UNDERSTANDING THE DYNAMICS OF NEONICOTINOID INSECTICIDAL ACTIVITY AGAINST THE GLASSY-WINGED SHARPSHOOTER: DEVELOPMENT OF TARGET THRESHOLDS IN GRAPEVINES

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ABSTRACT

Systemic neonicotinoid insecticides are effective against adult and immature stages of the glassy-winged sharpshooter. One reason for the use of systemic treatments is that they exploit the xylophagous feeding behavior of the insect. Our current data show that neonicotinoid treatments have an additional contact activity on emerging first instars before they begin feeding. Egg masses that were exposed to systemic treatments of dinotefuran were unaffected by the treatments and the first instars developed fully within the eggs. However, upon emergence, the insects became susceptible to the effects of insecticide residues that were present in the surrounding tissues. In a series of bioassays, we were able to show that there was a dose-response between insecticide residues and first instar mortality. From these data, and data currently being generated from additional bioassays, a target threshold for dinotefuran will be derived. This target value can then be used as an indicator of the efficacy of treatments and the level of protection vines are receiving.

LAYPERSON SUMMARY

The systemic neonicotinoids imidacloprid and dinotefuran are effective insecticides that growers can use for long-term management of glassy-winged sharpshooter (GWSS) populations. Because of the contrasting chemical properties of these insecticides (e.g. dinotefuran is about 80-fold more water soluble than imidacloprid), growers can now choose the most suitable product to meet their pest management needs. In this study, we are determining the concentration of dinotefuran that is needed within the xylem of plants to kill a feeding GWSS. We have demonstrated that the toxicity of dinotefuran against GWSS adults is close to that of imidacloprid, and we have also shown that nymphs emerging from an egg mass are susceptible to the contact activity of dinotefuran before they commence feeding.

INTRODUCTION

Our research program focuses on the use of chemical insecticides for the management of glassy-winged sharpshooter (GWSS). We are dedicated to formulating safe and effective treatment programs for California growers, given the almost complete reliance by the grape industry on this method of control. We have conducted extensive trials in Coachella, Napa and Temecula valley vineyards to evaluate the uptake and persistence of three neonicotinoids – imidacloprid, thiamethoxam, and dinotefuran – under the diverse range of climatic, soil, and agronomic conditions associated with these regions. We have an understanding about how the different chemical properties, particularly water solubility, of these neonicotinoids can be exploited to achieve optimum uptake into vines, and we have developed sensitive techniques that allow us to monitor the levels of insecticide present within the vines. To exploit this knowledge further for the benefit of California grape production, we need to ensure that the concentrations of insecticide present within the vines are reaching levels that are effective at rapidly killing GWSS before they can infect vines with Pierce's disease. We also need to understand whether there is a sub-lethal impact of these insecticides on GWSS, since anti-feedant activity may not necessarily eliminate the threat that an infective sharpshooter poses to a vine. Our past and current research projects have established the threshold levels of imidacloprid needed to kill a GWSS at 10 ng/ml xylem fluid, and optimized treatment regimes for growers that will ensure these thresholds are attained following applications via different irrigation methods (drip, sprinkler). In 2007, a new systemic neonicotinoid, Venom (active ingredient dinotefuran), received full registration for use on grapes. Our work in this area has demonstrated the excellent uptake of these new insecticides following systemic application to vines (Toscano et al., 2007). This is good news for vineyard operators who have experienced problems with imidacloprid. Imidacloprid has been the predominant neonicotinoid in use in vineyards, but our research has shown that its uptake and persistence within vines varies dramatically between regions (Coachella Valley, Napa Valley, Temecula Valley). Despite its apparent poor uptake, growers continue to rely on imidacloprid in many areas. The perception is that the insecticide will work well in all areas given its successful implementation in Temecula vineyards (Byrne and Toscano, 2006). Dinotefuran offers a potential solution to overcoming the problems encountered with imidacloprid use – its rate of uptake is faster and it can reach higher concentrations at peak uptake than imidacloprid under the more challenging situations. It also exhibits favorable persistence. Having established that the uptake and persistence of dinotefuran is superior to imidacloprid in terms of insecticidal titers reached in the xylem, it is important to ensure that the levels attained in the xylem are active against sharpshooters. Comparative data on the efficacy of systemic dinotefuran against GWSS is not available. This study addresses the gap in our knowledge of dinotefuran thresholds needed for effective control of adult and immature GWSS.

OBJECTIVE
1. Determine target thresholds for systemic neonicotinoids against GWSS in grapevines.

RESULTS AND DISCUSSION
Update on Adult Bioassays

In our previous report, we showed that the concentrations of dinotefuran in the xylem of cotton plants used for bioassays of adult GWSS could be effectively controlled (Byrne and Toscano, 2009). To further validate this finding, we have conducted additional tests that have incorporated lower dose rates. The inclusion of these lower rates will ensure that a full range of dose-response data will be available for the probit analysis.

Dinotefuran levels within the xylem are quantified by ELISA. Although the lower limit of detection of the ELISA is 1.5 ppb, the limit of detection for grape xylem is 10 ppb because of the need for a dilution step to eliminate matrix effects. In bioassays, we are detecting mortality when insects feed on xylem that has levels of insecticide below the detection range of the ELISA. For this reason, we need to better understand the correlation between treatment rate and xylem concentration. With a better understanding of the relationship, we hope to develop a simple model from which the concentrations in xylem from plants treated at the lowest rates (and which are undetectable by ELISA because they are out of range) can be determined by extrapolation.

Update on Bioassays of Egg Masses

We evaluated the effect of dinotefuran against the eggs of the GWSS. Adult GWSS were confined in cages with cotton, which is an excellent host for GWSS oviposition. Leaves with egg masses (not older than 24 hours) were cut from the plants and the petioles inserted into vials containing a range of insecticide concentrations. The uptake of insecticide into each leaf was allowed to proceed for 24 hours and the leaves were then transferred to leaf boxes. The leaf boxes were maintained under lights until the normal period of embryonic development was completed (untreated controls were used to indicate the normal period of development). Mortality of nymphs was assessed for up to five days after the beginning of emergence.

As with imidacloprid (Byrne and Toscano, 2007), the nymphs developed fully within the egg mass and only succumbed to the effects of contact with dinotefuran during emergence. In contrast to our previous data for imidacloprid, where we observed an LC_{50} of 39 ng/cm^2 leaf, the indications from our current data set show that dinotefuran is slightly more toxic to the first instars than imidacloprid (**Figure 1**). Also, the slope of the dose-response curve is extremely steep, as was observed for imidacloprid.

CONCLUSIONS
At current label recommendations, the rate of uptake of dinotefuran into grapevines is faster than imidacloprid and concentrations of dinotefuran at peak uptake are higher (Toscano et al., 2007). These two properties make dinotefuran a strong candidate for inclusion in a sharpshooter management strategy, provided that effective concentrations are reached within the xylem. Dinotefuran is highly toxic to emerging first instars, and our data suggest that the insecticide is slightly more toxic than imidacloprid. As with imidacloprid, the toxic effect is not manifested until the nymphs emerge from the egg mass, suggesting that dinotefuran and imidacloprid act as contact insecticides.

The systemic neonicotinoids imidacloprid and dinotefuran are effective insecticides that growers can use for long-term management of GWSS populations. Because of the contrasting chemical properties of these insecticides, growers can now choose the most suitable product to meet their pest management needs. One of the interesting observations from this study has been that the concentrations of insecticide present within the xylem can be managed by choosing the appropriate application rate. This is a very powerful tool that could be used to optimize insecticide applications and manage insecticide use more effectively.

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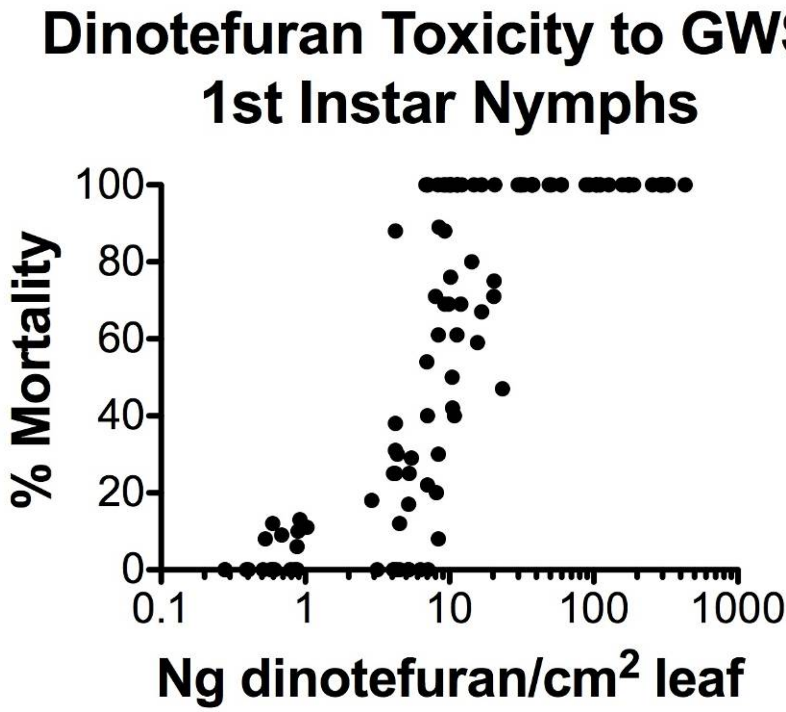

Figure 1. Toxicity of dinotefuran to emerging 1st instar GWSS. The petioles of leaves containing egg masses were placed in vials containing different concentrations of insecticide for 24 h systemic uptake. Leaves were then transferred to leaf boxes where the egg masses were allowed to continue their development. The survivorship of nymphs was determined for 5 days after the first indications of emergence.