California Avocado Society 1999 Yearbook 83: 141-162

Control of Avocado Thrips Using Aerial Applications of Insecticides

Wee L. Yee Phil A. Phillips Ben A, Faber
University of California Cooperative Extension, Ventura
Joseph G. Morse Mark S. Hoddle
Department of Entomology University of California, Riverside

Avocado thrips, *Scirtothrips perseae* Nakahara, is a major pest affecting avocados in Ventura, Riverside, San Diego, Orange, San Luis Obispo, Santa Barbara, Monterey, and Los Angeles Counties, California. The presence of avocado thrips has been a continual threat to the avocado industry. From 1996 to 1998, >15% of fruit from the Ventura area were downgraded because of thrips-caused aesthetic damage. Damage is normally restricted to young leaves, where adults lay their eggs and larvae feed. However, as leaves age and harden, eggs may also be laid in young fruit. Larvae feed on the young fruit, causing formation of brown, elongated, and patchy scars, or hardened, "alligator skin"-like scars that may cover the entire fruit. Heavily scarred skin can sometimes prevent the fruit from sizing properly. At high densities, thrips can also kill young leaves, causing a rat-tailed appearance to young branches.

Successful control of avocado thrips has thus far been achieved only by use of insecticides. Helicopter applications using Veratran D (sabadilla) (Dunhill Chem. Co., Azusa, CA) plus (additional) sugar, Agri-Mek (abamectin) (Novartis Crop Protection, Greensboro, NC), and, recently, Success (spinosad) (Dow AgroSciences, Indianapolis, IN) have been popular methods to control thrips in all growing areas of California. Avocados are often grown on hillsides, making ground application impractical. Even orchards on flat terrain can be unsuitable for ground spray equipment because of dense lower tree growth or close tree spacing. Riverside and Ventura County avocado growers may apply sabadilla five or six times during a season against avocado thrips, depending on the length of the bloom period and susceptibility of young fruit. Sabadilla is a botanical insecticide derived from seeds of *Schoenocaulon officinale* and acts as a stomach poison. The sugar mixed with sabadilla attracts thrips to the insecticide. Air applications of sabadilla have been used against the related citrus thrips, *Scirtothrips citri,* on citrus, but general observations suggest ground applications are more effective.

Abamectin is an insecticide and miticide derived from fermentation products of the actinomycete *Streptomyces avermitilis,* and was registered in February 1999 for emergency use (Section 18 of the Federal Insecticide, Fungicide, and Rodenticide Act) against avocado thrips. It was registered for use in response to efficacy problems with sabadilla, whose activity can be limited by wet and cold weather and short residual activity (1-2 weeks). Unlike sabadilla, abamectin has translaminar activity (absorbed by the leaf but not translocated), is rainfast, has a long residual activity inside the leaf (>30 d), and yet degrades readily on surfaces under sunlight. Abamectin is a neurotoxin and has been shown to be effective against avocado thrips when applied on single trees using a backpack sprayer.

Spinosad is a well known insecticide that is effective in controlling lepidopterous pests and thrips, and is derived from substances produced by the bacterium *Saccharopolyspora spinosa.* In March 2000 it received full registration for use on avocado against thrips. Rotation of sabadilla, abamectin, and spinosad in a control program may be of great benefit in delaying or reducing the possible development of insecticide resistance. Limited data from a trial using single tree replicates suggested abamectin was more effective than spinosad, but these results are questionable because oil was used with abamectin and not with spinosad. No direct comparisons of the efficacy of spinosad and abamectin using helicopter or speed sprayer application had previously been made.

Although helicopter applications are the most popular and sometimes only method of treating orchards on hillsides, orchard size and location can also affect application methods. In smaller (e.g., 1 acre) orchards, especially those next to housing, it may be impractical to use a helicopter application. In other situations, helicopter operators may refuse to treat small areas because there is no economic return for treating such areas given the high costs of operating the helicopter. Thus, application by ground, specifically using a backpack sprayer, may be the only choice.

There have been no prior large scale trials using sabadilla or abamectin against thrips on avocado. The main objective of the insecticide trials reported in this article was to determine the spray volume or range of volumes delivered via helicopter that provides the most efficacious control of avocado thrips using sabadilla, abamectin, and spinosad. Supporting objectives were to determine how the volumes differentially affect control on small and large trees, and to compare the efficacy of spinosad and abamectin when applied by air and of spinosad when applied using a backpack sprayer.

Aerial Spray Volume Trials Using Sabadilla

Three trials (Trials 1-3) using sabadilla (12-25 Ibs/acre) plus sugar in volumes of 40-210 gallons per acre (gpa) were conducted from April through June 1999 at sites in Santa Paula, Ventura County, with 'Hass' avocados in commercial orchards on level terrain. One used small (3-m tall) trees and two used large (6-9-m tall) trees. Trials were conducted using a randomized block design, usually composed of three replicates of six treatments each (including the control). Treatments were blocked on pre-treatment numbers of thrips larvae/leaf. Plots were divided evenly into those with lowest, intermediate, and highest numbers, and numbers from the three groups matched to produce similar means. Treatments were randomly assigned within these three groups afterwards. In all volume trials, a helicopter with a 32-ft long boom, with 32 nozzles, was used to make applications. A single pass was made over the one row, 6-17 tree-long replicates. Water-sensitive papers were stapled on leaves to determine spray coverage.

Results of these trials indicated that on small trees with 20 ft spacing, 40 gpa was sufficient to reduce thrips larval populations on leaves. However, in both large tree trials, data indicated that this volume was insufficient. Rather, volumes of 85-125 gpa seemed necessary for effective control. Regardless of volume, effects of sabadilla lasted only 6-13 days.

Based on our results, applying sabadilla in 40 gallons of water/ a via helicopter appears sufficient for significant control of thrips larvae on small, 3-m tall trees, but this volume was clearly insufficient on large, 6-9-m tall trees to achieve good control on the lower portions of the canopy. Only when volumes of 85-125 gpa were applied did sufficient spray penetrate the canopy of large trees to reach the lower levels, resulting in reduced larval numbers for at least 6 days after treatment. Because results were no greater at 125 than 210 gpa, there seems to be an optimal 'saturation' point. Perhaps this point was the volume at which the benefits of high coverage were negated by the dilution of the sabadilla, in which case a higher sabadilla rate would be needed for further increase in efficacy. It is important to note that at any given volume, control is likely to be greater on the upper tree levels, where spray coverage almost certainly is higher than at the lower levels, and that only control at lower levels was assessed in our study.

In all three trials, when the mean coverage on water-sensitive papers was 10% or greater within a treatment, regressions between spray volume and numbers of larvae were generally significant. This threshold percentage seemed to provide sufficient bait coverage to cause a significant kill. Higher spray coverage appeared unnecessary at densities of 3-10 mean larvae/leaf, as seen in our trials. Only 40 gpa was necessary to achieve 10% coverage on small trees, but on large trees, the lowest volumes that achieved this were 85-125 gpa. Because of this, it is more costly to control thrips using sabadilla on larger trees. Volumes greater than 100 gpa are generally considered impractical to apply by air because of the excessive helicopter stop and tank refill time, which greatly prolongs the application process and further increases costs.

Even with optimal or high spray coverage, significant effects of sabadilla only lasted from 6 up to 13 days after treatment. The lack of differences in residual effects among volumes was probably a result of the sabadilla degrading simultaneously in all treatments. In another study, when sabadilla and sugar (at the same rates as seen in one of our trials) were applied on 2-3-m tall trees using a backpack sprayer at an equivalent of 100 gpa, significant thrips control was seen up to 23 days after treatment. Numbers of larvae in the treatment (4 larvae/leaf) were equal to 44% of those in the control. Higher coverage achieved using a backpack sprayer was likely the major cause for the discrepancy in the periods of control between this study and our studies.

Regressions between spray volume and numbers of thrips adults/ leaf were similar as those seen with larvae, with 85-210 gpa being most effective on large trees. Significant regressions were seen at three days after treatment, indicating adults were immediately attracted to the sugar bait after application of higher volumes. The effects of these higher volumes on adults may be especially important just before fruit set because this reduces the numbers that can oviposit on the fruit.

In summary, the results indicate that aerial applications of saba-dilla in 40 gpa on small (3-m tall) trees can result in high spray coverage and effective thrips control. However, volumes > 85 gpa are required on large (6-9-m tall) trees for effective control, making applications on large trees more costly. The extra costs may not result in additional or longer periods of population suppression (up to 13 days), making it especially critical to properly time applications on large trees.

Aerial Spray Volume Trials Using Abamectin

Seven aerial spray volume trials (Trials 4-10) using abamectin were conducted in Ventura County from July 1999-May 2000. One was conducted on small (2-3-m tall) trees, one on medium (4-m tall) trees, and five on large (6-8-m tall) trees. Volumes tested ranged from 50-150 gpa, but were usually 50 or 100 gpa. Abamectin was applied as Agri-Mek 0.15EC at 10 or 20 oz/acre with 1 % NR 415 oil, and in some trials with Silwet, an organosilicone surfactant. Application methods and equipment were essentially the same as in the sabadilla studies.

The overall results indicated that a high rate of abamectin (20 oz Agri-Mek/a) in an aerial spray volume of 50 gpa delivered via helicopter can reduce larval thrips populations on lower leaves of small, medium, and large (6 m-tall) trees. However, on the largest (>8-m tall), closed-canopied trees, applying neither 50 nor 100 gpa seems reliable for effective control (at least at 10 oz Agri-Mek/acre) because these spray volumes were insufficient to penetrate the canopy to reach the lower levels. In these situations, it was not surprising that applying even 100 gpa can be ineffective. It appeared that spray coverage of <10% on the bottom of a leaf surface was usually ineffective in causing high mortality when a low abamectin rate was used. To obtain consistent results on these large trees, a volume > 100 gpa may greatly increase spray coverage and probably result in increased efficacy. However, because of costs to growers, such a volume is generally considered impractical for routine helicopter applications and thus was included in only one trial of our study. This problem may be alleviated when leaves on trees are relatively sparse during periods of heavy bloom. This increases the amount of open space within trees that would allow a spray volume of 50 gpa to sufficiently penetrate the canopy, which may have been the case in ' some plots in one of our trials. Pruning tree tops to keep tree heights below eight meters and to keep the canopy somewhat open may also help increase the efficacy of aerial applications.

Either 50 or 100 gpa was also effective in controlling adults, but in relatively few cases, perhaps because numbers of adults were too low to detect consistent differences and they are more active than larvae (depending on temperature), resulting in higher variability in numbers. Thrips adults also seem to prefer the younger reddish leaves, so sampling was often biased against those leaves with highest adult numbers. It was unclear if migration from adjacent untreated areas affected our results, but in the medium tree trial, numbers remained low in treated plots for > 78 days after treatment, suggesting migration was not significant during this autumn trial.

The effects of abamectin on larvae were seen earlier when spray coverage was high on small and large trees, indicating high spray coverage is the key for an early kill. However, regardless of coverage, it appears that the most stable or highest control can sometimes be delayed until at least three weeks after application on trees of all sizes. Thrips numbers declined earlier on small trees than on medium or large trees probably because of the higher spray coverage on small trees, but it was not until >20 days after treatment that equally stable reductions were achieved across all volumes. Large population reductions at 22, 23, and 37 days after treatment in three other trials also indicate effects of abamectin may not appear until after three weeks, consistent with results of the small tree trial. These results may explain some reports from growers of control failures soon after using aerial applications.

There are several explanations for the sometimes delayed effects of abamectin applied in 50 and 100 gpa by air. Abamectin acts slowly, taking up to four days to kill an insect after it has ingested it. Cessation of feeding, but not necessarily mortality, can occur during these days. On top of this, several weeks may be needed for a large percentage of the thrips population to encounter the scattered areas covered by abamectin from aerial spraying. Abamectin is not translocated, but stays in the leaf below the coverage site, where it can retain some insecticidal properties for up to 30 days after application. Thus, when spray coverage is scattered as small droplets on a leaf, such as can be the case after both 50 and 100 gpa are applied by air (documented on water-sensitive papers), populations of larvae need time to move around the leaf before a large percentage encounters the insecticide. This may explain why relatively poor coverage (6-11% of bottom papers) at 50 gpa on large trees in one of our trials eventually resulted in significant mortality. A third explanation for the delayed effect is egg hatching after applications. The increases in the percentages of 1st instars in the 50 and 100 gpa treatments from 6-13 days after treatment in the small and one large large tree trial were strong evidence for egg hatching after applications. This may have caused the rebound in populations after the initial knockdown. Newly-emerged 1st instars were also seen next to oil stains >seven days after treatment in the small tree trial. In both trials, the subsequent decreases in numbers suggest that the 1st instars eventually fed upon areas with abamectin. Increased egg hatch may be related to higher numbers of eggs being laid on treated leaves as well. There is evidence that pesticide treatments may stimulate egg laying by citrus thrips, *S. citri.* Finally, in the medium tree trial, the delayed effect may somehow be related to the rain that occurred after the application. It is unclear if the rain in this trial spread or diluted the abamectin, somehow delaying the onset of kill. It was clear, however, that the rain ultimately had little or no effect on efficacy, because the 1.5-2.5 hour dry period before the rain was sufficient for absorption, as evidenced by the high kill, consistent with studies that show abamectin is unaffected by rain after drying. Overall, the results suggest that early post-treatment population evaluations up to two weeks after treatment can be misleading and that it is important to monitor populations for up to three weeks after aerial applications to reliably evaluate the effects of abamectin in all volumes.

In one of our trials, some evidence suggested that a combination of high volume, high abamectin rate, and the presence of surfactant (which may increase abamectin efficacy by increasing spread or uptake by preventing quick water evaporation) was the most effective treatment. However, results on large trees were inconsistent and it did not appear combining these factors was always necessary or even effective for control. For example, Agri-Mek at a rate of 10 oz/a in 100 gpa was ultimately as effective as application at 20 oz/a in 100 gpa in two large tree trials. Agri-Mek at 20 oz/a applied using a backpack sprayer was also effective on smaller trees (in a separate study), but this rate in 100 gpa was not effective in our other three large tree trials. This indicates that applying Agri-Mek at 10 oz/a in 100 gpa on large trees can give erratic results. In addition to spray coverage or abamectin rate problems, some inconsistencies between trials conducted in August and March may have arisen because abamectin may be taken up differently depending on the physiology and age of the leaves, which will depend on the time of year. Evidence for this exists with strawberry, apple, and pear leaves.

There were other effects of our aerial applications that are important to note. Coverage achieved on the top and bottom leaf surfaces seemed equally high, indicating a high degree of leaf disturbance during applications. It is not known if coverage on top leaf surfaces has the same effect on thrips population reductions as coverage on bottom surfaces. Abamectin may not be easily absorbed through upper leaf surfaces, at least on apple and pear. It is possible that abamectin is more easily absorbed through the upper surfaces when avocado leaves are young, and the physiological state of the leaves at some times of the year make this easier than at others. In addition, effects of aerial applications are likely to be greater higher in the trees, where we did not sample, because of higher spray coverage. The single helicopter pass method used in our study provided accurate measures of volumes delivered per acre, but the coverage at a given volume/area will differ slightly in a commercial situation if overlapping passes are made over adjacent rows. Also, because adjacent rows were more or less untreated in our trials, there was a possibility that adults migrated in from them, although as mentioned previously, this did not seem significant.

Helicopter air speeds in the trials were 10-22 m/h for 100-50 gpa treatments. It has been known that flying at 5-11 m/h results in highest coverage in forest cover, but in our medium tree trial, there were no differences in the percentages of leaves stained or numbers of thrips killed when applications were made at the lowest or highest speeds. In all cases, 20-40% of leaves were stained and this appeared sufficient to reduce thrips numbers by 23 days after treatment. It is unclear if the rain that occurred after this trial affected the speed results.

In summary, it appears aerial applications using the high rate of Agri-Mek (20 oz/a) in 50 and 100 gpa can be equally effective for reducing thrips populations on leaves on trees up to 6.5 m tall. However, applications on the largest (> 8-m tall) trees using <100 gpa are usually not effective for control at the lower tree levels because of low spray coverage. Leaves of different ages and at different times of the year may possibly uptake abamectin differently and affect control accordingly. This, the delayed effect, and most importantly the variability in spray coverage on the lower levels of large trees may cause inconsistencies in the reporting of or in actual aerial application results.

Aerial Spinosad and Abamectin and Backpack Spinosad Trial

An aerial trial (Trial 7) comparing spinosad and abamectin in 1999 at 50, 75, and 100 gpa indicated the two insecticides were equally efficacious at 27 days after treatment. A more recent trial (May-August 2000, Trial 11) compared the efficacy of spinosad and abamectin by air and spinosad by backpack on 4-5 m tall trees. Treatments were: Success 2SC at 5 oz/a; Success at 10 oz/a; Agri-Mek 0.15EC at 10 oz/a; Agri-Mek at 20 oz/a; and Success at 10 oz/a by backpack. An untreated control was also used for comparison. All treatments and the control were replicated three times. Applications were made with the same helicopter used in all previous trials. However, there were 64 nozzles operated in this trial, and aerial volumes were all 75 gpa. Spinosad backpack applications were made using a Pacific Stihl low volume mist sprayer (Model SR-400, L&M Fertilizer, Temecula, CA) at a rate of 19 gpa. Applications were made about two weeks before major fruit set (appearance of many fruit 0.3-0.5 cm long). Variables recorded included numbers of larvae per leaf, numbers of larvae per fruit, percent of fruit scarred, and numbers of predatory mites and predatory thrips on leaves. Results are shown in Tables 1-5.

The results suggest that abamectin (Agri-Mek) is more effective than spinosad (Success) in reducing thrips numbers and damage on fruit when spray coverage is less than optimal (i.e., <50% of bottom leaf surfaces covered), which occurs when applications are made with a helicopter. Furthermore, given three week's time, air applications of abamectin, even with relatively low coverage, can be as effective as backpack applications of spinosad, which should result in ideal (50-100%) coverage. Given >30 day's time, the abamectin air treatments outperformed spinosad treatments by air or backpack, as determined by thrips numbers on leaves, numbers on fruit, and most importantly, scarring of fruit. The slow or delayed effectiveness of abamectin when applied by air is consistent with results seen in four out of seven trials in Ventura County (referred to in the previous section). The differences between the long-term effectiveness of abamectin and spinosad when applied by air suggest the two chemicals differ in their insecticidal properties inside the avocado leaves or in how they impact thrips populations over the long term. Both chemicals have translaminar activity, but abamectin may be more persistent in the plant tissues, retaining its toxic properties for a longer period. There is evidence that addition of 2-4% oil to spinosad, instead of the 1 % used in this study, can result in residual activity of 35 days. Perhaps this could make spinosad closer to abamectin in its long-term effectiveness when applied by air.

Our study also indicated that both backpack spinosad and aerial abamectin treatments made against thrips on leaves about two weeks before a major fruit set (appearance of 0.5-cm long fruit) may be equally effective in reducing numbers on the fruit. Few fruit were present when applications were made, and no thrips and no scarring on fruit were seen at 16 days after treatment. Yet, reductions in percentages of fruit with scars were seen at 34 days after treatment, strongly suggesting that it is not necessary to wait until fruit appear for air abamectin and backpack spinosad treatments to be effective. However, aerial spinosad treatments were less effective than aerial abamectin treatments at preventing damage to fruit when made about two weeks before fruit set. This suggests that aerial spinosad applications need to be made closer to the fruit set time, or perhaps even when fruit have set and adults have appeared on the fruit. This could result in effective control because spinosad has a fast knockdown ability when coverage is high.

The negative effects on natural enemies using spinosad and abamectin were short lived. In all cases, there appeared to be some reductions in predator numbers caused by applications. Predatory mites seemed less affected than were predatory thrips. No differences against mites among treatments were evident, except in the spinosad backpack treatment. In this treatment, mite numbers were reduced possibly because of dislodgment from the spray blast rather than from any toxic effect (the same effect has been seen when water was used). In contrast, populations of predatory thrips were reduced across all treatments up to 17 days after treatment. It is unlikely differences on all dates were caused directly by insecticides. The insecticides may have indirectly reduced the predatory thrips numbers because they removed the avocado thrips that served as their food source. The predatory thrips may also have ingested avocado thrips that had fed on the toxins. The dramatic decline in predatory thrips numbers during a period of high avocado thrips densities (at 24 and 35 days after treatment) was probably not related to any treatment effects and indicates that the predatory thrips had no role in reducing avocado thrips populations.

Conclusions

Helicopter applications using sabadilla, abamectin, and spinosad were all determined to be effective against avocado thrips. Abamectin and spinosad are relatively new insecticides in the avocado system, so much progress has been made in a very short time in chemical control efforts against the thrips. The main factor to consider in using appropriate volumes is the size of the trees in an orchard, which influences potential spray coverage. Thorough coverage with sabadilla seemed essential. With abamectin, thorough coverage is clearly also important; however, relatively poor coverage can still be very effective. The difference is that an effective kill will take more time. Spinosad appears as effective as abamectin when applied by air, but its efficacy in preventing scarring on fruit may be more dependent on precise timing of application. When abamectin and spinosad are applied by air at their label rates, abamectin results in longer control. Thus, for example, it is more effective than spinosad when it is applied two weeks before fruit set. Studies determining the effects of spinosad applied a few days before fruit set may lead to different results. Finally, backpack application of spinosad is very effective because of the high spray coverage. For practical purposes, it appears this type of application, at least on medium-size trees, is nearly as or as effective as aerial abamectin treatments. Further studies to determine the effects of timing of spinosad treatments on efficacy may lead to more effective thrips control on avocado.

Background Reading

Beers, E. H., A. Anderson, and R. D. Brown. 1996. Effect of leaf age on lengths of residual activity of abamectin in pome fruit foliage. J. Econ. Entomol. 89: 488-492.

Beers, E. H., A. Anderson, and R. D. Brown. 1997. Absorption and translaminar activity of abamection in apple and pear foliage as determined by spider mite (Acari: Tetranychidae) mortality. J. Econ. Entomol. 90: 566-573.

California Avocado Commission. 1999. Crop Profile, Avocados in California. 70 pp.

Eger, J. E., Jr., J. Stavisky, and J. E. Funderburk. 1998. Comparative toxicity of spinosad to *Frankliniella* (Thysanoptera: Thripidae), with notes on a bioassay technique. Fla. Entonmol. 81: 547-551.

Haney, P. B., J. G. Morse, R. F. Luck, H. J. Griffiths, E. E. Grafton-Cardwell, and N. V. O'Connell. 1992. Reducing insecticide use and energy costs in citrus pest management. Univ. Calif. Statewide IPM Project Publ. 15. 62 pp. Davis, CA.

Hoddle, M. S., and J. G. Morse. 1997. Avocado thrips: a serious new pest of avocados in California. California Avocado Society Yearbook. 81: 81-90.

Khan, I., and J. G. Morse. 1996. Field trials with abamectin for control of citrus thrips, 1995. Arthropod Management Tests. 21: 77-79.

Morse, J. G. 1994. Controlling citrus thrips with abamectin. Citrograph. 79 (6): 12-13.
Morse, J. G. and N. Zareh. 1991. Pesticide-induced hormoligosis of citrus thrips (Thysanoptera: Thripidae) fecundity. J. Econ. Entomol. 84: 1169-1174.
Morse, J. G., M. S. Hoddle, M. Hand, M. Nyberg, A. A. Urena, T. Roberts, and S. Peirce. 1999. Pesticide efficacy trial. Results of a 1998 avocado thrips pesticide efficacy trial near Fallbrook. Publication of the California Avocado Commission, Santa Ana, CA, 8 pp.
Nakahara, S. 1997. *Scirtothripsperseae* (Thysanoptera: Thripidae), a new species infesting avocado in southern California. Insecta Mundi. 11: 189-192.
Novartis. 1998. Agri-Mek miticide/insecticide technical bulletin. NCPNo. 80100053A1.
Phillips, P.A. and B. A. Faber. 1998. Avocado thrips subproject 2: pesticide evaluations and phenology in the field. *In* California Avocado Research Symposium, University of California, Riverside, pp. 21-22.
Ripper, W. E. and F. Tudor. 1948. Investigation of helicopter spraying. Bull. Entomol. Res. 39: 1-12
Sparks, T. C., G. D. Thompson, H.A. Kirst, M. B. Hertlein, L. L. Larson, T. V. Worden, and S. T. Thibault. 1998. Biological activity of the spinosyns, new fermentation derived insect control agents, on tobacco budworm (Lepidoptera: Noctuidae) larvae. J. Econ. Entomol. .91: 1277-1283.
Walsh, D. B., F. G. Zalom, D. V. Shaw, and N. C. Welch. 1996. Effect of strawberry plant physiological status and translaminar activity of avermectin B1 and its efficacy against the twospotted spider mite (Acari: Tetranychidae). J. Econ. Entomol. 89:1250-1253.
Wislocki, P. G.,L. S. Grosso, andR.A. Dybas. 1989. Environmental aspects of abamectin use in crop protection. *In* W. C. Campbell [ed.], Ivermectin and avermectin, Chapter 12, pp. 182-200, Springer-Verlag, New York.

Table 1. Trial 11. Mean numbers of **avocado thrips larvae/leaf** ± SE (60 leaves/replicate, 3 replicates) and results of analyses of variance (ANOVA) and LSD multiple comparisons from Success (spinosad) (S) – Agri-Mek (abamectin) (A) trial in Santa Paula, CA, May16-July 27, 2000. Means with different letters within rows are significantly different ($P < 0.05$). 5, 10, and 20 = oz/acre.

Date	DAT[a]	Control	S-5 Air	S-10 Air	A-10 Air	A-20 Air	S-10 Backpack	F^b	P
May 16-18	-7 to –5	16.4 ± 6.3a	16.3 ± 2.6a	16.8 ± 2.2a	16.9 ± 4.8a	16.2 ± 3.6a	16.3 ± 4.6a	0.55	0.733
26	3	12.2 ± 5.0a	2.3 ± 0.7b	2.0 ± 0.8bc	2.3 ± 0.7b	2.0 ± 0.3bc	0.4 ± 0.2c	11.25	0.0008
30	7	16.4 ± 6.0a	8.7 ± 2.4b	6.3 ± 1.4bc	5.2 ± 2.0bc	3.4 ± 0.7c	0.7 ± 0.3d	14.85	0.0002
June 2	10	16.9 ± 7.6a	12.4 ± 2.7ab	9.1 ± 1.6ab	7.9 ± 2.6ab	5.3 ± 1.1b	0.6 ± 0.1c	8.16	0.0026
9	17	14.5 ± 6.4a	5.9 ± 1.2b	4.8 ± 1.0bc	1.7 ± 0.5cd	0.7 ± 0.2d	0.4 ± 0.1d	14.77	0.0002
16	24	24.2 ± 7.6a	8.7 ± 2.9b	4.1 ± 1.1b	0.8 ± 0.4c	0.2 ± 0.1c	0.2 ± 0.1c	23.14	<0.0001
27	35	19.5 ± 8.1a	12.3 ± 2.8ab	10.7 ± 2.2ab	1.9 ± 0.5c	1.2 ± 0.3c	4.6 ± 1.1bc	6.36	0.0066
July 5	43[c]	12.1 ± 4.0a	10.2 ± 3.7ab	15.9 ± 4.4a	3.9 ± 0.7b	3.8 ± 1.2b	9.1 ± 2.3ab	3.36	0.0488
11	49[c]	12.2 ± 5.6a	7.5 ± 2.3a	8.9 ± 1.0a	2.9 ± 1.4a	1.8 ± 0.5a	6.8 ± 2.9a	2.40	0.1118
27	65[d]	13.2 ± 5.2a	7.5 ± 3.2ab	5.6 ± 1.8abc	3.9 ± 2.2bc	1.6 ± 0.2c	6.4 ± 2.1abc	3.38	0.0477

[a]Days after treament.
[b]All df = 5, 10.
[c]N = 30 leaves/replicate.
[d]N = 20 leaves/replicate.

Table 2. Trial 11. Mean numbers of **avocado thrips larvae/fruit** ± SE (30 fruit/replicate, 3 replicates) and results of analyses of variance (ANOVA) and LSD multiple comparisons from Success (spinosad) (S) – Agri-Mek (abamectin) (A) trial in Santa Paula, CA, May 16-July 25, 2000. Means with different letters within rows are significantly different ($P < 0.05$). 5, 10, and 20 = oz/acre.

Date	DAT[a]	Control	S-5 Air	S-10 Air	A-10 Air	A-20 Air	S-10 Backpack	F^b	P
June 2	10[c]	0.07 ± 0.03	0.07	0.00 ± 0.00	0.03	0.00	0.00 ± 0.00	----	-----
8	16	0.13 ± 0.02a	0.10 ± 0.02a	0.03 ± 0.02bc	0.06 ± 0.01ab	0.01 ± 0.01cd	0.00 ± 0.00d	9.70	0.0014
15	23	0.18 ± 0.08a	0.09 ± 0.07ab	0.00 ± 0.00c	0.00 ± 0.00c	0.01 ± 0.01bc	0.00 ± 0.00c	7.74	0.0032
26	34[d]	1.30 ± 0.60a	0.53 ± 0.42ab	0.38 ± 0.15abc	0.03 ± 0.03bc	0.01 ± 0.01c	0.07 ± 0.05bc	5.08	0.0142
July 3	41	1.78 ± 1.31a	1.18 ± 0.80a	1.48 ± 0.85a	0.11 ± 0.10a	0.03 ± 0.02a	0.54 ± 0.28a	1.46	0.2841
10	48[e]	2.01 ± 1.40a	1.11 ± 0.98a	1.54 ± 0.66a	0.09 ± 0.06a	0.00 ± 0.00a	0.91 ± 0.39a	1.06	0.4375
25	63[f]	4.20 ± 3.09a	1.75 ± 1.30a	1.63 ± 0.53a	0.53 ± 0.23a	0.40 ± 0.18a	0.97 ± 0.32a	1.76	0.2093

[a]Days after treament.
[b]All df = 5, 10.
[c]1 –3 replicates per treatment; data not analyzed.
[d]N = 60 fruit/replicate.
[e]N = 20-30 fruit/replicate.
[f]N = 20 fruit/replicate.

Table 3. Trial 11. Mean percentage of **fruit with scars** ± SE (x 100) (30 fruit/replicate, 3 replicates) caused by avocado thrips and results of analyses of variance (ANOVA) and LSD multiple comparisons from Success (spinosad) (S) – Agri-Mek (abamectin) (A) trial in Santa Paula, CA, May16-July 25, 2000. Means with different letters within rows are significantly different ($P < 0.05$). 5, 10, and 20 = oz/acre.

Date	DAT[a]	Control	S-5 Air	S-10 Air	A-10 Air	A-20 Air	S-10 Backpack	F^b	P
June 8	16	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	----	-----
15	23	3 ± 3a	4 ± 1a	0 ± 0a	0 ± 0a	1 ± 1a	0 ± 0a	2.98	0.0668
26	34[c]	33 ± 15a	17 ± 12ab	11 ± 2abc	2 ± 1cd	1 ± 1d	2 ± 1bcd	5.96	0.0083
July 3	41	47 ± 20a	24 ± 8ab	20 ± 8abc	4 ± 1bc	2 ± 1c	14 ± 3abc	4.01	0.0294
10	48[d]	52 ± 12a	37 ± 10a	32 ± 4a	6 ± 3b	3 ± 2b	13 ± 5b	7.36	0.0039
25	63[e]	55 ± 13a	42 ± 17ab	33 ± 6abc	10 ± 8c	8 ± 4c	13 ± 4bc	3.74	0.0361

[a]Days after treament.
[b]All df = 5, 10.
[c]N = 60 fruit/replicate
[d]N = 20-30 fruit/replicate.
[e]N = 20 fruit/replicate.

Table 4. Trial 11. Mean numbers of **predatory mites** ± SE (60 leaves/replicate, 3 replicates) and results of analyses of variance (ANOVA) and LSD multiple comparisons from Success (spinosad) (S) – Agri-Mek (abamectin) (A) trial in Santa Paula, CA, May 16-July 27, 2000. Means with different letters within rows are significantly different ($P < 0.05$). 5, 10, and 20 = oz/acre.

Date	DAT[a]	Control	S-5 Air	S-10 Air	A-10 Air	A-20 Air	S-10 Backpack	F^b	P
May 16-18	-5 to -7	0.48 ± 0.16a	0.53 ± 0.21a	0.61 ± 0.02a	0.85 ± 0.17a	0.52 ± 0.23a	0.57 ± 0.18a	0.82	0.560
26	3	0.82 ± 0.34a	0.45 ± 0.11a	0.64 ± 0.18a	0.65 ± 0.16a	0.36 ± 0.15ab	0.07 ± 0.03b	3.42	0.046
30	7	0.94 ± 0.41ab	0.65 ± 0.31ab	0.88 ± 0.10a	0.79 ± 0.28ab	0.28 ± 0.12bc	0.12 ± 0.07c	3.54	0.042
June 2	10	0.79 ± 0.36ab	0.65 ± 0.27ab	0.89 ± 0.17a	0.57 ± 0.10ab	0.23 ± 0.13bc	0.07 ± 0.01c	3.93	0.031
9	17	0.31 ± 0.15a	0.23 ± 0.11a	0.35 ± 0.04a	0.27 ± 0.13a	0.11 ± 0.07a	0.10 ± 0.04a	0.94	0.494
16	24	0.35 ± 0.19a	0.36 ± 0.20a	0.45 ± 0.07a	0.49 ± 0.12a	0.23 ± 0.17a	0.18 ± 0.09a	0.99	0.469
27	35	0.16 ± 0.08a	0.14 ± 0.10a	0.21 ± 0.09a	0.16 ± 0.07a	0.08 ± 0.07a	0.18 ± 0.04a	0.73	0.619
July 5	43[c]	0.12 ± 0.08a	0.08 ± 0.06a	0.09 ± 0.04a	0.07 ± 0.05a	0.06 ± 0.06a	0.10 ± 0.03a	0.39	0.844
11	49[c]	0.07 ± 0.03a	0.10 ± 0.06a	0.10 ± 0.03a	0.07 ± 0.04a	0.03 ± 0.03a	0.02 ± 0.02a	0.81	0.569
27	65[d]	0.00 ± 0.00a	0.03 ± 0.03a	0.02 ± 0.02a	0.05 ± 0.05a	0.00 ± 0.00a	0.02 ± 0.02a	0.54	0.742

[a]Days after treament.
[b]All df = 5, 10.
[c]N = 30 leaves/replicate.
[d]N = 20 leaves/replicate.

Table 5. Trial 11. Mean numbers of **predatory thrips**[a] ± SE (60 leaves/replicate, 3 replicates) and results of analyses of variance (ANOVA) and LSD multiple comparisons from Success (spinosad) (S) – Agri-Mek (abamectin) (A) trial in Santa Paula, CA, May 16-July 27, 2000. Means with different letters within rows are significantly different ($P < 0.05$). 5, 10, and 20 = oz/acre.

Date	DAT[b]	Control	S-5 Air	S-10 Air	A-10 Air	A-20 Air	S-10 Backpack	F^c	P
May 16-18	-5 to -7	0.04 ± 0.02a	0.03 ± 0.01a	0.03 ± 0.01a	0.03 ± 0.02a	0.03 ± 0.02a	0.03 ± 0.01a	0.07	0.995
26	3	0.06 ± 0.02ab	0.03 ± 0.02abc	0.02 ± 0.02bc	0.07 ± 0.02a	0.02 ± 0.00bc	0.01 ± 0.01c	3.63	0.039
30	7	0.10 ± 0.02a	0.03 ± 0.01b	0.06 ± 0.02ab	0.06 ± 0.02ab	0.05 ± 0.02ab	0.02 ± 0.01b	3.19	0.056
June 2	10	0.14 ± 0.04a	0.08 ± 0.04a	0.12 ± 0.03a	0.13 ± 0.03a	0.10 ± 0.02a	0.04 ± 0.02a	1.52	0.266
9	17	0.21 ± 0.09a	0.06 ± 0.01a	0.07 ± 0.01a	0.08 ± 0.01a	0.04 ± 0.02a	0.03 ± 0.02a	3.22	0.054
16	24	0.07 ± 0.02a	0.08 ± 0.01a	0.01 ± 0.01a	0.04 ± 0.02a	0.02 ± 0.00a	0.01 ± 0.01a	3.04	0.063
27	35	0.01 ± 0.01a	0.03 ± 0.01a	0.01 ± 0.01a	0.00 ± 0.00a	0.00 ± 0.00a	0.01 ± 0.01a	2.40	0.112
July 5	43[d]	0.02 ± 0.02a	0.03 ± 0.02a	0.03 ± 0.02a	0.00 ± 0.00a	0.00 ± 0.00a	0.01 ± 0.01a	1.92	0.178
11	49[d]	0.02 ± 0.02a	0.02 ± 0.02a	0.02 ± 0.02a	0.02 ± 0.02a	0.00 ± 0.00a	0.00 ± 0.00a	0.35	0.872
27	65[e]	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	-----	-----

[a] Includes larvae and adults of *Leptothrips mali*, *Franklinothrips* sp., and *Aeolothrips* sp.

[b] Days after treatment.

[c] All df = 5, 10.

[d] N = 30 leaves/replicate.

[e] N = 20 leaves/replicate.