NOTE

The Effect of Horticultural Spray Oil and Surfactants on the Residual Efficacy of Spinosad Against Avocado Thrips, *Scirtothrips perseae* (Thysanoptera: Thripidae)\(^1\)

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The avocado thrips, *Scirtothrips perseae* Nakahara (Thysanoptera: Thripidae), is a newly invasive species in California. This recently described species (Nakahara 1997) was first found damaging avocado fruit and foliage during June 1996 in a grove in Oxnard, Ventura County, California, and at nearly the same time approximately 100 km south in Irvine, Orange County (Hoddle & Morse 2003). In 1998, it caused $18.6 million in damage (Hoddle et al. 2003) and by 2003, its distribution covered 99% of the state’s avocado hectares (Hoddle & Morse 2003). Severe infestation of avocado thrips can cause leaf-drop and sunburned fruit, although primary economic loss occurs as the result of feeding by first and second instars and resultant scarring on developing fruit. Fruit remain susceptible for approximately 2 months or until growing to about 30 mm to 5 cm in length (Morse et al. 1999). During the most critical stage of fruit susceptibility, when fruit measure between 0.53 and 1.42 cm long, the accepted economic threshold is five larvae per leaf (Yee et al. 2001c).

Sabadilla (Veratran D, Dunhill Chemical Company, Asuza, California), a botanical bait mixed with sugar or molasses, abamectin (Agri-Mek 0.15 EC, Syngenta Crop Protection, Greensboro, North Carolina), and spinosad (Success 2 SC, Dow AgroSciences LLC, Indianapolis, Indiana) currently are registered for use against avocado thrips in California. Abamectin has a residual efficacy of between 1 and 2 months (Yee et al. 2001b, Hoddle & Morse 2003) in comparison with 1 to 2 weeks with sabadilla (Yee et al. 2001a) and 2 to 4 weeks with spinosad (Hoddle & Morse 2003). For this reason, growers rely largely on abamectin to control economic avocado thrips populations.

The heavy reliance on abamectin has caused concern among researchers (Hoddle & Morse 2003, Morse & Witney 2005). A related *Scirtothrips* species, citrus thrips, *Scirtothrips citri* (Moulton), has developed resistance to most insecticides used repeatedly for its control. Resistance development in avocado thrips may follow a similar pattern if the avocado industry does not manage the available chemical options properly (Morse et al. 2004). Only 3 years after this species first appeared in California, an 18.8-fold resistance to sabadilla at the LC\(_{90}\) was observed in a population of *S. perseae* from Ventura County, CA (Humeres & Morse 2006). To date, no cases of increased tolerance to abamectin have been reported; however, pesticide use data from 2002 shows that abamectin was used

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to treat more than 13-fold more hectares than spinosad and more than 9-fold more than sabadilla (Helliker 2002, pp. 29–31).

Several authors have shown that the residual efficacy of abamectin is increased when combined with horticultural oil or a surfactant (Dybas 1989, Horowitz et al. 1997). Although spinosad provides some residual control (Crouse et al. 2001), without the addition of oil or a surfactant, this molecule exhibits limited translaminar movement and is quickly broken down to inactive compounds when exposed to natural light (Crouse et al. 2001). Residual activity of both abamectin and spinosad results from some portion of the material moving into the epidermal layer of fruit or leaves where photolysis is greatly reduced. In this study, we examined the effect of horticultural oil and two commercially available surfactants on the residual efficacy of spinosad against S. perseae on avocado with the aim of developing a strategy in which spinosad could be used in rotation with abamectin and sabadilla to hopefully delay the development of insecticide resistance.

We conducted a field trial in Santa Paula, Ventura County, California, within an 8.9-ha avocado orchard of 8-year-old Hass avocado grafted on Mexican rootstock. The orchard was planted at a spacing of 6.8 m within rows north to south, by 7.0 m between rows. Tree canopies measured approximately 4.5 m in height by 5 m in diameter. On 23 June 2000, a pretreatment count of S. perseae was conducted by selecting 159 trees and counting the average number of immature thrips on the abaxial surface of five leaves per tree. Five succulent leaves, approximately 11 cm in length, and green–red to green in color were selected from different terminals around each tree canopy approximately 1–1.5 m above the soil surface. To allow for the variation of infestation densities within the orchard, the experimental design was a randomized complete block design. Ninety trees with the highest thrips levels per leaf were selected from among the 159 sampled trees. These were ranked highest to lowest based on pretreatment thrips levels and placed into 10 blocks by assigning the nine trees with the highest average thrips count to block one and the nine trees with the second highest average thrips count to block two. This pattern was repeated until 10 blocks were formed. Treatments were then randomly assigned to trees within blocks (10 replicates of nine treatments).

On 24 June 2000, nine treatments were applied: a water control, Success 2 SC at 0.187 g [AI] / liter, and the same rate of Success added to each of seven oil and/or surfactant combinations: 1% NR-415 (NR-415) horticultural spray oil (Lefﬁngwell, Pace International LP, Kirkland, Washington), 4% oil, Dyne-Amic (Helena Chemical Company, Memphis, Tennessee) at 0.312% alone and with 1 or 4% oil, and Silwet (Helena Chemical Company, Memphis, Tennessee) at 0.0156% alone or with 1% oil. Silwet and Dyne-Amic were selected for this study based on work conducted by Tollerup (2002); NR-415 oil was selected based on studies conducted by Morse (unpublished data). A Pacific Stihl low volume mist sprayer (Model SR-400, L & M Fertilizer, Temecula, California, spray nozzle setting four) was used to apply the treatments at approximately 1.03 L per tree (219 L / ha). This type of sprayer and application volume was chosen to approximate application by commercial helicopter, which is the norm for avocado groves, the majority of which are grown on steep hillsides in California. Treatments were applied by standing approximately 2 m from the tree-canopy and moving the mist blower in an elliptical motion from the tree’s top to bottom while circling the canopy; each
Table 1. The impact of the addition of oils and surfactants on the efficacy of spinosad against avocado thrips, Ventura County California, June 2000.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Day −1</th>
<th>Day 6&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Day 12</th>
<th>Day 19</th>
<th>Day 26</th>
<th>Day 33</th>
<th>Day 40</th>
<th>Day 47</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.22 ± 0.91</td>
<td>6.39 ± 1.46 b</td>
<td>3.67 ± 1.17 b</td>
<td>4.26 ± 0.60 b</td>
<td>4.27 ± 0.89 b</td>
<td>6.37 ± 1.86 b</td>
<td>7.19 ± 1.50 b</td>
<td>5.06 ± 1.47 b</td>
</tr>
<tr>
<td>Spinosad alone</td>
<td>5.00 ± 1.10</td>
<td>0.90 ± 0.31 a</td>
<td>0.67 ± 0.39 b</td>
<td>0.09 ± 0.07 a</td>
<td>0.35 ± 0.18 a</td>
<td>1.50 ± 0.54 a</td>
<td>4.68 ± 1.27 b</td>
<td>4.04 ± 0.99 b</td>
</tr>
<tr>
<td>Spinosad + 1% oil</td>
<td>4.92 ± 0.91</td>
<td>0.59 ± 0.16 a</td>
<td>0.26 ± 0.07 a</td>
<td>0.07 ± 0.02 a</td>
<td>0.11 ± 0.05 a</td>
<td>0.64 ± 0.27 a</td>
<td>3.13 ± 0.86 b</td>
<td>4.26 ± 1.40 b</td>
</tr>
<tr>
<td>Spinosad + 4% oil</td>
<td>5.28 ± 1.00</td>
<td>0.68 ± 0.30 a</td>
<td>0.53 ± 0.16 b</td>
<td>0.12 ± 0.05 a</td>
<td>0.19 ± 0.11 a</td>
<td>0.79 ± 0.28 a</td>
<td>2.38 ± 0.67 a</td>
<td>2.95 ± 0.87 b</td>
</tr>
<tr>
<td>Spinosad + Dyne Amic</td>
<td>5.10 ± 0.67</td>
<td>0.56 ± 0.14 a</td>
<td>0.27 ± 0.08 a</td>
<td>0.04 ± 0.02 a</td>
<td>0.09 ± 0.07 a</td>
<td>0.23 ± 0.07 a</td>
<td>1.74 ± 0.41 a</td>
<td>2.95 ± 0.63 b</td>
</tr>
<tr>
<td>Spinosad + Dyne Amic + 1% oil</td>
<td>5.18 ± 0.91</td>
<td>0.77 ± 0.23 a</td>
<td>0.54 ± 0.18 b</td>
<td>0.09 ± 0.03 a</td>
<td>0.14 ± 0.06 a</td>
<td>0.34 ± 0.10 a</td>
<td>2.43 ± 0.69 a</td>
<td>4.21 ± 1.03 b</td>
</tr>
<tr>
<td>Spinosad + Dyne Amic + 4% oil</td>
<td>4.98 ± 0.81</td>
<td>0.62 ± 0.18 a</td>
<td>0.33 ± 0.14 a</td>
<td>0.09 ± 0.06 a</td>
<td>0.08 ± 0.03 a</td>
<td>0.41 ± 0.13 a</td>
<td>2.47 ± 0.61 a</td>
<td>4.78 ± 0.94 b</td>
</tr>
<tr>
<td>Spinosad + Silwet</td>
<td>5.02 ± 0.74</td>
<td>0.90 ± 0.20 a</td>
<td>1.08 ± 0.44 b</td>
<td>0.08 ± 0.02 a</td>
<td>0.26 ± 0.07 a</td>
<td>0.95 ± 0.30 a</td>
<td>4.08 ± 0.90 b</td>
<td>4.87 ± 0.88 b</td>
</tr>
<tr>
<td>Spinosad + Silwet + 1% oil</td>
<td>5.18 ± 0.74</td>
<td>0.72 ± 0.23 a</td>
<td>0.47 ± 0.13 b</td>
<td>0.03 ± 0.02 a</td>
<td>0.12 ± 0.04 a</td>
<td>0.84 ± 0.17 a</td>
<td>3.22 ± 0.46 b</td>
<td>5.21 ± 1.29 b</td>
</tr>
<tr>
<td>F value</td>
<td>0.02</td>
<td>13.81</td>
<td>6.78</td>
<td>139.81</td>
<td>31.53</td>
<td>17.23</td>
<td>3.72</td>
<td>0.80</td>
</tr>
<tr>
<td>P value</td>
<td>1.00</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.001</td>
<td>0.61</td>
</tr>
</tbody>
</table>

<sup>a</sup>Means followed by the same letter within a column are not significantly different (df = 8, P < 0.1, Games-Howell multiple comparison test). No statistical separation was observed between treatments on Days −1 and 47.
tree took approximately 30 sec to spray. Treatment application began at 0,615 h with an ambient temperature of 18°C and was completed by 1100 h (23°C). Wind conditions remained calm during the application period. Throughout the 47-d experiment no precipitation occurred. The daily maximum and minimum temperature averaged (± SEM) 27.03 ± 0.33°C and 13.32 ± 0.32°C, respectively.

Data collection took place during a 47-d period at approximately 7-d intervals. Post-treatment sampling was conducted by randomly selecting at least 10 succulent red-green to green leaves using methods as described above for the pretreatment count. Because of a nonnormal distribution and unequal variance, data were transformed using a square root plus one transformation. The Games-Howell procedure (Games & Howell 1976) within SPSS Graduate Pack Version 13.0 (SPSS 2004) was used to determine differences among pre- and post-treatment means with a significance level of both 0.05 and 0.1. Because fine differences in efficacy based on addition of oil or surfactant to spinosad were investigated, data are presented with a significance level of 0.1.

One day before applying the treatments the average thrips per leaf counts were similar among the treatments (Table 1). During the 47-d field study, avocado thrips levels remained relatively stable on control trees, varying from 3.7 to 7.2 thrips per leaf. The low control mean at 12 days after treatment (DAT) was well below the treatment threshold and was statistically similar to the other treatment means. At 6, 19, 26, and 33 DAT, results with all chemical treatments did not vary from one another and each of the treatments effectively reduced thrips levels below the economic level and the level observed on control leaves. By 40 DAT, spinosad plus 4% oil and spinosad plus Dyne-Amic alone and Dyne-Amic with either 1 or 4% oil continued to suppress thrips populations below the economic threshold. No statistical separation was observed between treatment results at 47 DAT.

Avocado integrated pest management includes monitoring and use of an economic threshold to avoid unnecessary treatments, proper timing of applications, use of selective chemicals to maximize natural enemy effectiveness, and rotation of pesticides with different chemistries to slow the appearance of resistance (Hoddle & Morse 2003, Morse & Witney 2005). The longer residual period of abamectin decreases the probability of mistiming an application and increases the chance of effectively controlling economic levels of S. perseae during the most critical period of fruit development. Integrated pest management practitioners prefer the longer residual efficacy of abamectin over spinosad and sabadilla but one danger with a persistent material is that it selects for resistance for a longer period of time (Morse & Witney 2005). Our data show that spinosad plus 4% oil, Dyne-Amic alone, or Dyne-Amic with 1 or 4% oil effectively reduces avocado thrips populations below the economic threshold for up to 40 d. These data should encourage the addition of spinosad into a rotation of chemicals needed to control avocado thrips and reduce the potential for the appearance of resistance.

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