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

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ABSTRACT

The impact of systemic treatments of dinotefuran on the adult and egg stages of the glassy-winged sharpshooter (GWSS) is being evaluated using greenhouse and laboratory scale bioassays. One reason for the use of systemic treatments is that they exploit the xylophagous feeding behavior of the GWSS adult and immature stages. Our current data show that these treatments have an additional contact activity on emerging first instars before they begin feeding. In bioassays with adults exposed to grapevines treated systemically with dinotefuran, we quantified concentrations within the xylem by ELISA and related the concentrations to insect mortality. From these bioassays, we expect to generate a value that represents the effective concentration of dinotefuran needed to kill a GWSS adult feeding on a vine. This target threshold can then be used to guide growers in the selection of treatment rates, and as an indicator of the efficacy of treatments and the level of protection their 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, 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 can be used to optimize insecticide applications and manage insecticide use more effectively. 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 already demonstrated that dinotefuran is toxic to the GWSS adults, and we have also shown that nymphs emerging from an egg mass are susceptible to the contact activity of the insecticide 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 (PD). 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 efficacies of systemic dinotefuran against GWSS are not available.

OBJECTIVE

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

RESULTS AND DISCUSSION

The concentrations of dinotefuran in cotton plants used for bioassays of adult GWSS can be effectively controlled (**Figure 1**). In three independent experiments, the concentrations of dinotefuran in extracts of xylem fluid were consistent with the application rates used. After dilution of samples to eliminate matrix effects, the lower limit of detection of the ELISA was 30 ppb dinotefuran. This result shows that there is potential to control the levels of insecticide present in plants, provided there is a good understanding of the environment (soil type, irrigation, etc) under which the insecticide is being used.

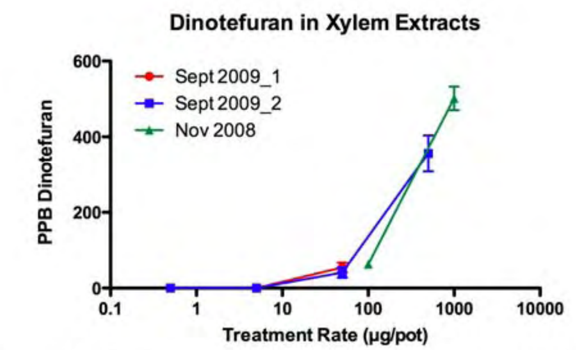

Figure 1. Concentrations of dinotefuran in xylem fluid sampled from cotton plants. Plants were treated with Venom 70 SG insecticide at different rates, and the xylem fluid extracted by pressure bomb at 5 days post-treatment when GWSS bioassays were completed. Not all concentrations were repeated for each bioassay.

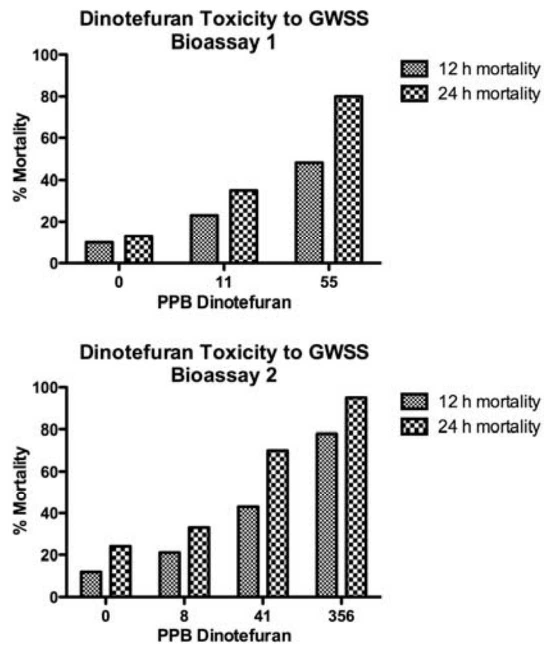

Figure 2. Toxicity of dinotefuran to GWSS adults. Mortality was assessed at 12 and 24 hours after the insects were confined on the treated plants. Data are from 2 independent bioassays.

The results of two independent bioassays are shown in **Figure 2**. Adult GWSS were caged on treated plants and mortality was assessed at 12 and 24 hours. In both bioassays, the control mortality was high. GWSS adults are difficult to work with because of the high control mortality, so it will be necessary to increase the number of replicates in subsequent bioassays in order to minimize this effect. Nevertheless, the results indicate the toxic nature of dinotefuran, with a clear dose response. The results from both bioassays were very consistent, indicating a robust bioassay system.

In the second set of experiments, 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 solutions. The uptake of insecticide into each leaf was allowed to proceed for 24 hours and the leaves are then transferred to leaf boxes. The leaf boxes were maintained under lights until the normal period of embryonic development was completed. Mortality was assessed at the time of emergence of the first instar.

As with imidacloprid, 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 3**). Also, the slope of the dose-response curve is extremely steep, as was observed for imidacloprid.

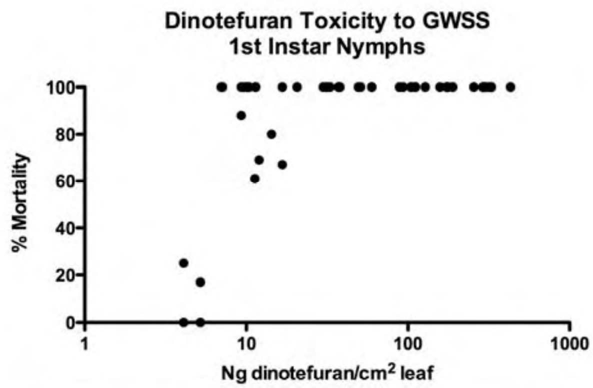

Figure 3. Toxicity of dinotefuran to emerging 1st instar GWSS. The petioles of leaves containing egg masses were placed in vials containing different concentrations of insecticide for 24 h systemic uptake. Leaves were then transferred to leaf boxes where the egg masses were allowed to continue their development. The survivorship of nymphs was determined for 2 days after emergence.

CONCLUSION

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. Our bioassay data are inconclusive at this point due to high control mortality, which is making the true insecticidal effects difficult to ascertain. It will be important to minimize the impact of control mortality in order to derive an effective target concentration for dinotefuran against adult GWSS, so further bioassays are needed. 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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