Recent Progress on Avocado Thrips Biology and Management

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Benefit to the Industry

Avocado thrips, *Scirtothrips perseae* Nakahara (Thysanoptera: Thripidae) was discovered in California in July of 1996, and spread rapidly from two initial sites of discovery near Port Hueneme in Ventura County and at the Irvine Ranch in Orange County. Avocado thrips larvae and adults can build to such high densities over the fall through spring period on young leaves on top-worked trees that leaves damaged from feeding can drop. The main source of economic loss attributable to avocado thrips, however, is scarring of immature fruit in spring by feeding thrips.

Economic losses attributable to avocado thrips have been calculated using pack-out records. Economic data for 22 anonymous growers were combined with costs of thrips control incurred by either using biological control agents, Veratran-D (sabadilla), or Agri-Mek (abamectin). An economic model was developed by an agricultural economist at UC Davis to estimate the effects to growers and consumers of rising production costs, retail prices, and decreases in quality. The model indicated an annual short-run loss to avocado growers of between $7.6 and $13.4 million in 1998 from the combined effects of losses in quality and increased production costs associated with avocado thrips management. Economic losses to avocado thrips continue to accrue annually, but the magnitude of decreased revenue will vary yearly depending on the severity of thrips infestations, costs of control (biological or chemical), percentage of crop damaged, severity of damage, and market value for harvested fruit.

Our research sponsored by the California Avocado Commission has taken a three pronged approach to investigating potential control strategies to minimize economic losses to avocado thrips. Our thrips management program is based on: (1) an improved understanding of this pest's biology, behavior, ecology, and natural enemies. We intend to use this information for the development of biological and cultural control programs for avocado thrips. (2) Screening and selection of IPM compatible insecticides and monitoring avocado thrips populations for resistance to these insecticides, and (3) investigating cost effective strategies for applying insecticides by air or ground as selected from screening trials.

Objectives

1. Investigate avocado thrips pupation behavior and determine if composted mulches used for root rot control are antagonistic towards pupating thrips larvae.
2. Investigate and determine the potential of the parasitoid *Goetheana incerta* and the predator *Franklinothrips orizabensis* for biological control of avocado thrips.
3. Evaluate the efficacy of pre-bloom insecticide applications for avocado thrips control and fruit damage reduction in northern and southern avocado growing areas.
4. Determine the efficacy of abamectin and spinosad applications applied at fruit set for avocado thrips control.
5. Develop base line metrics for measuring development of resistance by avocado thrips to sabadilla.
6. Evaluate the height range of a Stihl back pack power sprayer for applying insecticides to trees.

Avocado Thrips Pupation Biology & Organic Mulches for Thrips Control

Pupation Biology and Cultural Control (Work by Robinson, Carey, & Hoddle). Predatory and phytophagous thrips have been captured emerging from the ground beneath citrus trees, and pupation beneath host plants is common for pestiferous phytophagous thrips. Adult avocado thrips have been retrieved from leaf duff samples collected from beneath avocado trees in Ventura County indicating that this pest also pupates on the ground (Hoddle *et al*. 1998). The proportion of avocado thrips larvae that pupate on avocado trees or abandon trees to pupate beneath host plants was unknown until recently. We undertook laboratory studies to determine the proportion of avocado thrips larvae that either pupate on host plants or abandon branches to pupate beneath trees.

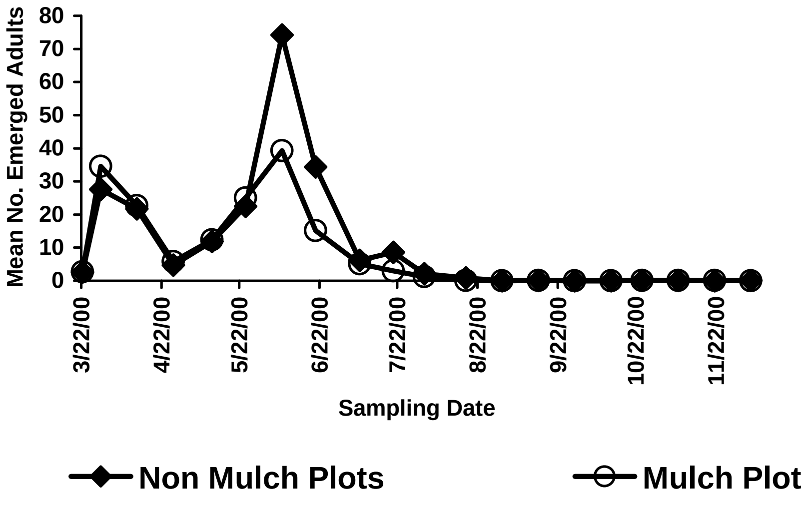
The pupation biology of avocado thrips was studied in the laboratory by placing known numbers of second instar thrips larvae on young ¾ expanded avocado leaves that were flushing on 2 m tall plants in pots. The base of each branch was coated with tangle foot to prevent larvae leaving experimental branches. Under each branch a clear sheet of plastic coated with tangle foot was placed to trap thrips larvae falling or jumping from experimental branches. After 3-4 days, branches were destructively sampled for thrips pupae and numbers of larvae trapped on plastic sheets were recorded. For each replicate 25-30 avocado thrips larvae were placed on a branch with suitable leaves for feeding and we replicated this study 12 times.

On average we managed to recover 77% of deployed avocado thrips larvae. Of those thrips recovered, 22% pupated in cracks on branches and 78% were recovered on plastic sheets beneath branches.

These laboratory data suggest that the majority of avocado thrips drop or jump to the ground to pupate. We are currently investigating the potential of green yard waste mulches that are used for biological control of avocado root rot for reducing avocado thrips pupation rates. We hypothesized that mulches may harbor invertebrates or pathogens antagonistic to avocado thrips that are not present in avocado leaf duff. Our current field experiments are designed to record numbers of avocado thrips falling from leaf flush onto mulched or unmulched soils, and the numbers of adult thrips that successfully emerge from mulched and unmulched soils. Concurrent with these observations we are recording monthly changes in diversity of the arthropod and entomopathogenic fauna of mulches and leaf duff to determine if any significant differences between the two soil types are correlated with suppressive activity towards avocado thrips.

Preliminary results from one year of field work that used thrips emergence traps to monitor emergence rates of adult avocado thrips over time indicates that composted organic mulches may be able to reduce peak emergence of avocado thrips adults from beneath trees by around 50% (Fig. 1).

Figure 1. Trapping Rates Of Adult Avocado Thrips That Emerged Beneath Mulched And Non-Mulched Avocado Trees In An Avocado Orchard In Temecula, California.



The mechanism of thrips suppression in mulches is unknown, and investigations are focusing on microarthropods that inhabit mulch but are absent in avocado leaf duff, along with entomopathogenic fungi and nematodes. Preliminary investigations indicate that there are differences between faunas that inhabit the mulch in comparison to leaf duff, and these populations exhibit distinct phenological patterns through time.

Biological Control of Avocado Thrips

Goetheana incerta Annecke *(Hymenoptera: Eulophidae). (Research by Morse and Urena)*.

This parasitoid was first observed attacking South African citrus thrips, *Scirtothrips aurantii* Faure, in 1995 (Grout and Stephen 1995) and we are interested in ascertaining whether it will attack avocado thrips and how effective it may in control of California citrus thrips, *S. citri* (Moulton). The first shipment of parasitoids from South Africa, sent in April of 1997, was lost because of our lack of knowledge regarding the parasitoid's basic biology (relatively little research has been done on thrips parasitoids worldwide). The second shipment arrived in April of 1998 and was also lost, because most of the parasitoids emerged in transit and only six were alive or emerged over the following four weeks in quarantine. On 20 July 2000, our third shipment of *Goetheana*, arrived at UCR's Quarantine Facility. After rearing the parasitoids through 2 generations on citrus thrips in quarantine, the colony was lost in December during a cold spell (unfortunately, the old quarantine facilities do not allow for temperature regulation). During this time in quarantine, however, we did learn a great deal about working with this parasitoid and believe we are very close to being able to rear the species successfully.

Goetheana is very difficult to work with. Adults are small and fragile and emerge from second instar thrips. So far, we have been able to keep adults alive for only 2-4 days. Behavioral differences allow us to separate males and females to some degree, otherwise sexual differentiation is very difficult, even when adults are slide mounted and examined under a microscope. The ovipositor of the female is tiny and visible under high magnification only when she is in the process of stinging thrips. Unmated females lay only male eggs (males are obviously of limited value in building up a colony except for their critical input during mating).

It appears that citrus thrips is recognized as a host (*Goetheana* has been observed host-feeding and parasitizing this species) but avocado thrips may not be recognized as a suitable host by the female (this has yet to be confirmed). Lack of host recognition may occur because of different host cues (e.g., odors) with avocado thrips that may be related to host plant chemistry. Regardless, we feel this work is quite important to possible control of avocado thrips by parasitoids because what we learn in rearing this species will be of great assistance in designing field parasitoid survey and rearing protocols for species that may be present in Mexico attacking avocado thrips. For example, an interesting preliminary observation is that healthy citrus thrips will readily feed on and consume ("cannibalize") parasitized thrips 3-4 days after parasitization by *Goetheana*. Once parasitized thrips become less active and unable to defend themselves, they are eaten by other members of the same species. This was a completely unexpected observation and may partially explain why we saw parasitization in the first shipment but relatively few parasitized thrips survived to pupation. It was only when we caught a thrips in the act of eating several parasitized thrips that we determined that "disappearing" thrips were not escaping but were being eaten.

In retrospect, this may explain the observation that parasitized citrus thrips go into early pupation behavior as second instars. Thus, in our quarantine work and during foreign exploration, it may be necessary to individually isolate parasitized thrips to protect them from being cannibalized. This is something we would not have anticipated and might have frustrated foreign exploration for avocado thrips parasitoids (assuming avocado thrips parasitoids show similar behavior as *Goetheana*). Another problem facing this project is that relatively few researchers around the world have conducted detailed behavioral studies with thrips parasitoids. Consequently, we have very little available research to assist us in designing a protocol for rearing and maintenance of our *Goetheana* colony. If we are able to maintain the *Goetheana* colony, our next steps will be to determine more precisely the host suitability of citrus thrips, avocado thrips, and several beneficial thrips species (e.g., *Franklinothrips orizabensis*) prior to requesting permission to release the parasitoid from Quarantine (APHIS has made this a requirement before we will be able to take this species out of quarantine). Our cooperator in South Africa is ready to send us another shipment of *Goetheana* as soon as UCR's new Insectary and Quarantine facility is open and certified for use (the required host specificity studies cannot be done in the current quarantine facilities).

Franklinothrips orizabensis (Thysanoptera: Aeolothripidae) (Research by Hoddle, Robinson, Flores, Oevering, Phillips, & Faber). This predatory thrips is the key natural enemy of avocado thrips in California. Work has been completed on determining the optimal temperatures and diets for mass rearing this predator and investigations into the pupation biology has revealed novel ways to harvest large numbers of this natural enemy as pupae. Furthermore, laboratory work investigating the functional response of *F. orizabensis* towards greenhouse thrips and avocado thrips has been completed as have detailed studies on the predatory behavior and host stage preferences of *F. orizabensis* towards these two pest thrips. The results of mass rearing studies have been extended to two California insectaries, Buena Biosystems and American Insectaries. Field trials are currently under way looking at the potential efficacy of augmentative releases of mass reared *F. orizabensis* for control of avocado thrips in avocado orchards.

Chemical Control of Avocado Thrips: Pre-bloom, Fruit Set, Resistance Monitoring, and Back Pack Sprayer Trials

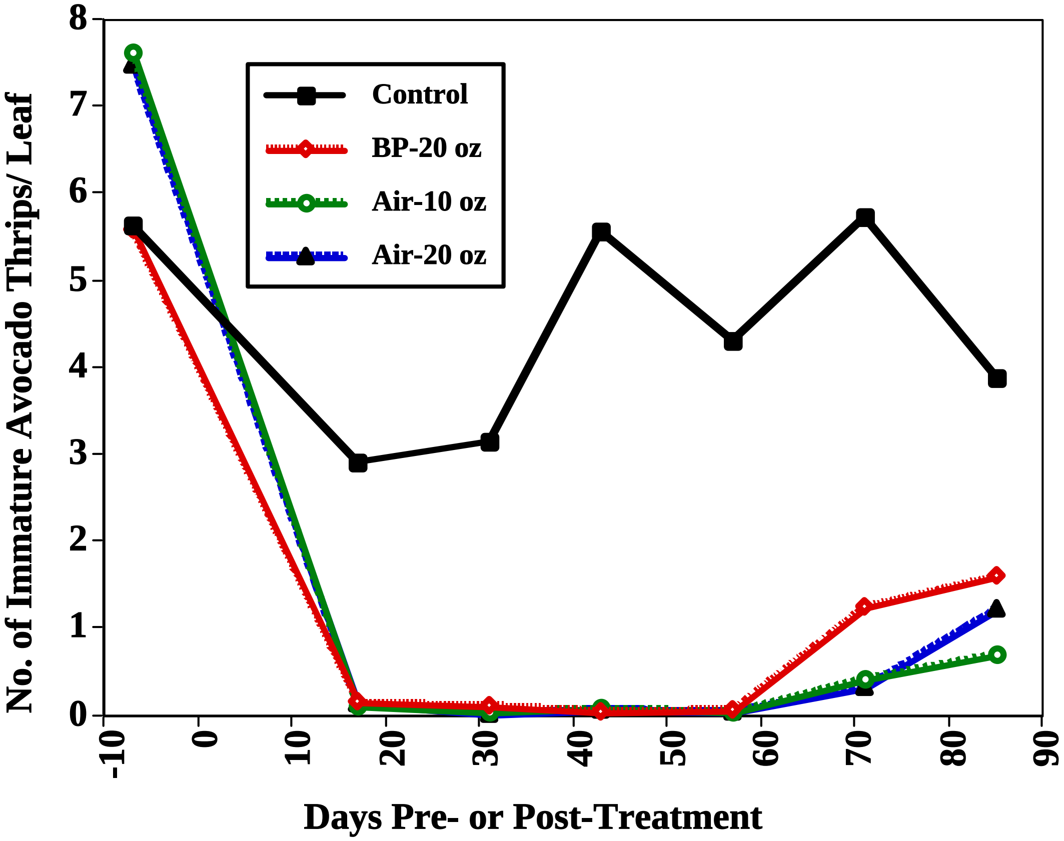
Pre-Bloom Abamectin Spray Trial with Avocado Thrips (*Research by Morse, Hoddle, and Urena; Companion field studies run in Ventura County by Phillips, Faber, and Oevering).*

A priority of spray trials this last year was to determine if early, pre-bloom treatments of abamectin might give persistent control of avocado thrips. Growers might want to use early treatments for two main reasons: (1) to avoid treatment when honey bees could be present in the grove during bloom and (2) because the number of helicopters available for air treatment is limited and waiting until fruit set for treatment might result in being placed in a "spray que" and if one is late in the que, significant thrips scarring could result prior to treatment. Past spray trials had shown that abamectin is a fairly persistent chemical and for this reason, it was chosen for evaluation rather than either sabadilla or spinosad.

For the trial in the South, two nearby avocado groves in the Fallbrook region were chosen for evaluation. Grove 1 was split into 12 plots and Grove 2 into 6 plots and 4 and 2 plots, respectively, were randomly assigned in each grove to each of 3 treatments (to minimize the number of trees that would be untreated and might suffer thrips scarring, plots randomly selected as control/backpack plots were one-half the size of the plots treated by air): (1a) untreated control / (1b) 20 oz Agri-Mek 0.15 EC per 100 gallons applied with a backpack sprayer, (2) 10 oz Agri-Mek per 100 gallons applied by helicopter, and (3) 20 oz Agri-Mek per 100 gallons applied by helicopter. Two percent Narrow-Range 415 Oil was added to all Agri-Mek treatments. A model SR-400 Pacific Stihl low-volume backpack mist-sprayer (L&M Fertilizer, Temecula, CA) set at setting #4 was used to deliver a fine mist spray to each tree. Treatments were pre-mixed in 5 gallon carboys and the applicator, sprayer, and 4 carboys were carried around the grove in a John Deer 4x4 Alligator ATV. A Bell (Jet Ranger) 206-B3 helicopter equipped with a 36-foot wide boom (40-foot wide spray swath) driven at 15-20 mph was used to apply the air treatments. Water pH for both air and backpack treatments was 8.0. Backpack treatments went on at 82 gallons per acre (note that the Agri-Mek Section 18 specifies a minimum of 100 gpa and we obtained an experimental use permit allowing this lower coverage) and helicopter treatments went on at 100 gpa. Grove 1 was a 21-year old grove of Hass variety avocados on a mix of Mentone, Zuntano, and Topa rootstock, were 25-30 feet high, and were planted 23 feet apart within a row with 23 feet between rows (82 trees per acre). Grove 2 was a 25-year old grove of mixed Hass and Bacon variety avocados on Zuntano and Topa rootstock, were 20-25 feet high, and were planted 14 feet apart within a row with 20 feet between rows (155 trees per acre). Within each plot, 8 data trees in the center of each plot (with a minimum of 4 buffer rows between data trees and the adjacent plot) were selected and tagged so that the same trees could be used for pre- and post-treatment counts. Thrips levels were monitored by selecting ten 3/4 to fully expanded young leaves from each tree (using a 14-foot long pole pruner to select leaves from throughout the canopy of each tree) and counting the number of immature avocado thrips (adults were not counted) from the undersurface of each leaf. Pre-treatment counts were taken 15-22 March, helicopter applications were made 24 March, backpack treatments 26-27 March, and post-treatment counts were taken approximately every 2 weeks until after most of the thrips moved to young fruit.

Fig. 2 shows the results of leaf counts in the Fallbrook spray trial. Abamectin, regardless of the rate or method of application, was effective in reducing thrips levels to very low levels on leaves until 57 days post-treatment (21 May). Between the last two counts (71 days post-treatment = 4 June and 85 days post-treatment = 18 June), thrips starting to move to young fruit. Because of the small number of fruit per tree, we did not assess thrips levels on fruit but we do plan to take fruit scarring assessments close to the time when fruit are harvested. Our conclusion from this trial is that early, pre-bloom treatments of avocado thrips with abamectin show substantial efficacy regardless of whether they are applied by ground with a backpack (BP) or by air with either 10 or 20 oz of abamectin per acre.

Figure 2. Results of the Fallbrook Avocado Thrips Abamectin Pre-Bloom Spray Trial.



Pre-Bloom Abamectin Spray Trial for Avocado Thrips in Somis (*Research by Phillips, Faber, and Oevering).*

A pre-bloom abamectin spray trial, similar to the trial undertaken in Fallbrook was initiated in Somis, Ventura County on April 23, 2001. A Hass grove on seedling rootstock, 18 years old, was split into 15 plots, 12×3 trees in size, of which 12 plots were used. Trees were 10-15ft tall, 20ft apart within a row, 20ft between rows. Six count trees were marked in the middle of each plot.

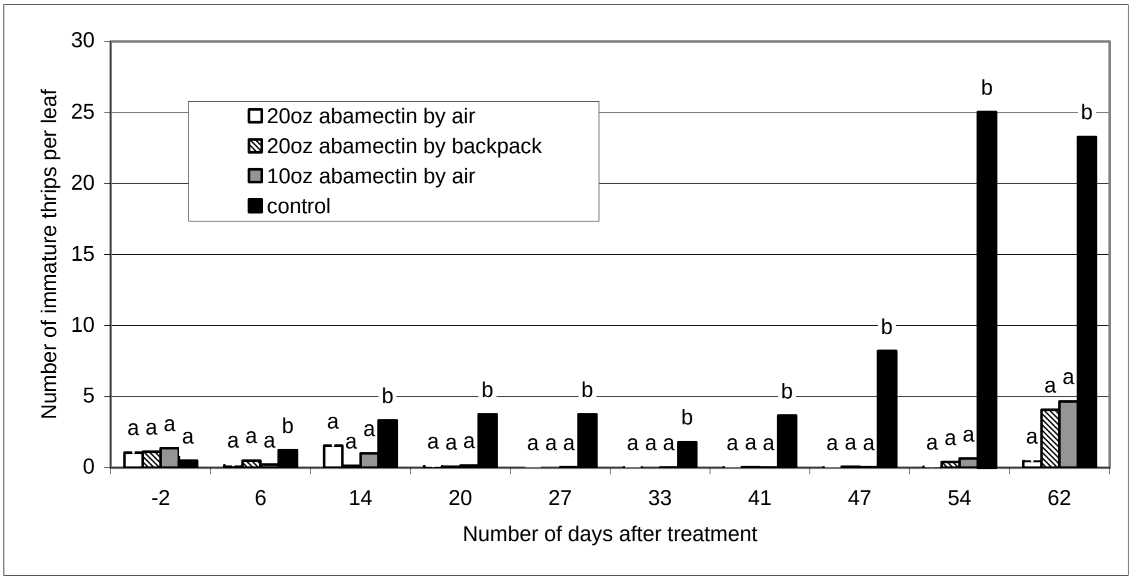
Three replicates of three treatments and one control were randomly assigned following a thrips pre-count; (1) 20oz abamectin (AgriMek) by helicopter (air) per acre, (2) 20oz abamectin by backpack (bp), (3) 10oz abamectin by air and (4) control (no application). All abamectin applications included 2% Narrow Range (NR) 415 oil. Pacific Stihl backpack sprayers (L&M Fertilizer, Temecula CA) and a Bell 206B3 Jet Ranger helicopter were used at similar volume, spray level and speed as described for Fallbrook above.

On each tree 10 younger leaves (at a height of 4-6ft) were sampled weekly and the numbers of immature (1st and 2nd larval instars) and adult avocado thrips per leaf were recorded together with the number of natural enemies (including all life-stages of predatory thrips, predatory mites, lacewings, ladybugs, small spiders and other general predators, not including parasitoids) encountered.

Treatment effects on number of immatures and natural enemies per leaf were analysed using randomised block analyses of variance (ANOVA) and are presented in this report. A least significant difference test (LSD) was used to separate effects among treatments. Similar data on adult avocado thrips (not reported in this report) is available on request.

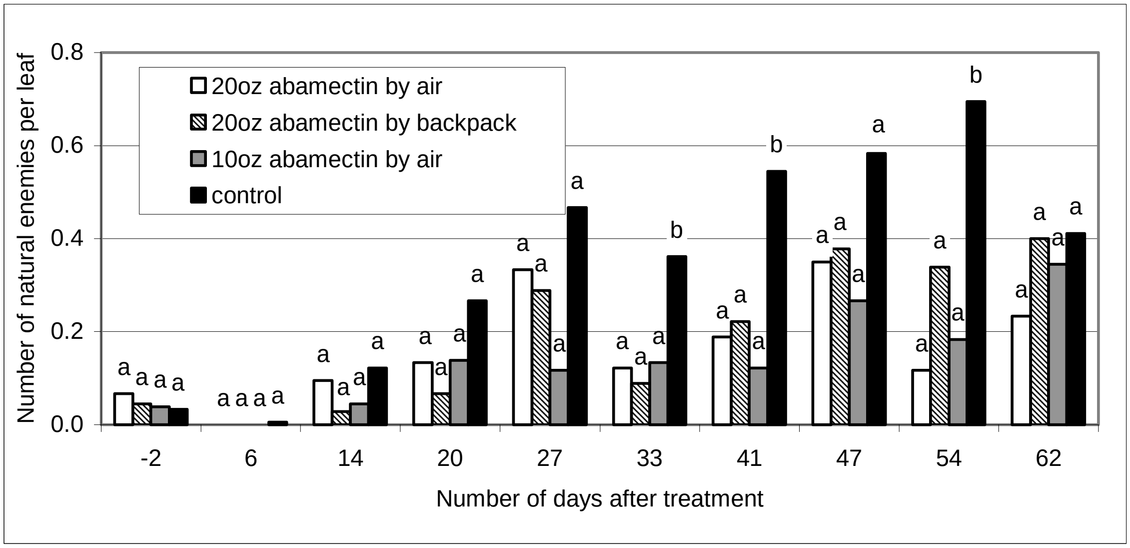
The number of immatures and natural enemies per leaf are presented in Figures 3 and 4, respectively. After treatment (6-62 days after treatment (DAT), Fig. 3) the number of immature thrips encountered was significantly (*P*<0.02) lower than the controls. No significant differences between the abamectin concentration applied, or the application methods used were found. For the first 27 days after application, abamectin treatments had no significant effect on the natural enemies population (Fig. 4). Between 33 and 54 DAT some significant reduction in the natural enemies population was observed in the treated plots. These reductions probably relate to the low prey (avocado thrips) availability in treated plots. On 62 DAT differences in number of natural enemies per leaf were no longer observed.

Figure 3. Mean number of immature avocado thrips per leaf from abamectin (AgriMek) pre-bloom application trials in Ventura, CA, April 23-June 27, 2001 (including first and second larval instars, 60 leaves per replicate, three replicates per treatment; air = helicopter application, volumes in oz per acre, ANOVA and LSD multiple comparisons analyses (*P*>0.05), different letters per date indicate significant differences).



Our preliminary conclusions from this trial are in line with the study conducted in Fallbrook. Abamectin can reduce thrips numbers for at least 60 days disregarding the application method or the concentration (10-20oz) applied. This study is continuing with initial fruit scarring and migration of thrips and natural enemies within the grove (as monitored by means of sticky traps) yet to be completed. Both will be assessed in the near future. Final scarring analyses are planned around harvest 2002.

Figure 4. Mean number of natural enemies per leaf from abamectin (AgriMek) pre-bloom application trials in Ventura, CA, April 23-June 27, 2001 (including all life-stages of predatory thrips, predatory mites, lacewings, ladybugs, small spiders and other general predators, not including parasitoids, 60 leaves per replicate, three replicates per treatment; air = helicopter application, volumes in oz per acre, ANOVA and LSD multiple comparisons analyses ($P>0.05$), different letters per date indicate significant differences).



Fruit Set Abamectin and Spinosad Spray Trial with Avocado Thrips (*Research by; Phillips, Faber, and Oevering in Ventura*)

In Santa Paula, Ventura County, a spray trial during fruit set was initiated May 15, 2001, to assess the impact of different methods of abamectin (AgriMek) and spinosad (Success) application (backpack and helicopter, details as described above) against avocado thrips. It also evaluates the application of two spinosad applications by helicopter, 3 weeks apart to compensate for the shorter residual of spinosad compared to abamectin as seen in previous trials.

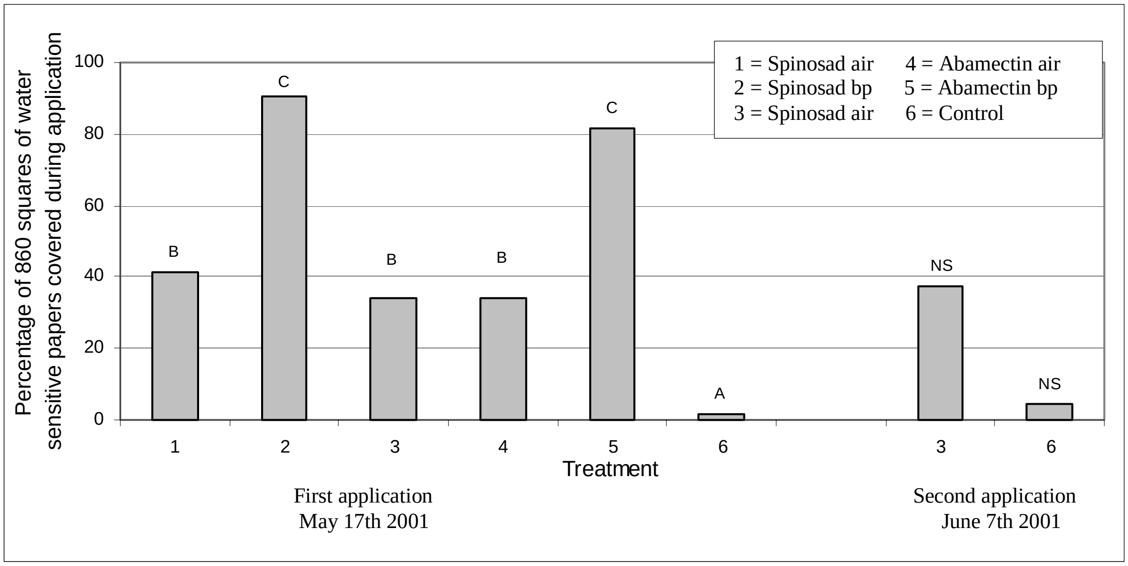
A 7 years old Hass grove, was split into18 plots, 12 ×3 trees in size. Trees were 15ft tall, 21ft apart within a row, 18ft between rows. Six count trees were marked in the middle of each plot. Three replicates of five treatments and one control were randomly assigned following a thrips pre-count; (1) 10oz spinosad (Success) by helicopter (air) per acre, (2) 10oz spinosad by backpack (bp), (3) 10oz spinosad by air followed by an identical application 21 days later, (4) 20oz abamectin by air, (5) 20oz abamectin by backpack (bp), (6) control (no application). All applications included 1% NR415 oil. Pacific Stihl backpack sprayers and a Bell 206B3 Jet Ranger helicopter were used to apply the materials in 50 gpa.

On each tree 10 younger leaves (at a height of 4-6ft) were sampled weekly and the numbers of immature (1st and 2nd larval instars) and adult avocado thrips per leaf were recorded together with the number of natural enemies (including all life-stages of predatory thrips, predatory mites, lacewings, ladybugs, small spiders and other general predators, not including parasitoids) encountered.

Just prior to application four water sensitive papers for monitoring spray distribution (Ciba-Geigy) were placed in tree 1 and 6 (extreme ends of 6 trees marked for observations) of each plot, one paper per quadrant, attached to the underside of leaves at a height of 4-6ft. Papers were removed when dry (1-2hrs after application). Spray coverage was assessed by counting the number of squares covered with droplets in an 860 squares transparent grid. Spray coverage of the different treatments was analysed using ANOVA and LSD ($P>0.05$). For convenience, the results are expressed as percentages hereafter. Treatment effects on number of immatures and natural enemies per leaf were analysed as described for the Ventura pre-bloom trial above. Data on adult avocado thrips (not presented here) is available on request.

Spray coverage during the first application was significantly lower in control than in sprayed plots, with coverage averaging 86% in backpack application compared to 36% in aerial application and 2% in control (Fig.5).

Figure 5. Percentage spray coverage recorded during helicopter (air) and backpack (bp) applications in abamectin and spinosad trials during fruit set in Ventura, CA, May 17 and June 7, 2001 (8 papers per replicate, 3 replicates per treatment, ANOVA: df=5, P<0.00001, different letters indicating significant differences (LSD, P<0.05), control 2nd application 6 papers per replicate, 2 replicates, NS = no statistics justified).



Two percent coverage observed in control plots are likely to be dew deposits present on all counts. Water sensitive papers were placed at 4-6ft high, where leaf counts were also conducted to allow for comparisons. However, this is likely to have under-recorded the cover of air application throughout the canopy. During the second application several cards in the control plots were lost (blown away) and remaining numbers were too low to justify statistical analyses.

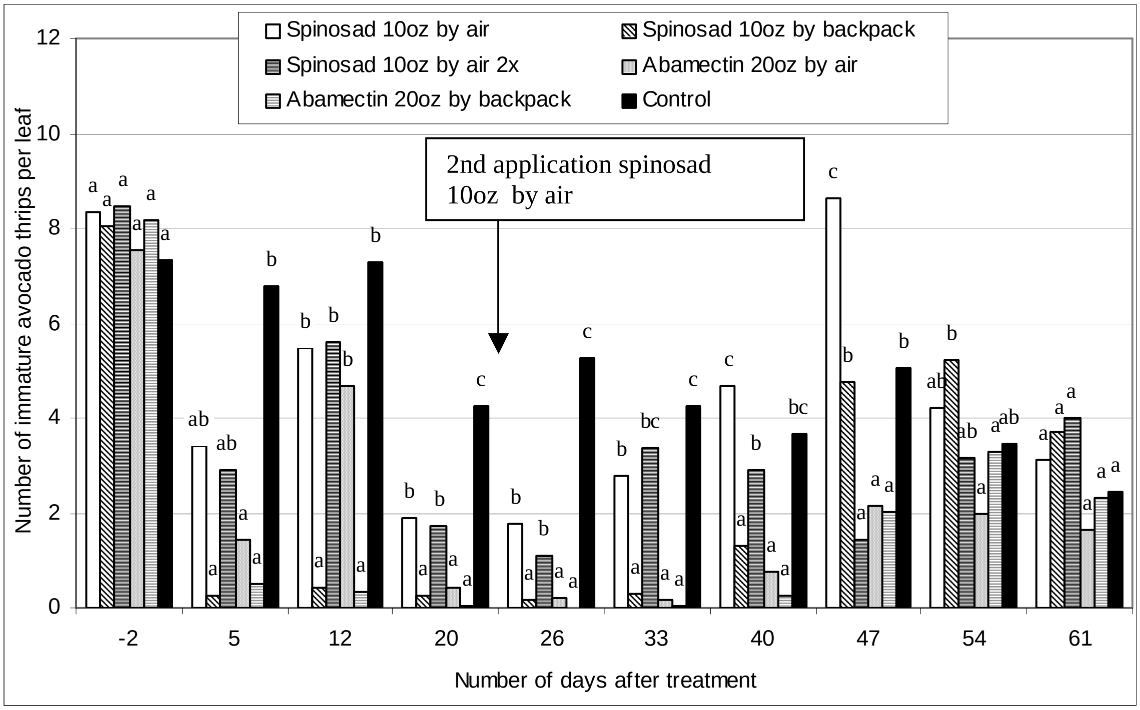
The mean number of immatures per treatment is presented in Fig. 6. The abamectin backpack showed a significantly larger reduction in number of immature thrips than the aerial application during the first 12 DAT. This effect disappeared at 20 DAT. Both treatments significantly reduced the immature thrips numbers until 61 DAT. A similar significant increase in early control of immature numbers was recorded in the spinosad backpack application compared to the aerial application. The high spray coverage of the backpack treatment in the surveyed region of the tree (at heights between 4-6ft) may be responsible for the quick suppression of immature thrips numbers. As sprays do not kill eggs, those present in the leaves still produce larvae that need to ingest the insecticide in order to be controlled. The high coverage achieved with backpack application (86%, Fig. 5) of these two non systemic insecticides increases the chance of newly hatched larvae ingesting insecticide, while the lower spray coverage achieved by aerial application (36%, Fig. 5) requires that larvae be more active to encounter and ingest either insecticide. Eventually both application techniques suppressed larval numbers significantly from the control (20 DAT, Fig. 6).

The single application of spinosad by helicopter showed a significant resurgence in number of immature thrips, exceeding the control at 47 DAT (Fig. 6). Applying spinosad a second time resulted in a significant increase in control of immature thrips compared with a single application 40 DAT and compared with backpack application 47 DAT. At 54 DAT the number of immature thrips per leaf in all spinosad applications were no different from the control. A reason for the resurge of numbers after a single application is not known. If a second application is not planned, a helicopter application would only control immature thrips numbers for a short (2 week) period.

With aerial application, abamectin gave a significantly greater reduction of immature thrips numbers than spinosad. Using the backpack sprayers both insecticides performed equally well. The abamectin aerial application gave more complete and consistent suppression than any of the other treatments. With a second application, spinosad significantly reduced numbers of immature thrips to levels matching abamectin treatments (47 DAT equals 26 days after 2nd application), although numbers increased to 3.4 immatures per leaf between the two spinosad applications.

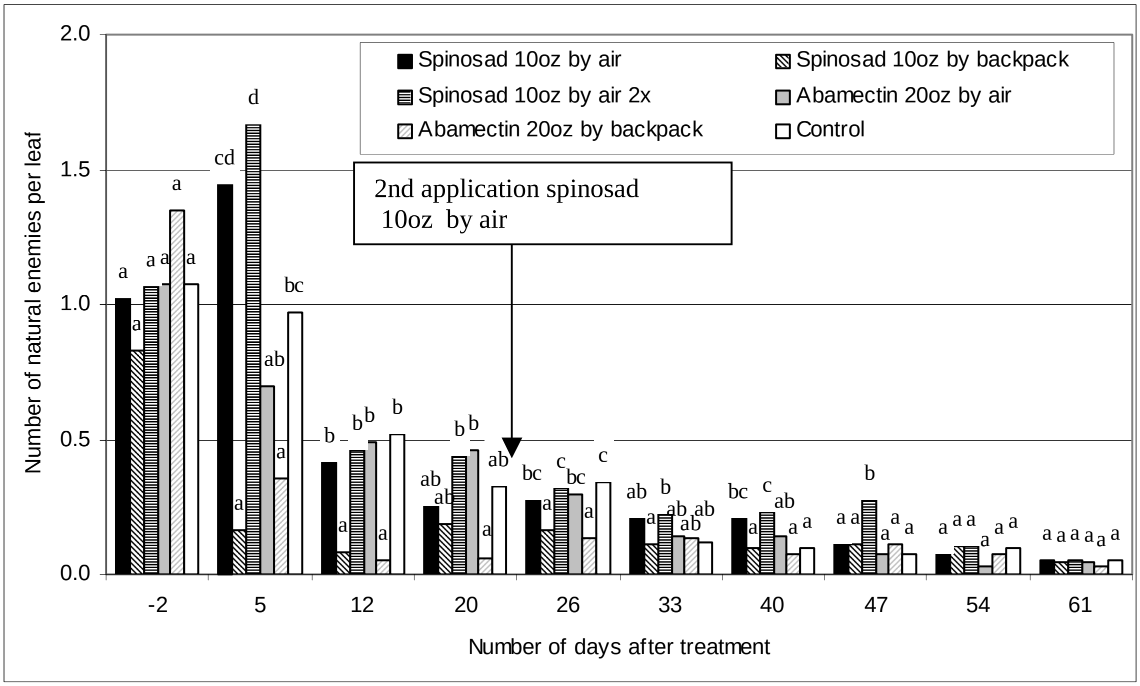
The effects of treatments on numbers of natural enemies are presented in Fig. 7. In the surveyed area of the tree, aerial applications of either insecticide had no significant effect on natural enemies. However, backpack application of abamectin and spinosad significantly reduced the number of natural enemies. This effect lasted 26 DAT for both abamectin and spinosad. In plots treated with double spinosad application by air, the natural enemy numbers were significantly higher than any of the other treatments at 47 DAT. These effects suggest that (in the surveyed area of the tree) the backpack spray either blows the natural enemies from their positions or numbers decrease rapidly in absence of prey (avocado thrips).

Figure 6. Mean number of immature avocado thrips per leaf from Spinosad (Success) and Abamectin (AgriMek) trials in Ventura, CA, May 15-July 17, 2001 (60 leaves per replicate, three replicates per treatment; air = helicopter application, volumes in oz per acre, ANOVA and LSD multiple comparisons analyses (*P*>0.05), different letters per date indicate significant differences).



Our preliminary conclusions from this trial are that backpack applications give faster avocado thrips control at heights between 4-6ft than aerial applications, which probably relates to higher levels of spray coverage. The significant effect of backpack application on natural enemies, although short lived, may be something to consider when the grove hosts large numbers of natural enemies. On smaller trees, backpack application will be a valuable alternative to aerial application. Assessment of backpack application effects on thrips and natural enemies at greater heights are needed to fully understand the extent of these effects. Abamectin can reduce thrips numbers for a period up to 49 days, a longer and more effective performance than spinosad. An alternative to abamectin application could be a double spinosad spray, although numbers were shown to resurge significantly between applications when applications are 21 days apart. Assessment of a shorter period between spinosad applications may be needed. This study is continuing with initial fruit scarring analyses to be assessed in the near future and final scarring analyses planned around harvest 2002.

Figure 7. Mean number of natural enemies per leaf from Spinosad (Success) **and Abamectin** (AgriMek) **trials in Ventura, CA, May 15-July 17,** 2001 (including all life-stages of predatory thrips, predatory mites, lacewings, ladybugs, small spiders and other general predators, not including parasitoids, 60 leaves per replicate, three replicates per treatment; air = helicopter application, volumes in oz per acre).



2nd application spinosad 10oz by air

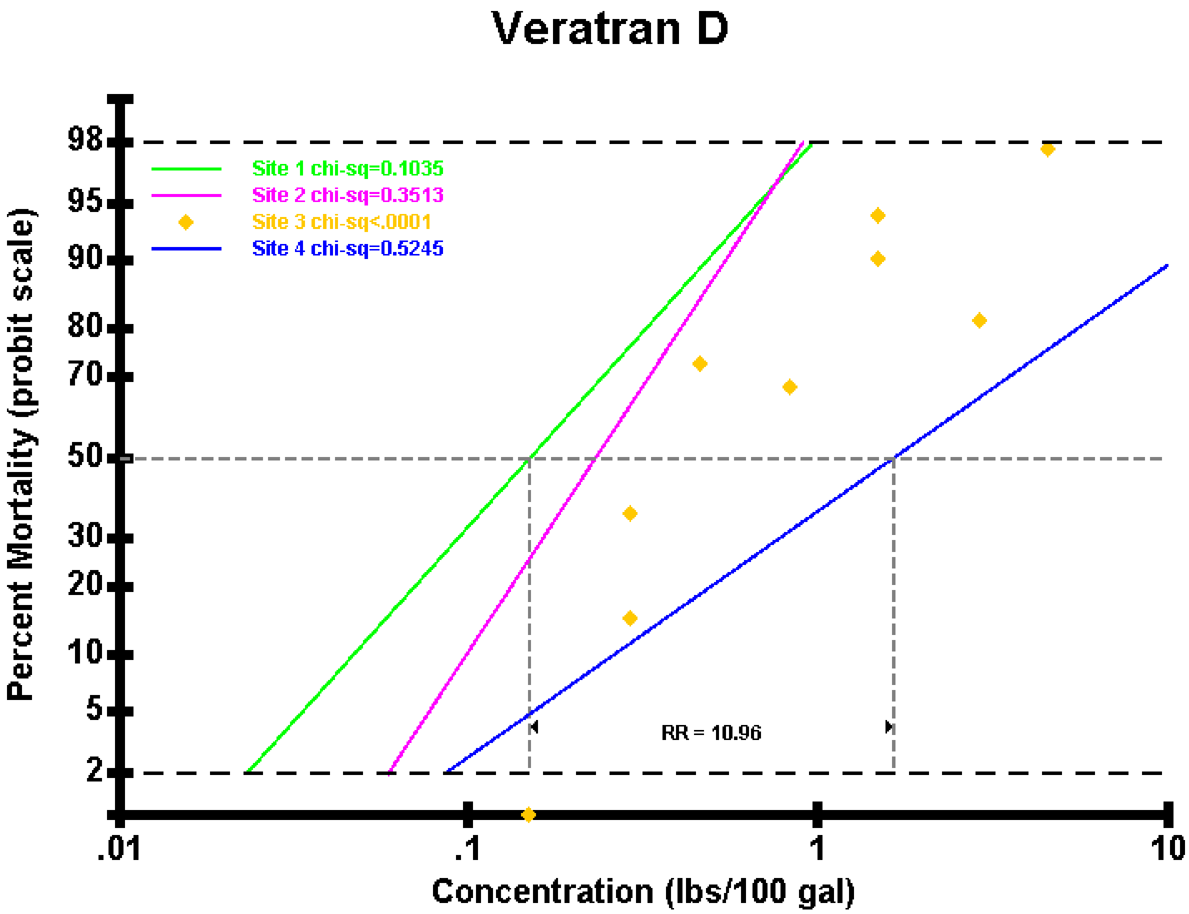
Baseline Pesticide Resistance Monitoring Studies with Avocado Thrips (Research by Morse, Urena, and Watkins)

Research on other economic thrips species, e.g., citrus thrips, indicates that thrips generally have the ability to develop resistance to pesticides that are used repeatedly for control (Morse and Brawner 1986, Immaraju et al. 1989a, b, Khan et al. 1998). For this reason, we initiated studies to determine the baseline susceptibility of avocado thrips to abamectin, sabadilla, and spinosad on populations of thrips that had minimal previous exposure to these materials. Using these data, any future cases of suspected resistance can be evaluated to determine if the cause of questionable control is in fact resistance or might be due to other causes (high thrips population pressure, less than optimal timing of treatment, poor spray coverage, etc.). In addition, we have evaluated several groves in which multiple applications of sabadilla were applied to see if sabadilla resistance was present.

A number of preliminary trials were run to develop a laboratory method of reliably monitoring for avocado thrips resistance. The method we settled on involves treating young but fully expanded avocado leaves with various rates of the test pesticide, allowing the spray to dry, then placing second instar avocado thrips on the leaves, and determining mortality of the thrips after 48 (sabadilla and spinosad) or 72 (abamectin) hours. The longer bioassay period for abamectin is needed because this material is relatively slow in killing the thrips and even after 72 hours, thrips mortality must be assessed with care. We describe below results only with sabadilla as data from additional groves will be needed before we are ready to publish results with abamectin and spinosad.

Fig. 8 presents results of avocado thrips tests with sabadilla at 4 avocado groves with different past treatment histories. The Grove 1 bioassay was done 26 January 2000 at a site in San Diego Co. with no previous exposure to sabadilla. The Grove 2 bioassay was done 13 March 2000 at a site in Orange Co. with limited past exposure to sabadilla (the grove of young trees bioassayed had no past treatments of sabadilla but nearby groves had been treated about once a year with sabadilla). The Grove 3 bioassay was done 26 August 1999 at a site in Ventura Co. with 10 past treatments of sabadilla over the period July 1996 to June 1999 (2, 5, 3, and 1 treatments in each of the 4 years 1996 to 1999 before the bioassay, respectively). The Grove 4 bioassay was done 19 August 1999 at a second site in Ventura Co. with 6 past treatments of sabadilla over the period April 1997 to July 1998 (3 treatments each year prior to the bioassay).

Figure 8. Resistance Bioassay Data with Avocado Thrips and Sabadilla.



Note that the data in Fig. 8 are plotted as lines (raw data are not shown) for Groves 1, 2, and 4 but as raw data points for Grove 3. With Grove 3, a statistically valid line (i.e. a relationship between thrips mortality as plotted on a probit scale versus $\log_{10}$ of the sabadilla concentration) was not obtained – this lack of a linear regression relationship during the early stages of resistance development is not uncommon. We consider the data from Grove 1 to be a good indication of the baseline susceptibility of avocado thrips to sabadilla (additional data will be gathered to confirm this). Using this baseline, the resistance ratio of Grove 4 at the LC_{50} (at the concentration of sabadilla required to result in 50% mortality of thrips based on bioassay results) was 10.96, i.e. an 11-fold higher concentration would be required to kill 50% of the thrips at Grove 4 versus Grove 1. Note that results of this laboratory bioassay should be extrapolated to expected field control with caution (i.e. because of the difference between field treatments and laboratory bioassays, one should not expect thrips mortality in the field at a specific sabadilla concentration to correlate with bioassay results indicated in Fig. 8).

Thus, it is clear that avocado thrips has the ability to develop resistance to sabadilla. Tests are currently underway to determine if this resistance is stable or whether it might revert to baseline susceptibility levels after sabadilla treatments are discontinued (growers at Groves 3 and 4 have been alerted to the development of resistance and have switched to using other materials). Our conclusion from these data is that repeated treatments of sabadilla (or any one chemical) should be avoided if at all possible. Resistance is even more of a concern with abamectin because this material is much more persistent than either sabadilla or spinosad. To date, no one has reported field failures related to resistance development with either abamectin or spinosad. We suggest that growers rotate between available pesticides and because abamectin and spinosad have similar chemistries, try to avoid more than two treatments of either of these two pesticides within a season.

Winter 2001 Powered Backpack Sprayer Trial (Research by Phillips and Faber)

Small growers can have problems applying materials by helicopter because of proximity to non-agricultural parcels. Applying materials by powered backpack sprayer is possible, but tree height may limit efficacy of application. Identifying the height limits of this application technology was the goal of this study.

Initially, the Stihl sprayer was calibrated to determine the effect of different nozzle settings on the sprayer's performance. Cards were placed at 15, 20, 25 and 30 feet onto a telescoping mast. The mast was erected and during a calm morning, the mast was sprayed at a position 10 feet from the base of the mast. The Stihl spray wand was aimed at each successive height on the mast and sprayed at one of the 5 volume control settings. The mast was taken down and the cards removed. New cards were then attached, the mast returned to the vertical and sprayed at a new setting. This process was repeated for each of the 5 settings.

As tree size changes, the angle and pattern of application will change. This is partly because the operator needs to stand in a different position relative to the foliage to be sprayed when spraying a small versus a large tree. This changing application pattern makes it difficult to interpolate from a large tree trial, what would be the maximum tree size for effective spray coverage with a powered sprayer.

In this trial, 4 tree sizes were evaluated (10, 20, 25 and 30 feet) and replicated 3 times. Spray cards were attached to the undersides of leaves on the outside canopy at 5-foot height increments in each of the 4 quadrants of the tree. For the 10 foot trees this meant 8 cards per tree times 3 trees or 24 cards. For the 20 foot trees there were 16 cards per tree times 3 trees or 48 cards. A nozzle setting of "3" was used in this trial, allowing sufficient water volume flow into the air stream to provide coverage without significant run off or wastage.

A man-lift was used to attach the cards at the taller heights. The different tree sizes were in proximity to each other and their heights were determined using a clinometer.

Cards were attached mid-morning after dew had dried. Trees were sprayed as soon as all cards had been attached and before late morning breezes came up. Trees were sprayed to coverage with water using a Stihl powered backpack sprayer, not exceeding 1.25 gallons of material per tree (assuming the minimum label rate of 50 gallons per acre at 20 oz. abamectin). This volume is something that is reasonable to expect for a grower to carry around on the back, as well, if they had something like 50 trees.

The spray cards were collected just after spraying and placed in plastic bags segregated according to tree and position. Percent spray card coverage for each card was determined in the lab using a grided template.

Spray coverage on trees 20, 25 and 30 feet tall was nearly 100% on cards placed at 5 and 10 foot heights in the canopy (Fig. 9). On 10 foot trees, coverage was less than 100% at 5 and 10 foot heights because the canopies were so dense. On 20 and 25 foot trees, coverage at 15 feet approached 80%. On 30 foot trees, coverage was less than 20% at 15 feet. On 20, 25, and 30 foot trees coverage at 20 foot heights was less than 20%. On 30 foot trees, coverage was less than 10% at 20, 25 and 30 foot heights. Poor coverage on these larger trees was due to the need to stand further away or to stand within the canopy to get coverage.

During the initial calibration study when evaluating spray coverage with different volume settings (1-5), at no setting were cards wetted at 30 feet (Fig. 10). At the 20 foot height, all 5 settings reached the spray cards. In the case of settings 4 and 5 (highest volumes), the cards were blue, and at settings 2 and 3, there was an acceptable spray pattern. At setting 1 (lowest volume), the mist was so fine that coverage was unacceptable above 15 feet.

Using the Stihl backpack sprayer in an ideal situation, a 20 foot height is attainable if there is a clear unobstructed target when the operator is standing 10 feet from the vertical and there is no wind. The longer the operator stands aiming the wand at a given point in the canopy, the greater the likelihood that 20 feet is attainable. The volume of material used at the 4 and 5 settings is unrealistic to expect a grower to use, as refilling the sprayer tank would be almost continuous. At 15 feet, setting 1 gave acceptable coverage, but settings 2 or 3 are best used if 20 foot height is to be attained.

Figure 9. Spray coverage on four different sized trees (10, 20, 25 and 30 feet tall; Standard deviation bars are for means of 3 replications at four cardinal positions in the tree).

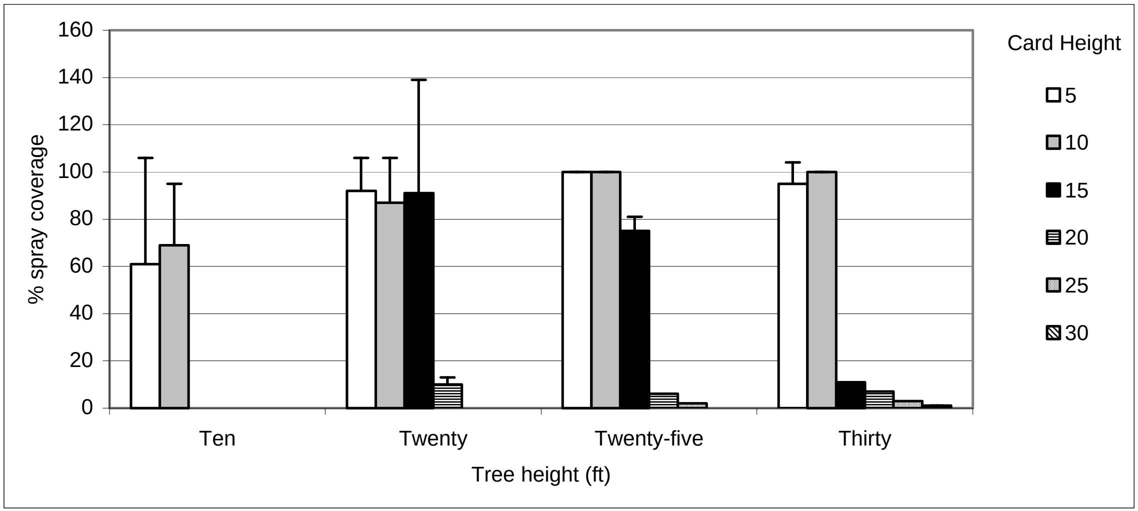
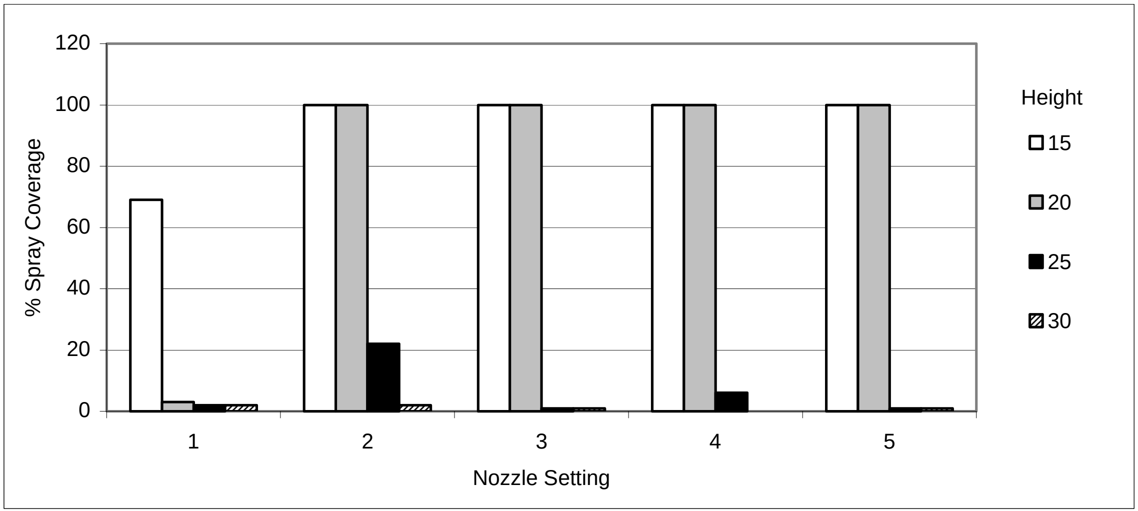


Figure 10. Percent spray coverage at four heights using five different spray volume settings on the Stihl backpack sprayer.



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