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Seasonal timing of neonicotinoid and organophosphate trunk injections to optimize the management of avocado thrips in California avocado groves

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ABSTRACT

The timing of trunk injections of the organophosphate, acephate, and two systemic neonicotinoids, imidacloprid and dinotefuran, was evaluated in field trials for the management of avocado thrips. Following treatments, leaves were sampled over a 6-month period to determine the period of efficacy for each insecticide. The efficacy of acephate was determined using bioassays. Imidacloprid and dinotefuran residues in leaves were quantified by ELISA to determine the window of efficacy for these treatments based on previously determined biological dose response data. In addition, residues in fruit were quantified to determine whether trunk injection of insecticides might present a greater risk for contaminating fruit than traditional application methods. The timing of trunk injection treatments significantly impacted the uptake of imidacloprid and dinotefuran, with mid- and late-leaf flush periods proving more effective in terms of rate of uptake and degree of persistence at threshold levels. Acephate was mobilized very rapidly and gave good control of thrips in bioassays; however, residues of acephate, and its insecticidal metabolite methamidophos, were detected in the fruit for up to 4 weeks after injection. Imidacloprid was most effective when injected during the mid-flush period, which allowed levels to establish within the trees over a period of time when thrips would be actively feeding on young leaf tissue. The establishment of dinotefuran in trees was very rapid following trunk injection. However, its use was compromised by the inability of the chemical to reach effective concentrations for thrips control. Residues of dinotefuran were detected in fruit sampled from one tree, but the levels were below typical MRLs for other crops treated with this insecticide. Imidacloprid was not detected in any fruit sampled from trees in which imidacloprid had established in leaf tissue at concentrations that were toxic to avocado thrips. Overall, trunk injection of imidacloprid could be a viable option for avocado thrips control. However, residues of acephate in fruit may preclude its use because of the requirement for increased pre-harvest intervals. Dinotefuran injections may also be useful due to the rapid uptake and establishment within the canopy; however, it will be necessary to determine whether higher doses of dinotefuran can deliver the required levels of insecticide necessary for thrips control, without contaminating the fruit with residues.

1. Introduction

The timing of an insecticide treatment is important if optimal pest control is to be achieved. Within the framework of an IPM program, applications are made when pest populations reach economic threshold (ET) levels. However, the decision on when to apply is more critical when choosing between foliar or systemic insecticide options, and these options largely reflect the pest in question. In California, the most important pest of avocados is the avocado thrips, *Scirtothrips perseae* Nakahara (Thysanoptera: Thripidae) (Hoddle et al., 2003). Since its initial detection in California in 1996 (Nakahara, 1997), it has established throughout all avocado-growing regions. The main source of economic loss attributable to the avocado thrips arises from feeding damage that causes scarring of immature fruit leading to a reduction in fruit quality at harvest (Hoddle et al., 2003; Nakahara, 1997). Effective thrips control has been exacerbated by the difficulty in establishing reliable ETs, so growers typically apply insecticides when avocado thrips levels

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begin to build during the spring growth flushes. Although flowering may have already commenced at this time and fruit are beginning to set, the thrips are especially attracted to tender young flush foliage that is reddish brown to light green. As the foliage matures, it becomes less attractive to the thrips and the insects begin to feed on immature fruit (Yee et al., 2001a).

The goal of an insecticide treatment is to protect the developing fruit from thrips feeding until the fruit reaches a growth stage that is no longer vulnerable to scarring. From a management standpoint, the ideal time to circumvent a major thrips problem is when numbers begin to establish on the spring flush. Generally, foliar applications of contact insecticides can prevent populations from reaching damaging proportions. However, the efficacy of foliar treatments may be short-lived if applications are made during a growth flush, and further applications may be required if the initial treatment does not suppress the target pest adequately. Systemic treatments, applied directly to the soil for root uptake, or as trunk injections, may take longer to establish within the trees (Byrne et al., 2012, 2005) but have the potential to persist longer and provide additional protection to new leaves during a growth flush.

By far the most commonly used insecticide for the management of avocado thrips is abamectin. It is a foliar-applied insecticide with translaminar activity (Lasota and Dybas, 1991) that provides persistent control of thrips through much of the spring flush. Aerial applications of abamectin by helicopter are needed for the majority of California avocado groves because most are grown on steep hillsides (Yee et al., 2001b). However, helicopter applications are expensive, and may not provide complete coverage of infested trees unless large volumes are applied (Yee et al., 2001b). In addition, during heavy pest years, helicopters may not always be immediately available when pest outbreaks occur. Grower reliance on abamectin also raises concerns about the development of resistance. To address the threat posed by resistance, and to overcome some of the operational difficulties associated with foliar applications within groves, there has been an increasing effort within California to register insecticides with different modes of action that could be incorporated into a sustainable insecticide resistance management program for avocado thrips (Zahn and Morse, 2013). As part of that effort, we are evaluating systemic applications of neonicotinoid insecticides (Byrne et al., 2012, 2010, 2007, 2005). Although neonicotinoids can be applied as foliar treatments, they are especially appealing as systemic treatments for a wide range of crops because they can be applied rather easily via irrigation systems (Byrne et al., 2007), or as trunk injections when soil applications are not feasible (Byrne et al., 2012).

Previous experiments evaluating trunk injections of neonicotinoids on avocados (Byrne et al., 2012) showed that, in terms of total residues measured within the leaf tissues, the uptake of both imidacloprid and dinotefuran was at least 10-fold greater than that measured with soil applications when the treatments were administered at the onset of the spring flush. The main objective of this study was to identify the most effective time during flush when systemic treatments could be applied. A second objective of the study was to generate dose–response data from bioassays of avocado thrips confined on leaves treated systemically with dinotefuran. Although dinotefuran is not currently registered for use on avocados in California, it was included in the study because of its *ca.* 80-fold greater water solubility (40 g l^{-1}) (Wakita et al., 2005) than imidacloprid (0.5 g l^{-1}) (Elbert et al., 1991), a characteristic that improves mobility within the xylem system, and which could potentially facilitate a more rapid uptake of the insecticide. In addition to the two neonicotinoids, we also conducted similar evaluations of the systemic organophosphate acephate because it represented a contrast both in water solubility (790 g l^{-1}) and insecticide mode of action. Furthermore, because acephate belongs to the high-risk organophosphate insecticide class (Van Steenwyk and Zalom, 2005), we were interested in evaluating likely fruit residue risks associated with the use of such a highly water-soluble chemical. Applications of insecticide treatments against avocado thrips are aimed at protecting the current year's developing fruit. However, at these times, there may be fruit awaiting harvest from the previous year's crop still on the tree. Contamination of these fruit by insecticide applications targeting pests of the current year's crop could render the fruit unmarketable if tolerances were not met, or delay the harvest until established pre-harvest intervals had elapsed.

2. Materials and methods

2.1. Insects

Avocado thrips were collected from commercial avocado groves in Temecula, CA, 1–2 days prior to conducting each set of bioassays. Field sites were chosen based on thrips availability and collections were limited to groves where insecticides had not been used during the past 2 years or longer.

2.2. Field trial

2.2.1. Description of the field site

In 2008, a field study was conducted in a 2.5 ha commercial avocado grove located in Temecula, California. The trees were 'Hass' on clonal Toro Canyon rootstock. The trees were uniform in size and canopy structure, were 8 years old, and 3 m in height. At this location, the soil type was classified as a Cajalco rocky fine sandy loam with a clay content of 10–20% between 0 and 13 cm and 25–30% between 13 and 18 cm, with organic matter content of 0.5–1% (NRCS, 2013). The trees were irrigated by micro-sprinklers consisting of a roto-spray micro-spinner (RS-15) that delivered 100 l h^{-1} for 16 h once a week.

The block of trees where we conducted the trial consisted of 132 trees arranged in rows that traversed a sloping terrain. The block was divided into 6 sections containing equal numbers of trees. Each section was considered a replicate. Within each of the 6 sections, suitable trees for the treatments were chosen based on tree size and apparent health/vigor. Trunk diameter measurements were taken to establish a consistent diameter size for the trunk injections and to ensure that all treatments ($n = 6$ trees for each treatment) were included in each section of the grove. The mean trunk diameter was 16 cm with minimum and maximum limits set at 12 and 20 cm, respectively, for use in the trial. Once suitable trees had been selected for the study, trees used for fruit sampling (previous year's crop due for harvest) were chosen from these trees based upon the total number of fruit on the tree at the start of the trial to ensure that sufficient fruit would be available for later analysis of pesticide residues. Prior to all treatments, trees within each of the 6 sections were numbered and then treatments randomly assigned to individual trees to give a total of 6 replicate trees per treatment in the study.

2.2.2. Insecticide applications

Trunk injections of 3 insecticides, representing 2 chemical classes – neonicotinoids and organophosphates – were injected on three different occasions relative to the spring flush. The insecticide formulations and injection equipment were provided by Arborjet, Inc. (99 Blueberry Hill Rd, Woburn, MA 01801, USA). Trees were drilled using a 9.525 mm titanium nitride coated wood drill bit to a depth of 2.54 cm. Three holes were drilled around the circumference of the main trunk at least 15 cm above the soil surface. A #4 Arborplug® was set into each hole using an Arborplug setter and