Evaluation of Systemic Chemicals for the Management of Avocado Pests

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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, trunk injection and trunk painting – to establish the methods that will provide the best uptake of insecticide for the protection of the trees. Our primary research focus has been on the avocado thrips and the avocado lace bug although this work may be very relevant to the 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; Danitol in the near future) 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.

Soil Treatments

Conventional drench applications of Admire Pro (imidacloprid) and Venom 70 SG (dinotefuran) were applied to the soil for uptake through the root system. In the 2009 trial, we evaluated two application rates for each product. Admire Pro was applied at 14 fl oz/acre (the recommended label rate for avocados) and 28 fl oz/acre (2x label rate). Venom was applied at 6 oz/acre and 12 oz/acre, the latter rate being the maximum allowable amount of active ingredient (a.i.) supported by agriculture labels (no label is currently available for avocados). The amounts of a.i. applied per tree for each product are summarized in Table 1.

Table 1. Concentrations of active ingredients applied to avocado trees during the 2009 trial

Product	**Active Ingredient (a.i.)**	**Application Rate**	**Grams a.i./tree**
Admire Pro	Imidacloprid	14 fl oz/acre (max label rate)	1.9
		28 fl oz/acre	3.8
Venom 70 SG	Dinotefuran	6 oz/acre	1
		12 oz/acre (max label rate)	2

Neither product proved effective when applied as a soil treatment at maximum use rates (Figure 1). Based upon our most recent bioassay analyses for imidacloprid and dinotefuran, the concentrations of insecticide present within the leaves would not provide effective control of avocado thrips. The LC$_{50}$s for imidacloprid and dinotefuran against the avocado thrips were 73 ng/cm^2 leaf and 545 ng/cm^2 leaf, respectively. Neither level was reached in any tree. Imidacloprid levels did reach 30 ng in some trees and these concentrations would have some effect on thrips populations. However, these concentrations were only reached at 10 weeks after treatment, an unrealistic time delay if avocado thrips are already infesting the trees at the time of application.

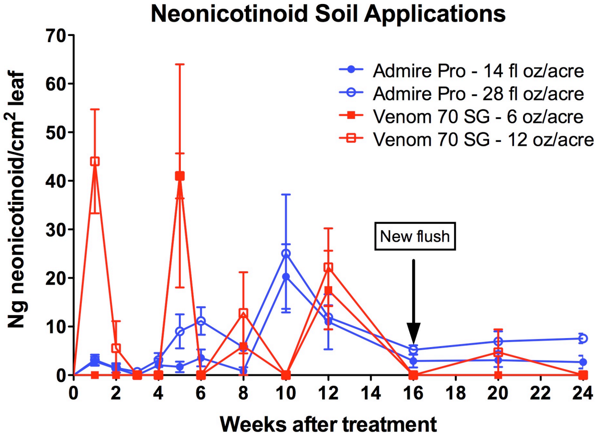

Figure 1. Uptake of imidacloprid (Admire Pro) and dinotefuran (Venom 70 SG) applied as soil drenches. Two rates of each insecticide were applied during irrigation. Each point represents the mean concentration (+/- SEM) of insecticide in leaves sampled from six trees for each treatment.

This result confirms our earlier work that showed very poor uptake of either imidacloprid or dinotefuran when applied as soil treatments. Furthermore, we can now confirm that raising the level of imidacloprid above the current maximum label rate would not provide any benefit in terms of increasing uptake to levels required for effective thrips control. Given that imidacloprid (0.5 g/liter) and dinotefuran (40 g/liter) represent the extremes in terms of neonicotinoid solubility in water, we conclude that this mode of application is not effective for use in avocado groves to control avocado thrips populations.

We have now run a series of field trials replicated on different soil types, tree sizes and age. For avocado thrips, soil treatments were only effective on young trees that were not much older than 5 years. In trees that were older than this, we have shown 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 would not be controlled effectively, and the immature fruit would be under significant threat from thrips damage when they moved from the aging foliage. The general conclusion has been 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. We believe that the main problem with soil treatments in avocado groves is linked to the leaf litter and organic rich soil, which combine to retard the movement of insecticide into the trees. By eliminating the soil component from the uptake, trunk injections have dramatically improved our capability of establishing effective concentrations of insecticide within the trees.

Trunk Injections

The residues of imidacloprid and dinotefuran in leaves 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 of imidacloprid – 1.8 g and 3.6 g a.i. per tree - and 3 rates of dinotefuran - 1.8 g, 3.6 g and 5.4 g a.i. per tree. In addition to the 10% experimental formulation of dinotefuran (1.8 g and 3.6 g rates), we also evaluated an additional experimental formulation of 22.5% dinotefuran (1.8 g, 3.6 g, 5.4 g rates). Joe Doccola at Arborjet prepared the dinotefuran formulations.

For our work in 2009, we established a trial at the same commercial avocado grove used for our 2008 study, using the previously injected trees for the new treatments. The trees were Hass on the clonal Toro Canyon rootstock and were then 8 years old. Joe Doccola of Arborjet advised on the trunk injection procedures. No trees were treated with the same insecticide in consecutive years.

In the 2009 trial, we conducted our evaluations at one injection timing. Trees were injected on May 13 at a time when the trees were actively flushing. There was a high density of flowers on the trees this year, a prolonged flowering period, and the leaf flush was considerably later than in 2008. At the time of the injections, the fruit was beginning to set on the trees, so we determined that the timing was a good test of the ability of the injections to protect trees from avocado thrips at a time when the fruit was extremely vulnerable to attack.

Imidacloprid Trunk Injections

The LC_{50} for imidacloprid against avocado thrips was determined from bioassays to be 73 ng/cm^2 leaf. In our 2009 trial, the imidacloprid concentrations in flushing leaves reached this level with both the 1.8 g and 3.6 g injection rates at 5 weeks after injection (Figure 2). The major surge in concentrations occurred between weeks 3 and 6, when the spring flush leaves had stopped expanding. Of particular concern was the lack of a rate effect, with both injection rates resulting in similar levels of insecticide. In our study, we used a syringe device (QUIK-jet®) that was developed by Arborjet to permit the rapid injection of trees. Based on the trunk diameters of the trees (12 inches), we were advised to use 3 injection ports. With 3 injection ports per tree, our top imidacloprid rate (3.6 g/tree) required injection volumes of 24 mls IMAjet (5% formulation) per port. These volumes cannot be injected into the trees at one visit. Therefore, we injected each port with 12 mls during an initial injection visit. The trees were injected with a second 12-ml dose of insecticide after 1 hour had elapsed. The 1-hour interval between injections was to allow uptake of the insecticide to occur. At the second visit, however, it was extremely difficult to inject many of the ports with the additional 12 mls, and often leakage occurred from the port or the solution leaked inside the outer cambial layer. Clearly, the initial injection volume had not cleared sufficiently from the injection site to allow for a second injection to be administered. It is for this reason that Arborjet recommends the use of the Tree IV® system. With the Tree IV, the operator can inject the tree over a longer period of time, allowing the insecticide to move into the tree at a rate that matches the xylem flow within the tree. We do not believe that this is feasible for avocado growers, however, because of the extra time required to inject trees. Also, there may be negative impacts on the industry based upon public perception of avocado trees being placed on a drip system for insecticide treatments. One possible solution to the problem is to increase the number of injection ports, which would lower the volume needed at each injection site, but the disadvantage of this is the increased cost of the injection plugs and the increased damage to the trees arising from the need to drill more injection sites.

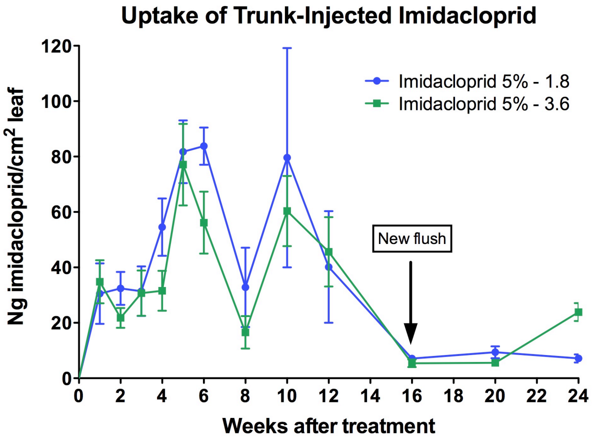

Figure 2. Uptake of imidacloprid injected as IMAjet at 2 rates. Each point represents the mean (+/-SEM) concentration of imidacloprid for 6 trees. Trees were injected on May 13, 2009.

Dinotefuran Trunk Injections

Dinotefuran is more soluble than imidacloprid and can therefore be formulated at much higher concentrations. In 2009 we evaluated the 10% experimental formulation we used in previous studies, and a new 22.5% formulation (also experimental). Both formulations were taken up by the trees very effectively (Figure 3). At equivalent injection rates of dinotefuran, the 2 formulations resulted in very similar concentrations of insecticide in the leaf tissue, and were apparently not affected by injection volumes. Furthermore, there was a clear rate effect on subsequent residue levels in the leaves due to the ease of injection and the lack of any leakage from the injection ports. It appears that the greater solubility of dinotefuran allowed for better uptake. At equivalent imidacloprid and dinotefuran rates of injection, dinotefuran levels were almost 10-fold higher than imidacloprid within 2 weeks of injection.

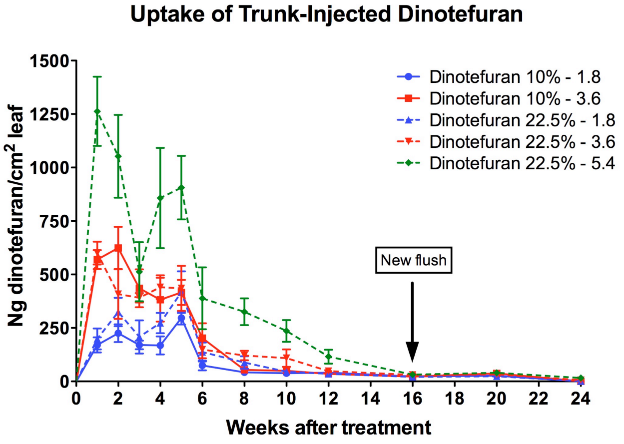

Figure 3. Uptake of dinotefuran injected as experimental formulations at 3 rates (2 formulations were evaluated). Each point represents the mean (+/-SEM) concentration of dinotefuran for 6 trees. Trees were injected on May 13, 2009.

The LC_{50} for dinotefuran against avocado thrips is 545 ng/cm^2 leaf. This concentration was measured in leaves with both formulations at the 3.6 g injection rate, and was exceeded with the 5.5 g injection rate. These results suggest that trunk injections of dinotefuran could be very promising for avocado thrips control, provided that residues above the MRL (yet to be established for avocados) are not detected within the fruit.

Impact of Phosphorous Acid on Neonicotinoid Uptake

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. In our 2009 trial, we evaluated the compatibility of imidacloprid (IMAjet) and dinotefuran (22.5% formulation) with phosphorous acid (Fosphite). Because of the volumes needed, we injected the trees at 2 visits. At the first visit, trees were injected with 30 mls Fosphite (10 mls per injection port). After 1 hour, the trees were injected with 1.8 g insecticide.

Fosphite had dramatic effects on the uptake of imidacloprid (Figure 4). The concentrations of insecticide were significantly lower than in leaves sampled from trees that were pre-treated with Fosphite, and were often lower than the detection limit of the ELISA. In contrast, the effect of pre-injecting Fosphite had only a minor impact on dinotefuran uptake (Figure 4).

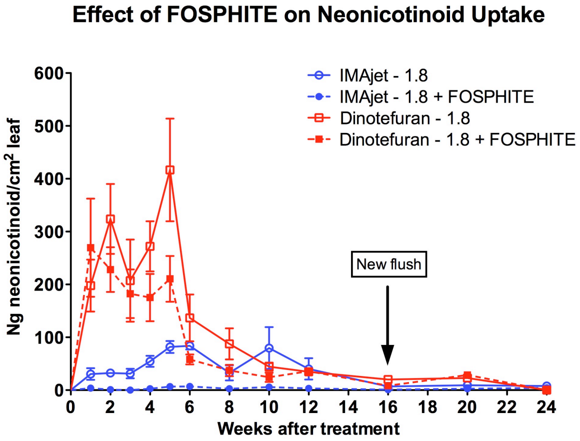

Figure 4. Uptake of imidacloprid and dinotefuran injected at 1 hour after a phosphorous acid (FOSPHITE) injection. Each point represents the mean (+/-SEM) concentration of insecticide for 6 trees. Trees were injected on May 13, 2009.

Mixing of the insecticide and phosphorous acid at the injection site had a deleterious effect on imidacloprid uptake, while effects on dinotefuran uptake were minimal. One possible explanation for this difference is likely to relate to the different chemical properties of imidacloprid and dinotefuran. Imidacloprid is slightly basic. Therefore, in an acid environment, such as that created by our pre-injection with phosphorous acid, the imidacloprid is likely to precipitate out at the injection site. With such poor deposition of imidacloprid in the leaves, it seems that the imidacloprid does not dissolve in the xylem fluid during subsequent irrigations. This scenario is in contrast to our results for dinotefuran. There appears to be no negative impact of the acid on the insecticide. Given that we only tested the compatibility of phosphorous acid and dinotefuran at the 1.8 g injection rate, the results are promising for the combined use of these two products.

Effect of Leaf Flush on Uptake

In previous studies, we have clearly shown that the concentrations of insecticide are higher in leaf tissue that is present on the trees at the time of treatments, and that the levels in new flushing foliage are very much dependent on timing. In 2009, we investigated this trend again to gain additional data to support earlier findings. At week 24 (Oct 28) of our sampling schedule, we sampled 2 sets of leaves from trees that had been treated at the highest rate for both imidacloprid (3.6 g) and dinotefuran (5.4 g). From the same terminal, we sampled the youngest fully expanded leaves (Summer/Fall flush) and mature leaves from the previous flush (Spring flush leaves present on the tree at the time of the treatments which had now hardened off). The concentrations of both insecticides were higher in the older leaves (Figure 5), again confirming that leaves present on the tree at the time of treatments will take up more of the insecticides. This result also confirms our recommendation that timing of treatments is critical if their maximal impact against target pests is to be realized.

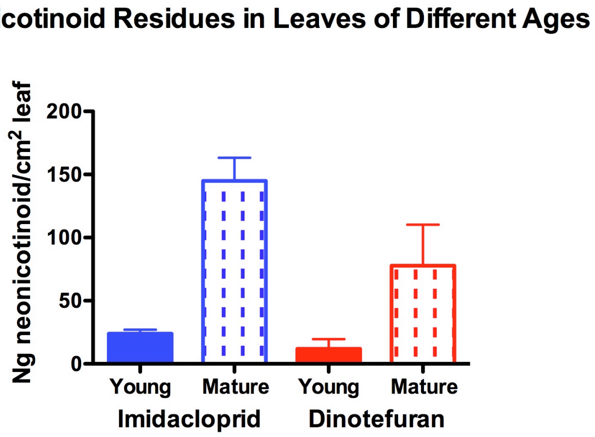
Neonicotinoid Residues in Leaves of Different Ages

Figure 5. Concentrations of imidacloprid and dinotefuran in leaves sampled from different flush cycles during 2009. Leaves were sampled from the same terminals for each of 6 trees for each treatment. Each point represents the mean (+/- SEM) concentration of insecticide for 6 trees. Trees were injected on May 13, 2009.

Fruit Residue Analyses

There were insufficient fruit available on the trees to conduct a meaningful insecticide residue study, and so this objective will be addressed during the 2010 trial. Fruit yields were generally very low this year due to a poor fruit set in 2008 caused in part by excessive temperatures during bloom. In 2008, we detected 0.1 ppm dinotefuran in fruit sampled at Week 12 from a tree that was injected at the mid-flush timing with 1.8 g dinotefuran. It is imperative that we evaluate the fruit for dinotefuran injections at the 3.6 g and 5.4 g a.i. injection rates.

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 growers practical solutions with respect 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

- The uptake of soil treatments of imidacloprid and dinotefuran are confounded by the soil conditions in avocado groves. Neither chemical is effectively taken up by trees, raising concerns about the use of these chemicals as soil applications.

- The uptake of these insecticide is greatly improved when they are injected directly into the trees, eliminating the impacts of soil conditions.

- Trunk injections of imidacloprid using the Quik-jet syringe are limited by imidacloprid solubility that necessitates large injection volumes. The need for large injection volumes could be overcome by increasing the number of injection ports, although the rate of uptake of imidacloprid is still too slow to be an effective “rapid-response” treatment to a pest outbreak.

- Dinotefuran is an ideal trunk injection candidate for the management of insect pests on avocado. The insecticide moves rapidly within the xylem, and high injection volumes are possible because of its favorable water solubility.

- Dinotefuran is compatible with phosphorous acid injections, whereas imidacloprid is not.

- The results of previous fruit residue analyses were encouraging. In 2009, we were unable to continue our residue studies due to poor fruit loads on the trees. We postponed this objective until 2010.

- We have a clearer understanding of the factors likely to impact the efficacy of trunk injections of neonicotinoids in avocado trees. One of our major objectives has been 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. To achieve this, we will need to use the Tree IV system.

- A major objective of our work in 2010 will be to focus on trunk paints of neonicotinoids. This procedure eliminates any soil impacts on uptake and is less damaging to trees because it does not require any drilling. Mixing neonicotinoids with surfactants has been shown to increase absorption through the cambium to the xylem, particularly with highly soluble compounds such as dinotefuran.

- We will discuss with Arborjet the likelihood of developing a trunk injection formulation of clothianidin. Clothianidin is less soluble than imidacloprid; however, it does not have a charge that is likely to impede its movement within the tree (as occurs with imidacloprid).

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