 2003; Dufault and Ward, 2009), but blocking UV light has also been found to reduce disease and pest incidence in tunnel-grown crops (Espi et al., 2006; Heidenreich et al., 2008). Ultraviolet light that reaches the earth's surface has a wavelength from 280 to 400 nm, slightly shorter than the visible light spectrum for humans. The visible spectrum of light for insects, however, includes UV light, and disrupting this has been shown to have behavioral effects on dispersion, feeding, and mating of whiteflies, aphids, and some other pests (Antignus et al., 2001; Costa et al., 2002; Diaz and Fereres, 2007; Doukas and Payne, 2007; Johansen et al., 2011; Ben-Yakir and Fereres, 2016). Blocking UV light transmission also reduces disease incidence, since it is required for sporulation by many common fungal pathogens (Reuveni et al., 1989; Nicot and Baille, 1996; Raviv and Antignus, 2004; Paul et al., 2005; Ben-Yakir and Fereres, 2016).

While these plastics may be promising for reducing disease and insect pest pressure in raspberry production, occasional pesticide applications are still required for controlling pest outbreaks, and these plastics have the potential to affect pesticide degradation. This is especially important for managing the invasive insect, spotted wing Drosophila (*Drosophila suzukii*), a devastating new pest of this and other berry crops (Asplen et al., 2015). Management of this insect can include cultural (Leach et al., 2016, 2017) and biological (Daane et al., 2016; Woltz and Lee, 2017) approaches, but in larger commercial production settings, frequent insecticide applications are commonly used to protect berries from infestation by its larvae (VanTimmeren and Isaacs, 2013; Diepenbrock et al., 2016). It is important to maintain control of *D. suzukii* through the long ripening period of raspberries, and high tunnel coverings that reduce pesticide degradation may allow for less frequent applications and/or improved control.

The rates of degradation of pesticides are influenced by light, plant metabolism, temperature, and microorganisms (Baskaran et al., 1999; Burrows et al., 2002; Sinderhauf and Schwack, 2003). Photodegradation by sunlight is a major abiotic degradation pathway of chemicals largely caused by light in the ultraviolet spectrum (Schwarzenbach et al., 2003). Photodegradation of pesticides tends to happen within the first few hours after the application, so reducing UV light is expected to change the initial degradation curve of these chemicals (Burrows et al., 2002; de Urzedo et al., 2007; Weber et al., 2009). Reduced degradation of pesticides has previously been reported on crops grown under protective structures compared to open fields (Garau et al., 2002; Weber et al., 2009; Allen et al., 2015; Sun et al., 2015). Van Emden and Hadley (2011) found that the insecticide cypermethrin can provide sustained control on the confused flour beetle (*Tribolium confusum*) for up to 6 months longer in bioassays when exposed to a UV reducing plastic compared to a UV transparent plastic. However, the dissipation of commonly used insecticides under protected culture with UV reducing plastics has not been studied in raspberries or other berry crops, despite the widespread use of these plastics across this industry. This may be increasingly important in many berry production regions due to the invasion by *D.suzukii* (Asplen et al., 2015) that is primarily managed using insecticides (Leach et al., 2016). Understanding how insecticides may degrade differently under specialty plastics will be important for developing appropriate intervals between applications, and for exploring potential prolonged efficacy on pests and also longer periods of risk to beneficial arthropods.

The objectives of this study were (1) to determine how different agricultural plastics alter UV transmittance under small-scale tunnels compared to field conditions, (2) to determine how ten different insecticides degrade on raspberry foliage across these treatments in early and late summer, (3) to determine how these insecticides degrade differently on raspberry fruit under these treatments in late summer, (4) to observe the degradation of these chemicals over time across the different plastic treatments, compared to uncovered tunnels, and finally (5) to compare the efficacy of insecticides under UV-blocking plastics in comparison to open conditions.

2. Materials and methods

2.1. Experimental setup

This research was conducted in small research-scale tunnels covered with different plastic types at the Horticultural Teaching and Research Center in East Lansing, Michigan, USA. The tunnels were 1.2 $m \times 3$ m and each tunnel covered eight potted raspberry plants (cv. "Polka"). The same plants were used in each of the leaf sample trials described below. Plants were irrigated daily using 3.2 GPH Netafim spray stakes (Trickl-Eez Irrigation Inc., St. Joseph, MI) inserted into the base of each 11.4 L pot. Each tunnel was constructed from five hoops of 1.9 cm diameter metal conduit, shaped using a hoop bender (QuickHoops™, Johnny's Selected Seeds, Fairfield, ME) (Fig. 1). The hoops were anchored by sliding them over 1.3 cm diameter conduit stakes that were pounded into the ground, 0.75 m apart and leaving 0.6 m above the ground. Plastic was secured on the sides of the tunnel using 3.8 $cm \times 8.9$ $cm \times 3$ m wood on each side, raised 0.3 m above the ground to allow for airflow (Fig. 1). In 2015, we constructed 12 tunnels, with two plastic types covering each of four replicates and uncovered controls arranged in a randomized complete block design. Tunnels were 2 m apart from each other. The following plastic types were compared: diffuse Luminance® plastic (Visqueen, Stevenston, UK) and diffuse Lumisol® plastic (Visqueen, Stevenston, UK). In 2016, we constructed 16 tunnels with 4 replicates covered in three plastic types and uncovered controls arranged in a randomized complete block design. The three plastic types were Luminance®, research-grade clear UV-blocking (Visqueen, Stevenston, UK), and research-grade clear UV-transparent (Visqueen, Stevenston, UK). The uncovered control was left uncovered unless rain was predicted, in which case

Fig. 1. Research tunnels containing eight potted raspberry plants and covered with different plastic types, replicated in a randomized complete block design. Tunnels measured 0.6 $m \times 3$ m and the edge of the plastic was raised 0.3 m above the ground to allow for airflow.

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