

Evaluation of Systemic Chemicals for Avocado Thrips and Avocado Lace Bug Management

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Project Overview

We are evaluating systemic insecticides for the management of current and newly emerging pests of California avocados. Studies are being conducted in commercial avocado groves, under normal agronomic practices. Trees are treated using a variety of techniques – soil application and trunk injection – to establish the methods that will provide the best uptake of insecticide for the protection of the trees. Our primary research focus is on the avocado thrips and the avocado lace bug although this work may have application to control of armored scales if one or more species were to establish in California. Despite its recent introduction, the avocado thrips is already an established pest of avocados in California. The avocado lace bug is a more recent introduction, and has not yet established widely within the avocado growing regions. Current management practices for avocado thrips are centered on the use of foliar insecticides. Several foliar treatments are available (Agri-Mek, Delegate, and Veratran D) for the control of avocado thrips. However, the number of products is limited, the mode of application can be difficult (helicopter use on steep hillsides, applications near urban regions), and there are risks of resistance development, particularly to Agri-Mek due to it also being used against persea mite during the summer. Systemic neonicotinoid insecticides are relatively easy to apply (via established sprinkler irrigation systems or by modern trunk injection systems), and have a mode of action that has not been in use for the management of avocado thrips. A new mode of action would substantially lower the resistance risk associated with Agri-Mek, and alleviate operational difficulties in the use of foliar treatments.

To measure insecticide uptake, we are using two techniques. First, we collect leaves that are attractive to avocado thrips and avocado lace bug for feeding and conduct bioassays by exposing the insects to these leaves for a pre-determined period of time. Leaf punches from these bioassay leaves are also used to quantify the levels of pesticide present within the leaves. In this way, we are able to compare the levels of mortality in our bioassays with the quantity of insecticide that is present in those same leaves. With this information, we can establish effective concentrations for the insecticides, and subsequently evaluate the capacity of different application strategies at achieving these required concentrations. Insecticides that fall short of the activity thresholds will not be recommended for use for control of avocado pests.

We are also testing the fruit for pesticide residues. It is important to growers that their fruit not be contaminated with pesticides as a consequence of any pest management effort. To address these concerns, we have established a residue analysis program in collaboration with Dr. Robert Krieger at UC Riverside.

Trunk Injections

Soil applications of Admire Pro (imidacloprid) and Venom (dinotefuran) are generally ineffective on mature avocado trees. The results of the 2007 trial showed that the residues of insecticide present within the flushing leaf foliage were not at levels that could kill thrips in 72 h Munger cell bioassays. Under such conditions, avocado thrips will not be controlled effectively, and the immature fruit will be under significant threat from thrips damage when they move from the aging foliage. The study trees were estimated to be about 25 years old, and the tree height ranged between 40 and 60 feet. There was a dense layer of leaf litter on the floor of the grove, beneath which lay soil that was high in organic content. This trial site represented the extreme in terms of tree age, height, and soil type, and we concluded that under the prevailing grove conditions, the rate of uptake could not match the rate of leaf growth in the flushing foliage, thereby compromising the impact of the treatments on thrips management. The data for trunk-injected neonicotinoids (imidacloprid and dinotefuran) and the organophosphate (acephate) were more encouraging, and it is this system of application that we focused on during 2008. To meet our objectives, we continued our collaboration with Arborjet, Inc., a company specializing in trunk injections. In the 2007 trial, we showed that their proprietary avermectin (with a similar mode of action to Agri-Mek) was ineffective as a trunk injection material, and so we discontinued work with that chemical.

For our work in 2008, we established an experimental trial at a commercial avocado grove west of Temecula. The trees were Hass on the clonal Toro Canyon rootstock. The trees were very uniform in size and characteristics, and were 8 years old. Trunk diameter measurements were taken to establish a consistent diameter size for the trunk injections. The trunk injection procedures were supervised by Joe Doccola of ArborJet, Inc. In addition to determining the residues of insecticide in leaves (using avocado thrips bioassays and ELISA), we also conducted fruit residue analyses. The trees used for fruit sampling were selected based upon total fruit on the tree at the start of the trial with provisions for significant fruit drop during the trial period.

One of the factors that we identified from the results of the 2007 trial as being highly critical for the success of trunk injections was the timing of the treatments in relation to the Spring flush of leaf growth. In the 2008 trial, we evaluated the uptake of acephate, dinotefuran and imidacloprid when they were injected into trees before (pre-flush), during (mid-flush) and after (post-flush) the major Spring flush. The pre-flush injections were conducted on April 1, when most of the flowering was completed. At this time, there was some evidence of flushing, although it was very sporadic within the grove, and flush leaves were no longer than 1". The mid-flush injections were conducted at 4 weeks (April 29) after the pre-flush injections. At this time, the fruit was now at an immature stage of development and the leaf flush was very advanced with fully expanded leaves on all trees. We chose this timing for the mid-flush injections because we considered this to be the beginning of the most critical period for avocado thrips management in terms of protecting the developing fruit. Our post-flush timing was set at 2 weeks after the mid-flush timing (May 13), and although most trees were still pushing out some new growth, we estimated that the main flush was over. The purpose of injecting at this later stage was to ascertain whether some of the trunk injections might act quickly enough to protect the fruit at a very vulnerable stage in development. The leaves on the trees at this timing were still very supple and ideal for avocado thrips feeding, but with little new growth to keep the thrips on the leaves, there was a greater likelihood of thrips moving to the immature fruit. Even at the end of our study, we determined that the immature fruit would still be vulnerable to thrips damage, although large populations would be needed to have a significant effect on fruit at that stage of development.

Avocado thrips bioassays were conducted to evaluate the acephate treatments, while ELISA was used to evaluate the neonicotinoid treatments. Fruit was sampled from all trees for up to 12 weeks after treatments to test for possible insecticide residues.

Bioassays Were Used To Evaluate The Efficacy of Acephate Treatments

Bioassays were conducted on fully expanded leaves sampled from trees that were treated with acephate (Figure 1). For each of the timings, the uptake of acephate was rapid and provided effective control within 1 week of treatment (when the first bioassays were conducted). The efficacy of the pre-flush treatment (shown in red in Figure 1) declined at week 5 when we switched the age of the bioassay leaves to the newly flushing leaves. The switch was made so that our bioassays included the leaves that would be most attractive to thrips, thereby reflecting conditions in the field. This is an important finding because it indicates that the acephate was distributed among the leaves that were present on the trees at the time of the treatments. If the treatments are made too early, the subsequent flush will not be protected (see weeks 5 and 7 on the pre-flush graph) and the developing fruit will receive little protection from thrips damage. Further evidence for this comes from the results of the injections that were made in trees when the flush was under way (the mid-flush data are shown in green in Figure 1). Although we observed the same degree of persistence in the pre-flush and mid-flush treatments, the mid-flush treatments would be more effective under normal operating conditions within a grove because the acephate was distributed within the leaves that are most attractive to thrips for feeding. Finally, with the post-flush timing (the blue line graph in Figure 1), we observed rapid uptake of acephate and prolonged persistence. Although it appears that the persistence of the treatment at the post-flush stage is greater than in the other two timings, the reason for this is that all of the leaves used in the bioassays from these trees up to week 7 were present on the trees at the time of the injections. When we chose younger leaves for the final bioassay on week 9, the acephate was clearly not present at toxic levels.

We can conclude that trunk injections of acephate at 5.4 g a.i. per tree will provide 3 weeks of effective avocado thrips control in leaves likely to be targeted for feeding by this insect.

Fruit Residue Analyses Showed That The Levels Of Acephate And Methamidophos In The Avocado Fruit Were Very Low

Mature, marketable fruit were collected from treated trees and insecticide residues tested using standard IR-4 protocols. As in 2007, we followed IR-4 protocols because this format will be needed to generate data required for subsequent pesticide registration applications.

Acephate and its primary metabolite, methamidophos, were detected in fruit collected from trees injected with acephate. In Figure 1, we included the residue data, so that they are easier to compare with the efficacy data generated for the avocado thrips in bioassays. Also, we combined the acephate and methamidophos values to generate a composite residue reading.

For each injection timing during the Spring leaf flush, the peak detection levels for acephate and methamidophos insecticides occurred at 2 weeks after the treatments. Thereafter, the residues declined dramatically, with no detectable insecticide at 6 weeks (4 weeks for the post-flush injections). The residue levels were remarkably consistent between timings (0.03 ppm), suggesting that pre-harvest intervals will not be difficult to establish for this product should it become registered for use. Furthermore, despite the smaller tree size (8 years versus 25 years in the previous trial) and the equality of injection rates (5.4 g a.i. per tree) used in the 2008 study, the residues did not surpass those detected in the fruit during the 2007 trial by as much as we expected. In 2007, the highest combined acephate/methamidophos residues measured at 2 weeks after treatment were 0.022 ppm. In both years, the residues were well below established MRLs for other commodities.

Efficacy of Acephate Trunk Injections Against Avocado Thrips

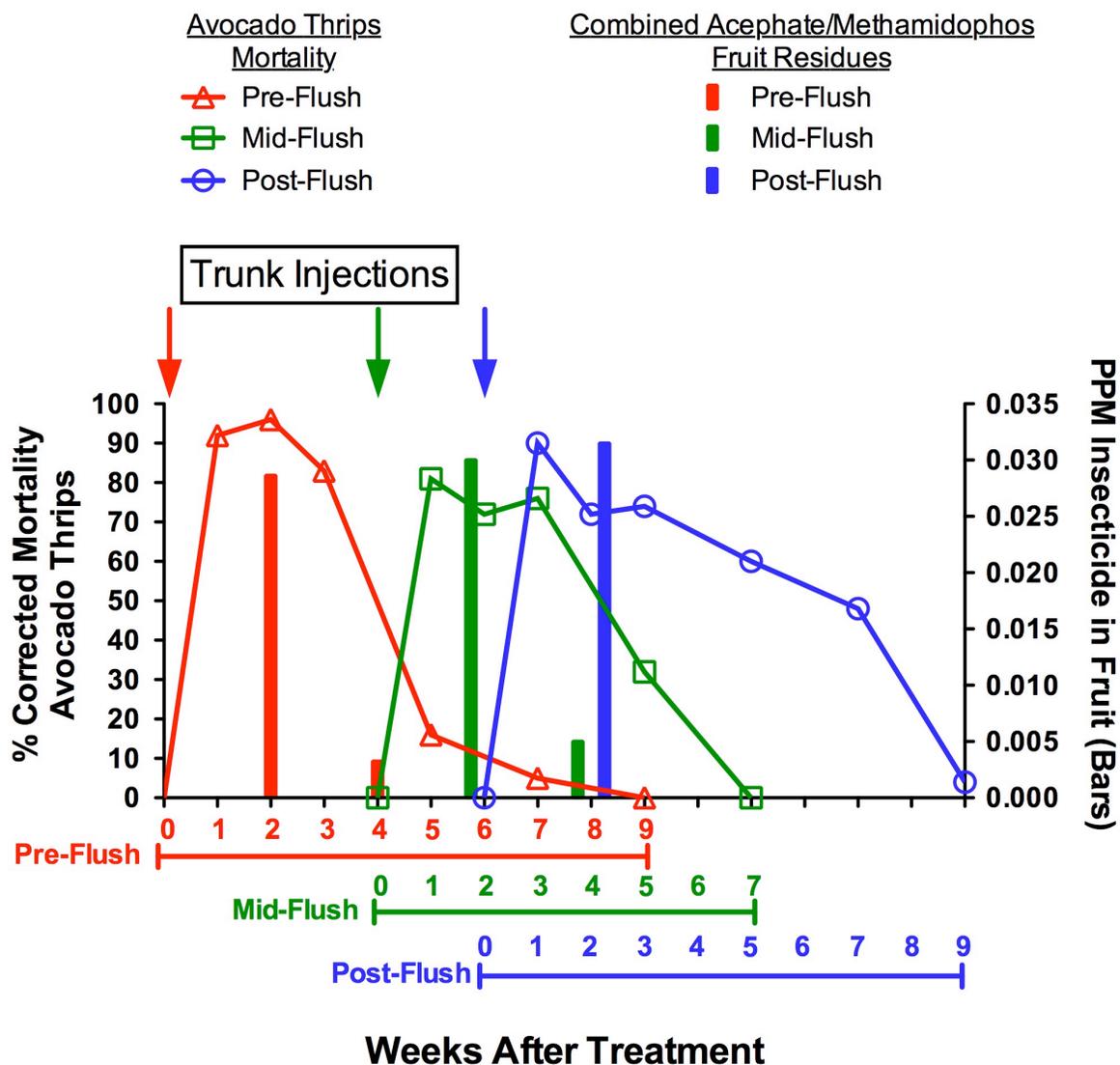


Figure 1. Efficacy of acephate against avocado thrips and residues in fruit. Each point on the colored line graphs represents the mean mortality of avocado thrips after exposure to leaves sampled from trees treated by trunk injection at different timings around the Spring leaf flush. The colored bars represent the mean concentrations of the combined residues of acephate and methamidophos (a metabolite of acephate) in avocado fruit sampled from 4 trees per sampling date. Two sets of 6 fruit were sampled from each tree for 12 weeks after injection (data for weeks 8 and 12 not available yet).

Residues Of Imidacloprid And Dinotefuran Were Quantified In Leaves Using ELISA

The residues of imidacloprid and dinotefuran were measured using commercially available ELISA kits, which utilize insecticide-specific antibodies for quantifying insecticides. We compared the concentrations of both insecticides in leaves sampled from trees treated with 2 rates – 0.6 g a.i per tree and 1.8 g a.i. per tree).

The target threshold concentration of imidacloprid for the management of avocado thrips was set at 100 ng imidacloprid/cm² leaf. Below this concentration, thrips mortality will occur; however, we have observed most consistent mortality when the levels are at least 100 ng. In 2007, when we injected the large trees with 1.8 g a.i. per tree (the 2007 upper injection rate), imidacloprid residues within the leaves never exceeded 60 ng/cm² leaf. Although these concentrations would have provided some control of avocado thrips, the concentrations were not reached until 16 weeks after the trees were injected. The uptake of imidacloprid into trees of this size was better when it was trunk injected than when it was applied through the irrigation system (chemigation); however, trunk-injecting imidacloprid would not provide growers with a rapid response to an insipient thrips outbreak. For younger trees, trunk injection may provide a better option for growers, provided that the timing of injections relative to the Spring flush is carefully managed.

Timing Of Imidacloprid Will Be Critical If Target Thresholds Are To Be Reached

Regardless of the timing of the injection in relation to the Spring leaf flush, the target threshold was not reached when trees were injected at our lowest rate (0.6 g a.i. per tree) (Figure 2). However, in trees injected with this rate at the mid- and post-flush timings, the uptake into the younger foliage still reached levels that would have some impact on an avocado thrips infestation. The problem with these treatments was the delay in reaching the peak concentrations. Concentrations in trees injected at mid-flush peaked at 7 weeks, while those injected post-flush peaked at 5 weeks. A 3-fold increase in the injection rate (1.8 g a.i. per tree) improved the efficacy of imidacloprid treatments at mid-flush and post-flush timings (pre-flush trees were not treated at this concentration), with target thresholds reached in 4 weeks (mid-flush timing) and 5 weeks (post-flush timing), respectively. Because the immature fruit were now developing on the trees, this delay in uptake could have important consequences if avocado thrips move from the young foliage to fruit.

The steady increase in the uptake of imidacloprid is a function of its chemistry. Even when the chemical is injected directly into the trunk, bypassing potential soil absorption problems, the rate of uptake is still slow. In rapidly flushing trees, the rate of leaf growth and maturation may exceed the rate of uptake, an effect that will be accentuated in larger trees. In our study, we have shown that the optimal timing for imidacloprid was at mid-flush when, by our definition, the first fully expanded leaves were establishing on the trees. A 2-week delay in injecting the trees will result in a lower rate of uptake, and lower overall concentrations at peak uptake. It appears that the energy that the tree expends during the Spring leaf flush can be exploited for the trunk injections. This was even more evident from the dinotefuran data.

Imidacloprid Residues In Avocado Leaves Trunk Injection @ Two Rates

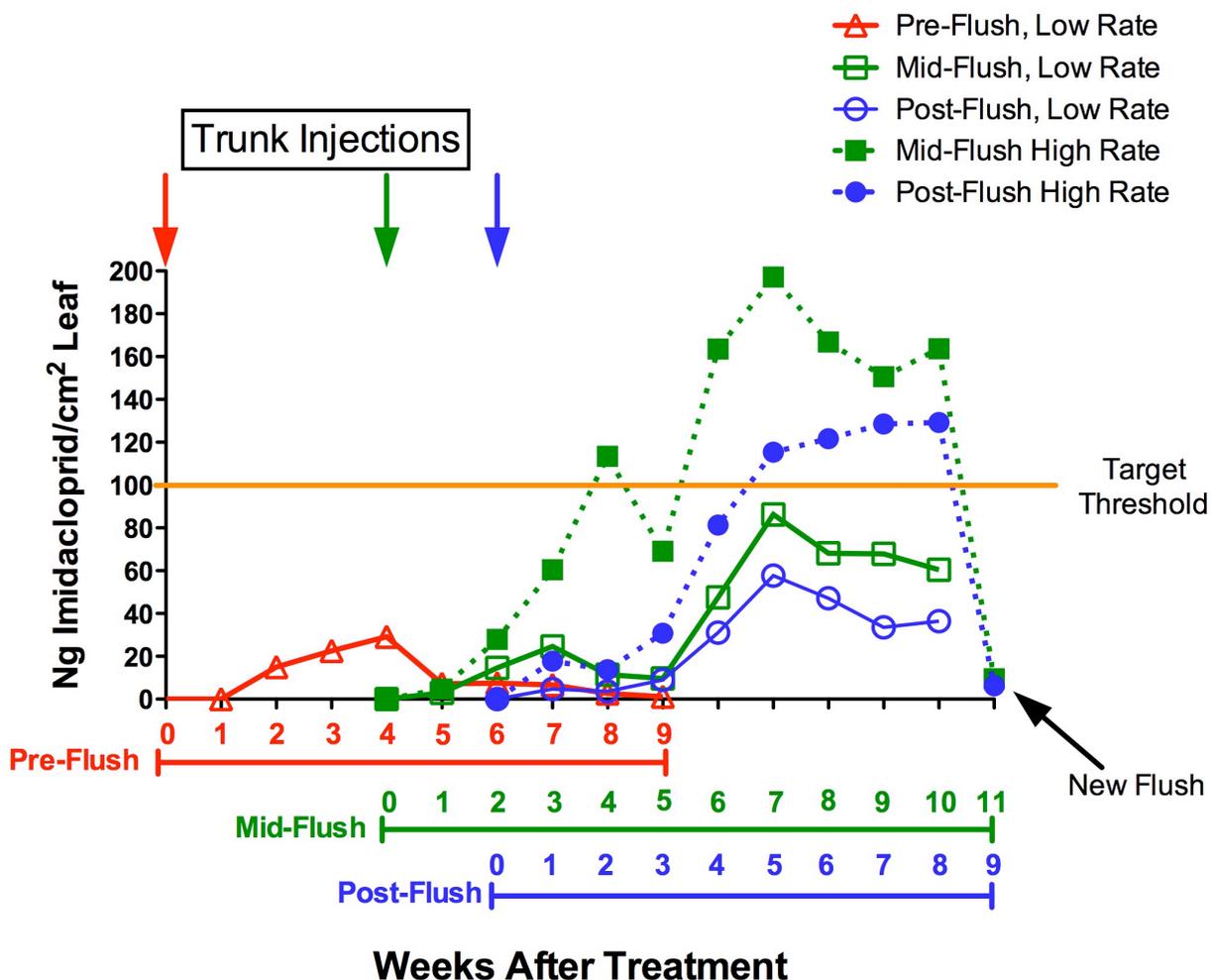


Figure 2. The uptake of imidacloprid injected as IMAjet at two rates and at three timings. The 'Low Rate' was 0.6 g a.i. per tree, the 'High Rate' was 1.8 g a.i. per tree. Each point represents the mean concentration of imidacloprid measured for 6 trees, with 6 leaves sampled per tree. The orange line represents the effective concentration needed to kill avocado thrips.

Physiological Changes In The Tree At The Time Of The Spring Leaf Flush Affected The Uptake Of Dinotefuran

Effective concentrations of dinotefuran for the avocado thrips have not yet been established. However, we have set a minimum concentration of 80 ng dinotefuran/cm² leaf as our tentative target based on our 2007 study (Figure 3). At this concentration, there was about 40% mortality of avocado thrips in bioassays. Clearly, higher concentrations will be necessary in leaves if effective management of the avocado thrips is to be achieved.

Efficacy of Dinotefuran Trunk Injections Against Avocado Thrips

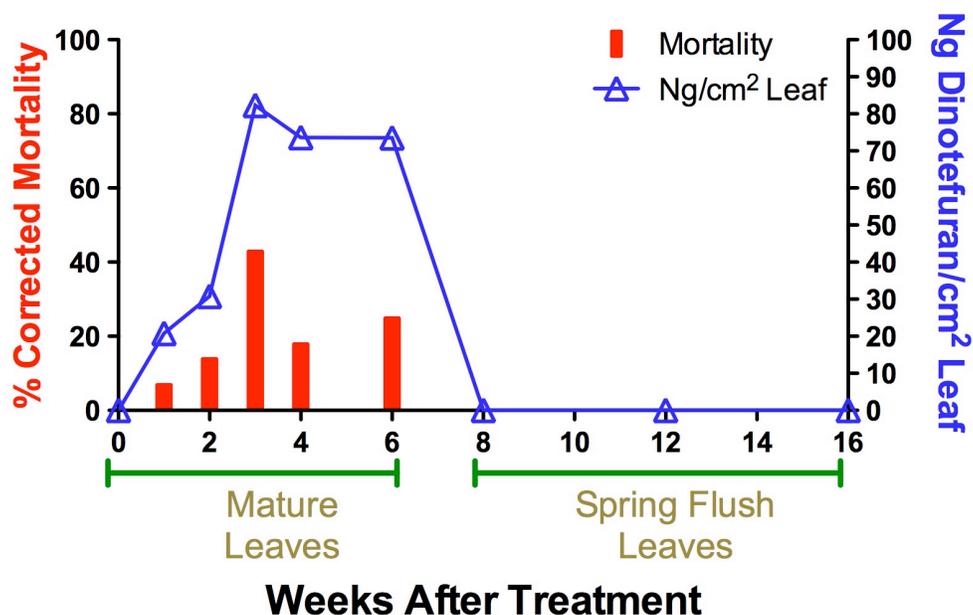


Figure 3. Uptake of dinotefuran trunk injected into large avocado trees during the 2007 trial. The efficacy of dinotefuran residues against avocado thrips was measured by bioassay. Each point on the colored line graph represents the mean concentration of dinotefuran in the bioassay leaves. The colored bars represent the mean mortality scored at 48 hours after exposure of the avocado thrips to the treated leaves. Mortality was only observed in the mature leaves sampled from the trees, indicating that the insecticide was distributed among the leaves present on the trees at the time of the injections, and had been depleted by the time the Spring leaf flush began.

All injections of dinotefuran (at the 3 timings and 2 rates) resulted in concentrations of dinotefuran that exceeded the 80 ng/cm² leaf target threshold (Figure 4). At the lower rate of injection (0.6 g a.i. per tree), optimal timing was at pre-flush. For the first 2 weeks after the pre-flush injection, there was surprisingly little dinotefuran present in the leaves. However, with the onset of the flush (from week 3 onwards), there was a dramatic surge in uptake. At week 5, when we switched to fully expanded younger leaves (to better compare the pre- and mid-flush injection timings), there was little dinotefuran present within the leaves. It appears that the dinotefuran was distributed among the leaves that were present on the trees at the time of the treatments, corroborating the results of the acephate study.

In contrast to imidacloprid, the uptake of dinotefuran injected at mid-flush was rapid (Figure 4). After an initial spike in leaf concentrations, however, the uptake of dinotefuran then became more moderate. Significantly, however, the concentrations present in the leaves remained above our lower critical threshold.

Our results suggest that dinotefuran will be suitable for trunk injection at the beginning of flush when there is extensive nutrient flux to developing leaves. The slow uptake of dinotefuran in trees injected 4 weeks prior to the onset of the leaf flush may be due to the energy resources of the tree being expended on flowering and fruit set. Support for this hypothesis comes from the acephate fruit residue data, which showed high levels of acephate in the fruit prior to the onset of the leaf flush. With the onset of the leaf flush, xylem reserves of insecticide were then shunted to the developing leaves.

This was evident from the spikes in dinotefuran uptake observed 3 weeks after the pre-flush injection (when the major flush was occurring) and at the onset of the mid-flush injection.

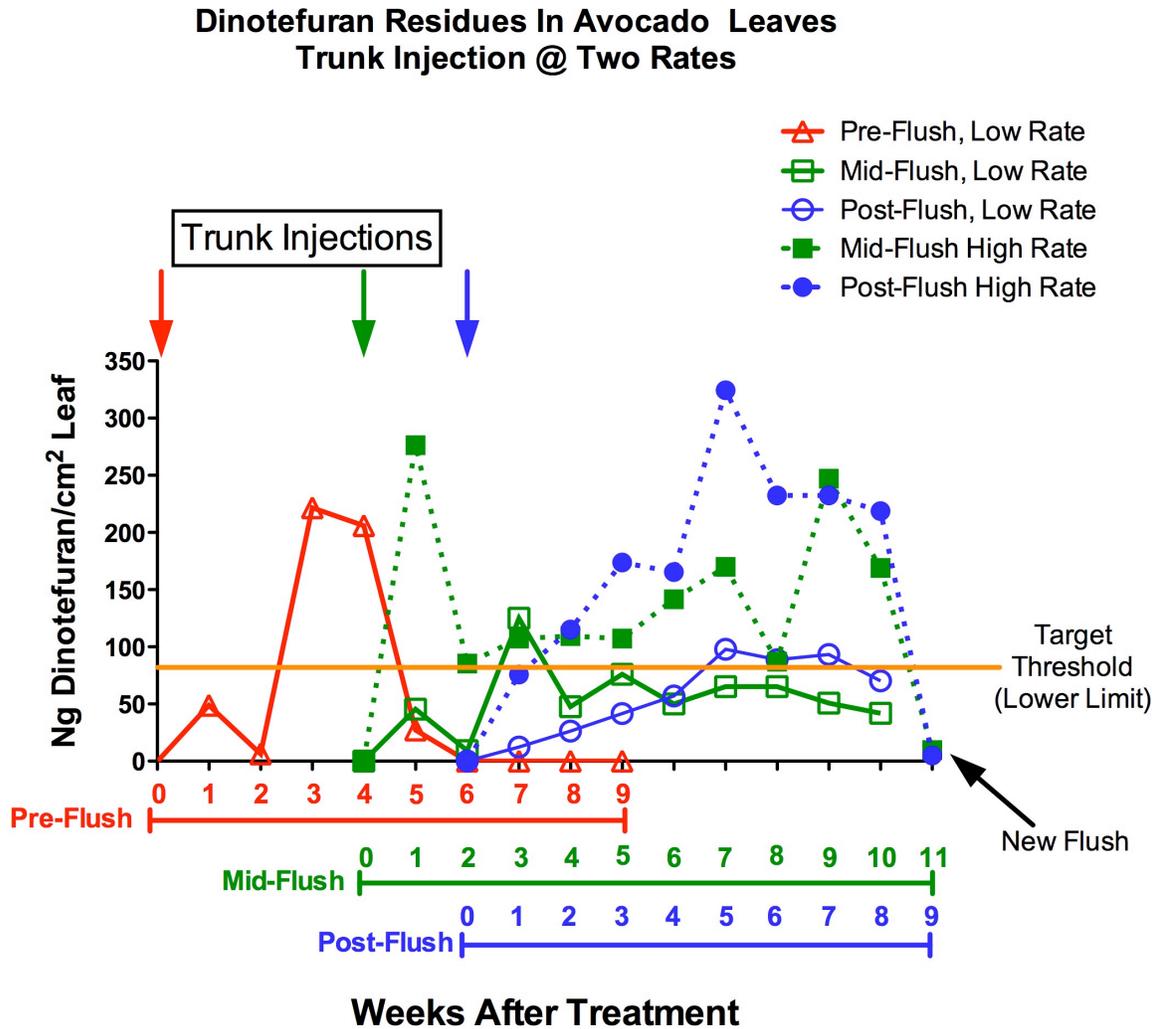


Figure 4. The uptake of dinotefuran injected at two rates and at three timings. The 'Low Rate' was 0.6 g a.i. per tree, the 'High Rate' was 1.8 g a.i. per tree. Each point represents the mean concentration of dinotefuran measured for 6 trees, with 6 leaves sampled per tree. The orange line represents a concentration of dinotefuran needed to kill 40% of avocado thrips in bioassays. The final effective concentration for avocado thrips has not yet been established, but will be higher than this value.

No Residues Of Imidacloprid Were Detected Within The Fruit

Despite using the same injection rates as last year, there were no detectable levels of imidacloprid in the fruit sampled for 12 weeks after treatments. This is extremely encouraging for our study. In order to achieve acceptable rates of uptake for imidacloprid, higher injection rates will need to be evaluated. We can proceed with this objective knowing that we are not likely to compromise the fruit. When acephate was injected at a 3-fold higher rate than both imidacloprid and dinotefuran, the residues in the fruit were relatively low and short-lived. Because imidacloprid is less water-soluble than acephate, the likelihood of contaminating the fruit will be lower if similar injection rates are used.

Dinotefuran Residues Were Detected In The Fruit From One Tree

Injecting dinotefuran at higher rates will require closer scrutiny because of its high water solubility. We detected 0.1 ppm dinotefuran in fruit sampled at Week 12 from a tree that was injected at the Mid-flush timing. Although this was the only positive detection of dinotefuran in the 12 week fruit sampling program, it serves notice of the need for continued monitoring of residues within the fruit. The data suggest that, for trees of this size, the 1.8 g a.i. per tree may be the threshold injection concentration above which residues will occur within the fruit.

Benefits of the Research to the Industry

The payoff for the avocado industry for supporting this research will be a thorough evaluation of systemic insecticides for the management of important avocado pests. While we have already established from bioassays that acephate, dinotefuran and imidacloprid are inherently toxic to avocado thrips, the mode and timing of application will be the key element that ensures proper delivery and optimized performance. Upon completion of this research, the industry will know what chemicals will work for them, and how they need to be applied. The neonicotinoids will be a valuable addition to the arsenal of chemicals available to growers, and because they are a new mode of action for avocado thrips control, they will lessen the resistance risk faced by other products currently in use. We do not anticipate that every chemical we evaluate will work for the industry. We have already eliminated one product from our study (the proprietary avermectin developed by Arborjet). Our ultimate goal is to present to the growers practical solutions to their pest problems, and guidelines for improved pest management in a climate of increasing pest pressure. In addition to hoping we can add to the arsenal of chemistries available for avocado thrips control, the neonicotinoid insecticides (either as soil- or trunk-applied materials) show good efficacy against avocado lace bug should it spread outside the current containment area. Also, one of the unregistered neonicotinoids shows promise in control of armored scale insects, should one of the species present on avocados imported from Mexico establish in California.

Achievements and Future Prospects

- Acephate, dinotefuran and imidacloprid are ideal trunk injection candidates for the management of insect pests on avocado. One of the major achievements of this project has been the establishment of the optimal timing of the injections.
- We have completed a second round of residue analyses for fruit. The results are again encouraging, and suggest that pre-harvest intervals (PHI) need not be excessive for these insecticides. Imidacloprid was not detected in any fruit samples, whereas dinotefuran was detected in one sample. Although acephate was detected, its peak residues occurred at 2 weeks after treatment, with extremely low levels detected thereafter.
- Acephate showed promise as a trunk injection. Bioassay data confirm that acephate is rapidly taken up into leaves following injection, and has a long residual activity against both avocado thrips and avocado lace bug.
- There are new objectives that will need to be addressed if trunk injections are to be a viable option for growers. One of our major objectives will be to determine a suitable injection rate for imidacloprid, because its current rate of uptake is too slow to provide a rapid response to an insipient outbreak of avocado thrips. Adjusting the rate will not increase the speed of uptake but it will shorten the lag time between injection and when effective concentrations are reached.

- Many growers are already familiar with the trunk injection method for treating avocado trees with phosphorous acid fertilizers, suggesting that the adoption of this technology for injecting systemic pesticides would be a relatively smooth transition for growers. It would be especially appealing to the industry if the phosphorous acid and systemic pesticides could be injected using the same injection ports because this would minimize tree damage, labor and reduce the cost of injection site plugs. A major objective of our work will now focus on evaluating the compatibility of phosphorous acid use and trunk injection of insecticides.

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