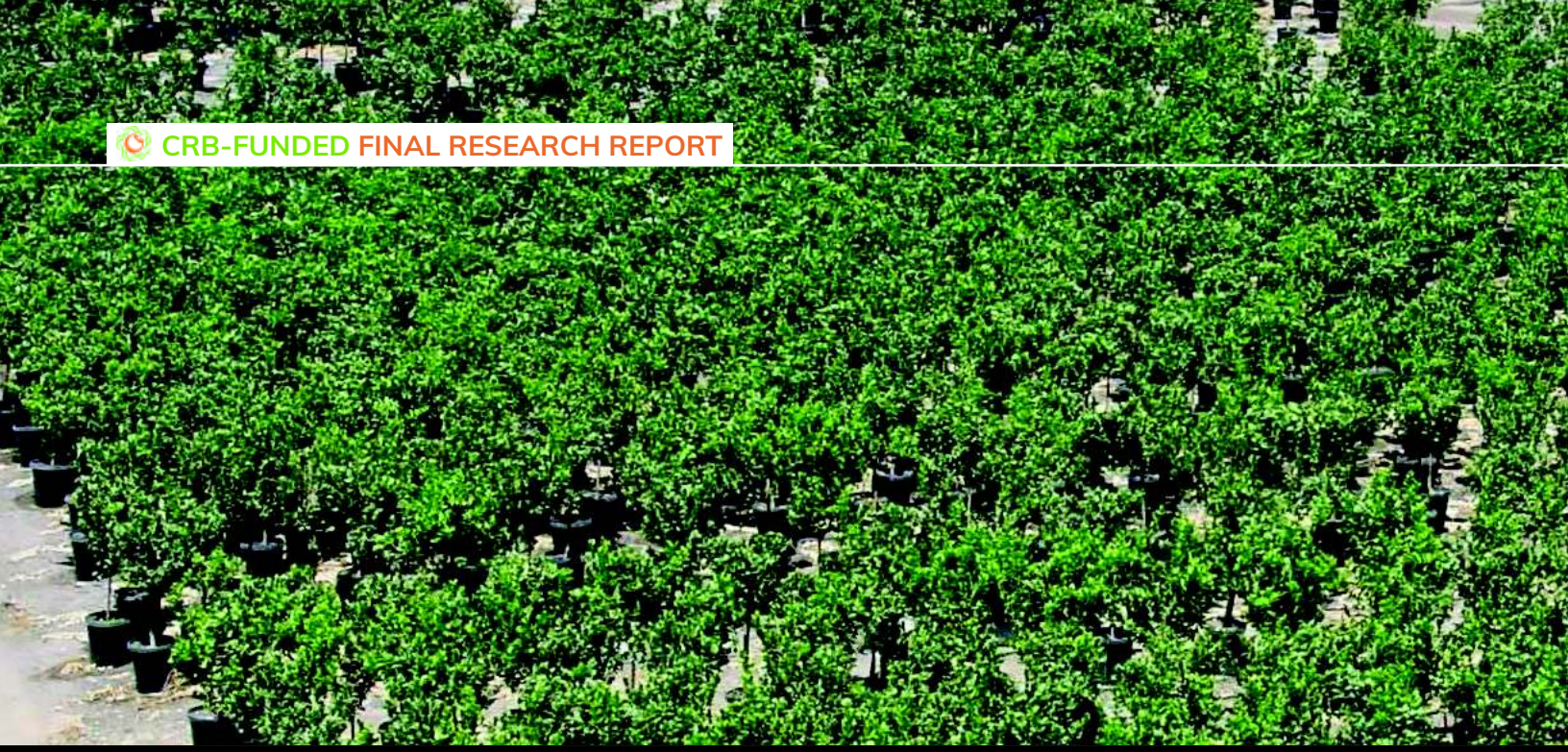
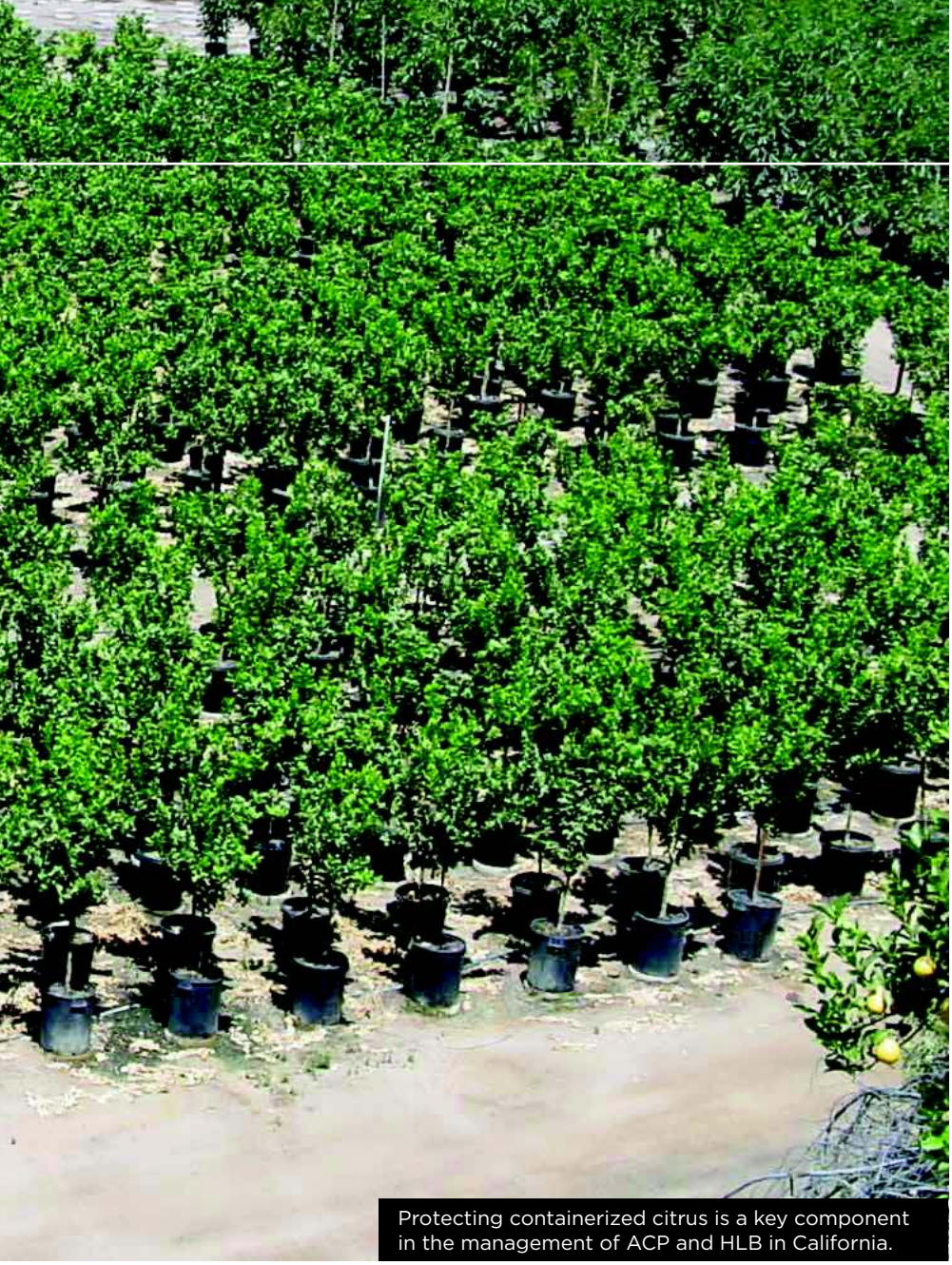


RAPID UPTAKE OF IMIDACLOPRID IN CONTAINERIZED NURSERY CITRUS

Frank Byrne, Elizabeth Grafton-Cardwell and Matthew Daugherty

Project Summary

Current U.S. Department of Agriculture-Plant Protection and Quarantine (USDA-PPQ) and California Department of Food and Agriculture (CDFA) regulations require that production nurseries within quarantine zones must follow specific insecticide treatment protocols prior to the shipment of containerized citrus trees both within and also to areas outside of the quarantine zones. Shipments of nursery stock to areas outside the quarantine zones, including interstate movement, must be treated with a systemic neonicotinoid no less than 30 days and no more than 90 days before they can be shipped from production sites to retail outlets outside of quarantine areas. With a 90-day post-treatment certification period, a substantial part of this time has elapsed by the time that trees are legally allowed to be shipped from production sites. The major goal of this project was to compare the uptake and retention of imidacloprid at four application rates in four citrus varieties. Following treatment, imidacloprid was established in trees at Asian citrus psyllid (ACP) threshold levels within three days at all application rates evaluated. However, the protective effect of the treatments beyond 90 days occurred only at the higher rates. The results from this project will assist regulators in making decisions about when it is safe for production nurseries to ship their stock after mandated treatments have been completed.



Protecting containerized citrus is a key component in the management of ACP and HLB in California.

Introduction

In 2008, following the detection of ACP in San Diego County, the CDFA established a quarantine area around the find site that restricted the movement of ACP host plants from areas known to be infested with the insect. Since that initial find, ACP has spread throughout southern California, where it is now well established in residential and commercial citrus. The areas under quarantine have been adjusted continually as new find sites are discovered, with the consequence that the entire citrus industry in southern California must now comply with state and federal quarantine regulations. Production nurseries within quarantine areas are required to treat all citrus nursery stock with both an approved foliar insecticide and a systemic neonicotinoid insecticide in order to receive a 90-day certification, during which time plants may be shipped from the production facility to retail outlets. For shipments outside of the quarantine areas, including interstate movement, nurseries must apply these treatments no more than 90 days and no less than 30 days prior to shipment (CDFA 2017).

The 30-day restriction was implemented by the USDA-PPQ at a time when nursery trees were produced outdoors rather than in approved insect-proof screenhouses, and it was based on the best knowledge available at that time about how fast imidacloprid became fully systemic within a citrus tree. At that time, no data were available for containerized citrus trees. In mature citrus trees, however, imidacloprid uptake was known to take several weeks (Castle et al. 2005), and this influenced the decision to instigate a 30-day hold on nursery stock to ensure that all potential life stages of ACP were killed prior to shipment.

Previous research (Byrne et al. 2017; 2018) showed that containerized citrus trees treated systemically with imidacloprid could be shipped within two weeks of treatment, when peak residues were established within trees. However, before considering a change to the regulations, the USDA-PPQ requested additional studies that focused on the early uptake (i.e., within the first week following application) of imidacloprid, since this information was lacking.

Evaluations of additional imidacloprid application rates and how the uptake and retention of residues within plants might be affected by over-watering also were requested. The latter could seriously compromise the efficacy of the nursery treatments if insecticide was leached from the potted trees due to excessive irrigation at retail outlets (Byrne et al. 2018).

Currently, all existing ACP quarantine control requirements apply only to production nurseries. There are no treatment requirements for retail outlets, a decision likely guided by the expectation that plants would reside at these nurseries for a short time. Data from the CDFA and our independent surveys at retail outlets in California confirmed that numerous trees were resident at nurseries well past the 90-day certification period (Byrne et al. 2018), thus indicating that many trees were susceptible to infestation by ACP and highlighting the importance of the nursery treatments to protect trees awaiting retail sale. The overall goals of this project were to determine how rapidly imidacloprid and other

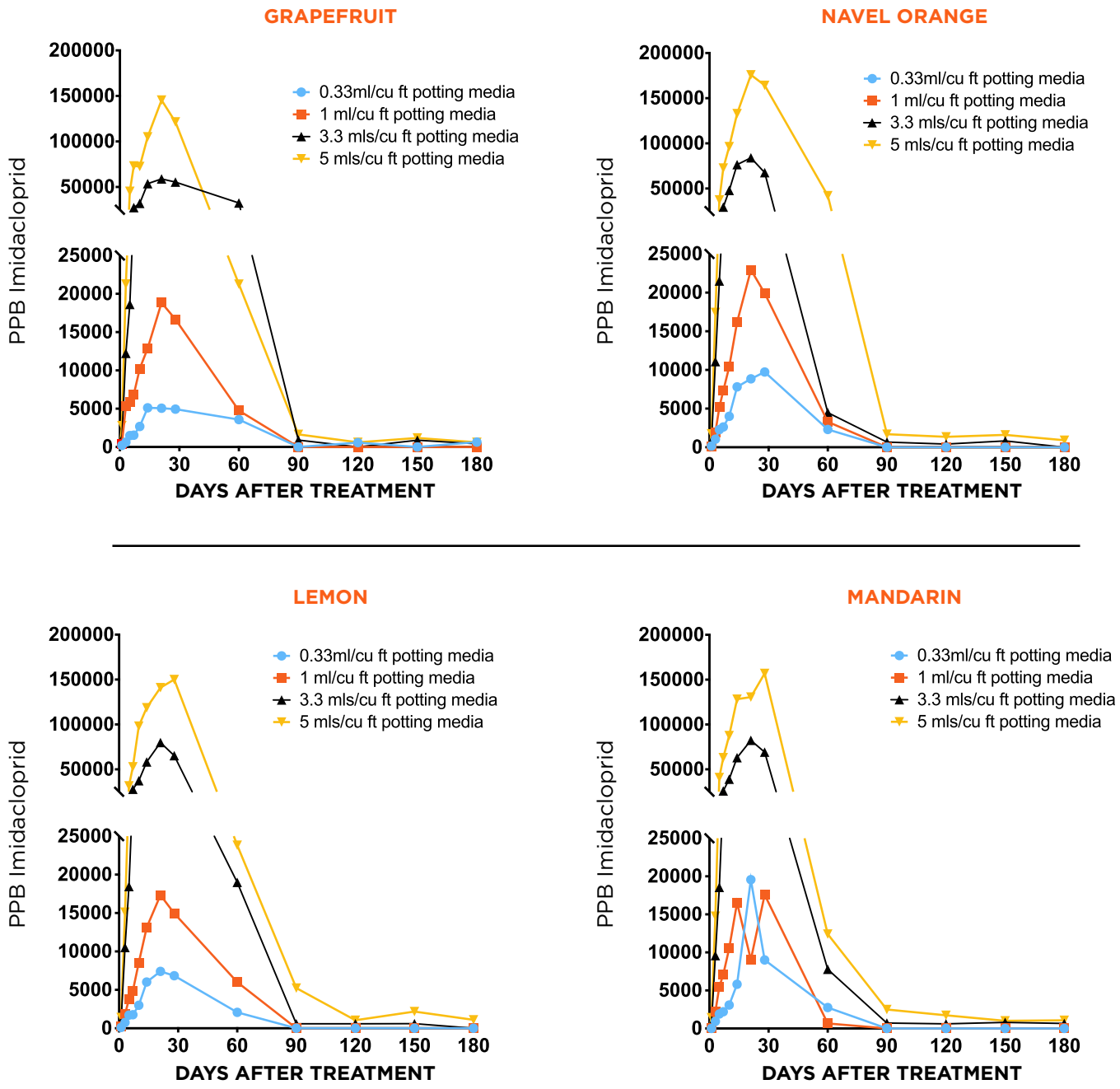


Figure 1. Imidacloprid residues measured over six months in four varieties of citrus following treatment with Admire Pro®. Each point represents the mean imidacloprid concentration for ten trees. The y-axis is split into two parts to better show the extreme range in residues over the four application rates.

neonicotinoids became fully systemic within nursery trees and how long residues remained at concentrations known to be effective in preventing the colonization of trees by ACP.

Comparison of Imidacloprid Application Rates

We compared the uptake and retention of imidacloprid in four citrus varieties treated with a range of Admire Pro® application rates. The rates of application ranged from the highest rate permitted by the insecticide label to a rate that was 15-fold lower than the maximum. All trees had been budded one year prior to the treatments and were grown in five-gallon pots. All trees were watered at 100 percent evapotranspiration[1] (ET). The target concentration of imidacloprid in trees is 220 parts per billion (ppb), a threshold level that prevents the colonization of leaf tissue by ACP nymphs (Sétamou et al. 2012).

There was a clear effect of application rate on the temporal profiles of imidacloprid residues within the trees

(**Figure 1**), with the highest residues occurring in trees treated with the highest insecticide rate. The profiles were similar for the different rates and were characterized by an initial rapid uptake of insecticide, followed by a rapid decline in residue levels. The ACP target threshold of 220 ppb imidacloprid was reached at all rates within three days (**Figure 2**) and was maintained in trees treated at the two lower rates (0.33 and 1.0 ml Admire Pro/cubic foot potting media) for 90 days. At the two highest rates (3.3 and 5.0 ml Admire Pro/cubic foot potting media), the threshold was maintained for up to 150 days post-treatment.

Effect of Over-watering on Insecticide Residues

We compared the uptake and retention of imidacloprid in mandarin oranges under two irrigation regimens, with one set of trees provided with replacement water (100 percent ET), and a second set of trees provided with an excess of water (400 percent ET) to promote leaching of insecticide from the bottom of the container. The objective of monitoring imidacloprid levels in trees that were over-watered was to mimic the situation in many retail outlets where over-watering is likely to occur. Excessive watering could compromise the efficacy of insecticide treatments that were applied at the production facility prior to the arrival of the trees at the retail site.

The effect of over-watering trees on residue levels was dramatic, with substantially lower concentrations of insecticide present in the leaf tissue at all application rates (**Figure 3**). At the highest application rates, excessive watering reduced peak residue levels by as much as three-fold, thereby significantly lowering the overall protective effect of the treatments. Despite the over-watering, however, the initial uptake of imidacloprid was still fast enough to ensure that threshold levels of imidacloprid were reached within three days at all application rates evaluated. Yet long-term retention of residues was significantly shortened in trees that were over-watered.

The effect of over-watering trees also was evident in trees treated with the label rate of thiamethoxam, another neonicotinoid insecticide that is used for psyllid control. Although the uptake of thiamethoxam was rapid, the treatment effect did not extend past 30 days.

Benefit to Industry

This study provided a comprehensive assessment of how different rates of imidacloprid application and watering regimens affect the uptake and retention of insecticide in containerized citrus. The results show that imidacloprid uptake is rapid, surpassing required thresholds in the trees within as little as three days. Thus, the current requirement

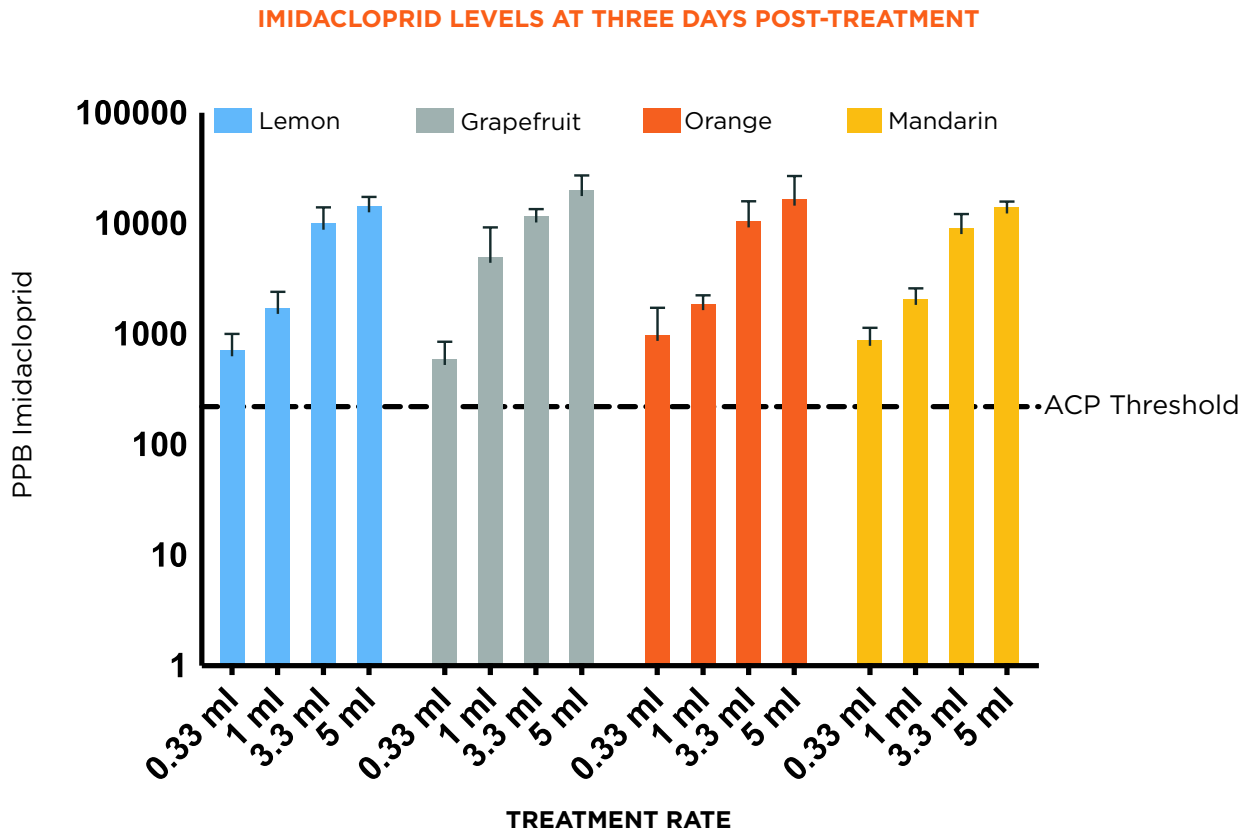


Figure 2. Imidacloprid residues in leaf tissue sampled from citrus trees three days after treatment with Admire Pro®. Each bar represents the mean imidacloprid concentration for ten trees. The y-axis is represented as a log scale to better show the range of imidacloprid residues following the four application rates.

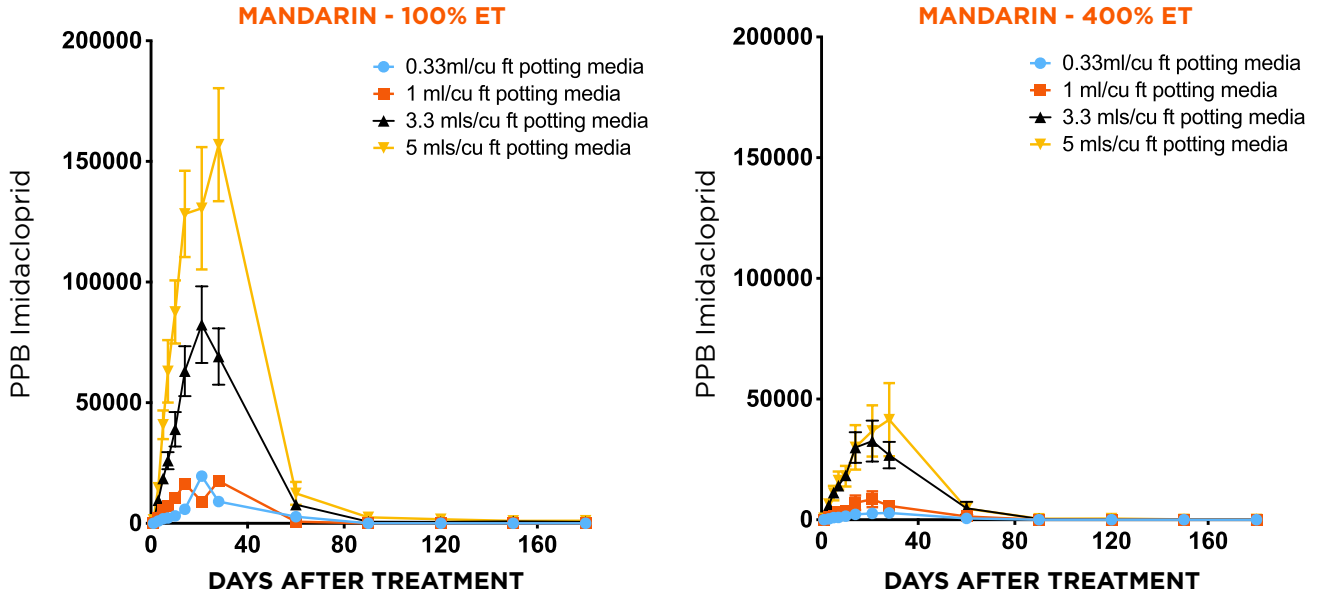


Figure 3. The effect of over-watering on the uptake and retention of imidacloprid in mandarin trees irrigated daily at 100 percent (left) and 400 percent (right panel) evapotranspiration (ET).

for a 30-day delay between treatment and shipping dates is unnecessarily long and is not maximizing the benefits of the nursery treatments. Trees systemically protected with insecticide are held at production facilities for periods longer than is necessary. In fact, the lengthy delay is counter-productive to the overall goal of preventing the spread of ACP on containerized citrus, as it shortens the protective effect of the systemic treatments while the trees are awaiting sale in retail.

Of the four imidacloprid application rates evaluated, the two higher rates provided protection to trees for up to five months. The two lower rates satisfy the current 90-day post-treatment certification period.

Thiamethoxam also is rapidly taken up by the trees, offering the nursery industry another fast-moving systemic insecticide that could be used to protect their trees from ACP. However, under current regulations, having to wait 30 days post-treatment before shipping means that thiamethoxam treatments would not protect trees from a potential infestation once the trees leave a production facility since residues already have dissipated by the time the trees are legally ready to ship.

Glossary

[1]**Evapotranspiration:** A measure of the loss of water from a plant due to a combination of evaporation and transpiration.

References

Byrne, F.J.; Daugherty, M.P.; Grafton-Cardwell, E.E.; et al. 2017. Evaluation of systemic neonicotinoid insecticides for the management of the Asian citrus psyllid *Diaphorina citri* on containerized citrus. *Pest Management Science* 73(3):506-514.

Byrne, F.J.; Grafton-Cardwell, E.E.; Morse, J.G.; et al. 2018. Assessing the risk of containerized citrus contributing to Asian citrus psyllid (*Diaphorina citri*) spread in California: Residence times and insecticide residues at retail nursery outlets. *Crop Protection* 109:33-41.

Castle, S.J.; Byrne, F.J.; Bi, J.L.; et al. 2005. Spatial and temporal distribution of imidacloprid and thiamethoxam in citrus and impact on *Homalodisca coagulata* populations. *Pest Management Science* 61(1):75-84.

CDFA. 2017. Asian citrus psyllid quarantine program. *http://phpps.cdfa.ca.gov/PE/InteriorExclusion/pdf/acptreatments.pdf*, Accessed date: 19 November 2019.

Sétamou, M.; Rodriguez, D.; Saldana, R.; et al. 2010. Efficacy and uptake of soil-applied imidacloprid in the control of Asian citrus psyllid and a citrus leafminer, two foliar-feeding citrus pests. *Journal of Economic Entomology* 103(5):1711-1719.

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