GLASSY-WINGED SHARPSHOOTER IMPACT ON 'WASHINGTON' NAVEL ORANGE YIELD, FRUIT SIZE, AND QUALITY

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ABSTRACT
Prior to this study, it was unknown what impact the glassy-winged sharpshooter (GWSS), *Homalodisca coagulata*, had on fruit yield, fruit size, and quality as well as tree vigor. The effects of the high feeding populations of GWSS on navel orange peel nutrient status and metabolism have been consistent for the four years of the study. High GWSS feeding populations significantly reduced peel Ca and Mg concentrations all years of the study: year 1 ($P \leq 0.05$) and year 2 compared to the low GWSS population ($P \leq 0.001$). High GWSS feeding populations significantly disrupted N metabolism causing high peel nitrate-N or total N in years 1 and 2, respectively ($P \leq 0.05$). High GWSS feeding populations significantly increased peel arginine and putrescine concentrations in four years of the study with the magnitude of the difference between the two treatments greater in years 2 and 3 ($P \leq 0.05$). High GWSS feeding populations resulted in a numerically higher concentration of proline in year 1 and a significantly higher proline concentration in year 2 ($P \leq 0.05$). Although GWSS feeding causes changes in peel Ca, Mg and N status, high levels of feeding and the induced changes occur after maximum peel thickness and, thus far, have not affected external fruit quality. The changes in metabolism induced by GWSS feeding are indicative of tree stress. The increased magnitude and statistical significance of these metabolic changes over the first two years of high GWSS feeding pressure is consistent with cumulative stress to the trees. High feeding pressure resulted in significant yield losses in 'Washington' navel oranges.

INTRODUCTION
Prior to this study, it was unknown what impact the glassy-winged sharpshooter (GWSS), *Homalodisca coagulata*, had on fruit yield, fruit size, and quality as well as tree vigor. The goals of this project were to determine the usefulness of management of GWSS to prevent yield loss, fruit size reduction, and degraded fruit quality. This information is paramount before we can even begin to incorporate these into conventional IPM programs. First we have to know what impact GWSS has on citrus, and second we need to know how to use the currently available materials against the GWSS in IPM programs to prevent potential losses without disrupting citrus IPM programs. Prior to this study, efforts to manage GWSS in citrus were primarily to suppress populations to limit the spread of *Xylella fastidiosa* in areawide management programs.

OBJECTIVES
This research was initiated to:
1. Address the impact of GWSS on fruit yield, and distribution of fruit size when GWSS are controlled compared to untreated blocks of Valencia oranges, and 'Washington' navel oranges;
2. Evaluate the effects of high GWSS populations have on fruit quality (sugar/acid ratios, peel thickness, sugar/acid ratio, juice quality, peel texture and firmness, susceptibility to post-harvest disorders) in Valencia and Navel oranges;
3. Evaluate the effects of large GWSS populations have on water stress, nutrient loss (Ca etc.), metabolite loss (amino acids, xylem translocated PGRs) due to xylem feeding and fruit drop and fruit quality, and fruit drop;
4. Determine if Admire enhances fruit size, tree health and vigor in the absence of GWSS.

RESULTS AND DISCUSSION

Objectives 1 and 2

The Navel orange experiment was initiated on August 21, 2001 for 'Washington' Navel oranges. A site was established in Mentone with a completely random design with five replications with high and low GWSS populations. Each population level has three rows of 43 trees (two guard rows and one central harvest row). The low populations (as close to '0' as possible) were established by applying 32 oz. of Admire 2F via drip irrigation on August 21, 2001, April 7, 2002, and May 6, 2003. Insects were monitored weekly by trapping, and visually counting adults, nymphs and egg masses. Efforts to establish differential populations were successful. On July 3, 2003, visual searches revealed 139.6 adults/3 minute search/tree (± 3.7 SEM) in the high population trees verses 3.0/3 minute search/tree (± 0.5 SEM) in the low population trees (Figure 1). The adult peak for 2002 occurred on June 25 with 104.6 GWSS/3 minute count (± 6.5 SEM). The high and low population trees had 2.7 (± 0.6 SEM) and 0.9 (± 0.2 SEM) egg masses/25 leaf turns respectively. One tree from a guard row was tented and fumigated for absolute counts on August 27, 2002. The absolute counts ranged from 1,149-4,999 GWSS/tree in the high population trees and 10-21 GWSS/tree in the low population trees.

The data from the four seasons of this study indicate that chronic high feeding of GWSS on orange reduces overall yield and size distribution. At the beginning of the study, two population levels were established in a 'Washington' navel orange grove. The low population level had essentially 0 GWSS/tree and the high population level trees had more than 1,100 GWSS/tree during July, August, and September of 2001, 2002, and 2003. At the beginning of this study, there were no differences in the mean number of cartons packed by total yield or size distributions (Hix et al. 2002). However, as the influences of chronic high GWSS feeding were removed, differences were detected (Hix et al. 2003, 2004a, and 2004b). For unknown reasons, the populations at the Mentone grove began to decline during the summer of 2004 and the trend continued during the summer of 2005. A neighbor treated a 35-acre grove across the street in June 2004. The counts peaked on August 12, 2004 with the high population trees at 38.7 (± 8.7 SEM) adult GWSS per three minute count compared to 1.1 (± 0.82) in the treated trees. The counts peaked on August 12, 2005 with the high population trees at 2.4 (± 0.7 SEM) adult GWSS per three minute count compared to 0.7 (± 0.22) in the treated trees. As a result, the January 2005 harvest essentially became a "tree recovery" evaluation. The yield seemed to recover because the separation in the mean yield was not as significant in January 2005 as in previous harvests (Figure 2).

Navel oranges were harvested from 37 trees within the harvest rows January 21, 2005 and sent to the California Citrus Packing House in Riverside for packout and evaluation. Two cartons from two sizes (88 and 113) and two grades (Choice & Export) from each replication (total of 96 cartons) were selected. Trans-Pacific shipment was simulated by storing the 96 cartons from at the packinghouse for 21 days at 37° F after which time the fruit was sent to Kearney Agricultural Center (KAC) for storage at 68° F for four days followed by 55° F for five days. For post-harvest evaluation at harvest, initial measurements of general appearance, pitting, puff and crease, peel firmness, thickness, color, TA, TSS, and % juice were taken from a 20 fruit sub-sample. Fruit was evaluated for general appearance, rind pitting, and decay following simulated shipment.

Objective 3

The results provide significant evidence that (1) the peel nutrient status of navel and oranges is reduced in a manner related to GWSS population density and (2) peel metabolite concentrations indicative of stress also change in a manner related to GWSS population density.

The peel nutrient status of navel orange fruit collected from the high and low GWSS treatments at Mentone during a period of low population density in July 2002 were not significantly different. At this site the GWSS population density increased on approximately Aug 8 and remained high through the end of August-early September. Peels from navel oranges collected at the time of intensive GWSS feeding on shoots in the high GWSS treatment had significantly lower concentrations of the Ca, Mg and NO_3 than peels of fruit collected from the low GWSS treatment. The results are consistent with reports in the literature that high concentrations of Ca and Mg are found in GWSS excretions. In addition, peel samples of fruit collected from trees with high populations of GWSS tended to have a 10% and 12% less Mn and Mo, respectively. However, these differences were not statistically significant. For fruit samples collected from the high GWSS treatment on August 11, 2002 just three days after the GWSS populations began to increase, the two contrasting population densities had no significant effect on peel arginine concentration. However, for navel orange fruit collected during the period of high GWSS populations (August 20, 2002), peel arginine concentration was significantly greater for fruit from the high GWSS treatment than the low GWSS treatment. It is worth noting that arginine tends to accumulate in parallel with the build up of the GWSS population over time. Elevated arginine concentrations are indicative of biotic and abiotic stress conditions. The accumulation of arginine in navel orange peels in response to increasing GWSS population density also paralleled the increase in peel putrescine concentration. Arginine is the immediate precursor for the biosynthesis of putrescine, which is also known to accumulate under stress conditions. Depending on the regulation found in different plant species, concentrations of spermidine increase, decrease or remain the same during stress. Spermine, which is typically found in lower concentrations than putrescine and spermidine, is usually unaffected by stress. These results strongly suggest that high population of GWSS cause significant stress. Proline concentrations decrease under stress when carbohydrates become limiting. Whereas peel proline concentrations tended to be lower for fruit collected from the high GWSS treatment, there was no significant difference in peel proline concentration between the two GWSS population densities. For both GWSS populations, the proline concentration decreased with time.

The effects of the high feeding populations of GWSS on navel orange peel nutrient status and metabolism have been consistent for the four years of the study. High GWSS feeding populations significantly reduced peel Ca and Mg concentrations all years of the study: year 1 ($P \leq 0.05$) and year 2 compared to the low GWSS population (control trees treated with Admire) ($P \leq 0.001$). High GWSS feeding populations significantly disrupted N metabolism causing high peel nitrate-N or total N in years 1 and 2, respectively ($P \leq 0.05$). (Note that nitrate-N concentration is lower than that of total N and easier to perturb.) High GWSS feeding populations significantly increased peel arginine and putrescine concentrations in four years of the study with the magnitude of the difference between the two treatments greater in year 2 and 3 ($P \leq 0.05$). High GWSS feeding populations resulted in a numerically higher concentration of proline in year 1 and a significantly higher proline concentration in year 2 ($P \leq 0.05$). In year 1, the yield of the 24 data trees in the high GWSS feeding population treatment has numerically lower than the yield of the 24 control trees treated with Admire (low GWSS feeding population). In year 2, the yield reduction caused by the high GWSS feeding population was approximately 50% and significant ($P \leq 0.05$). The effect of GWSS feeding appears to be cumulative over the first three years of the study as the magnitude of the changes tended to increase in magnitude and significance from year 1 to year 2 and year 2 to year 3. Although GWSS feeding causes changes in peel Ca, Mg and N status, high levels of feeding and the induced changes occur after maximum peel thickness and, thus far, have not affected external fruit quality. The changes in metabolism induced by GWSS feeding are indicative of tree stress. The increased magnitude and statistical significance of these metabolic changes over the two years of high GWSS feeding pressure is consistent with cumulative stress to the trees.

Yield (kg/tree) for the individual navel orange trees sampled for fruit peel analyses was similar to the whole row harvest (37trees/row) data obtained at Mentone. Trees in the high GWSS populations tended to have fewer commercially valuable large size fruit as some function of yield (Figures 1 and 2).

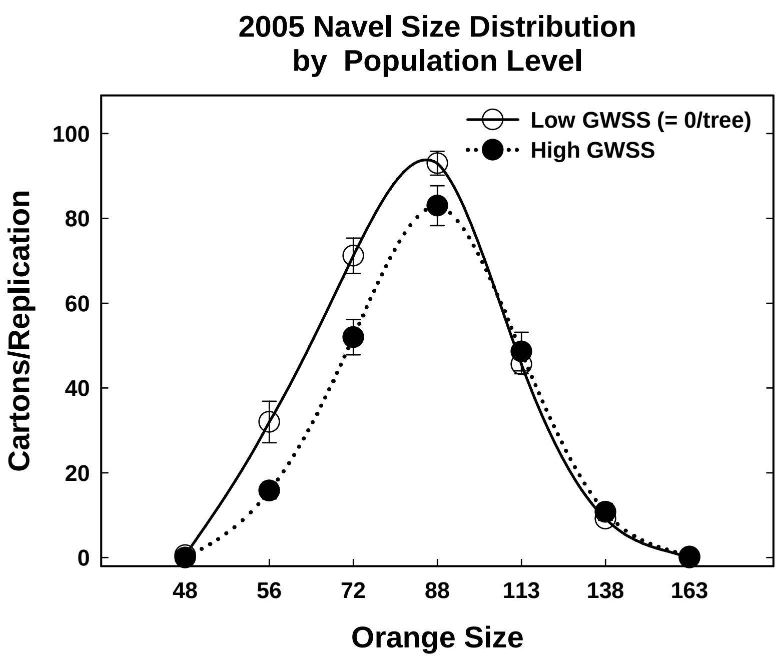

Figure 1. Mean number of cartons packed fresh (choice and export) between the high and low GWSS populations for the 21 Jan 2005 Navels. Low population (virtually 0 GWSS) trees were treated on April 7, 2002, May 1, 2003, and May 5, 2004. 5 reps (Each rep = 37 trees) ± SEM.

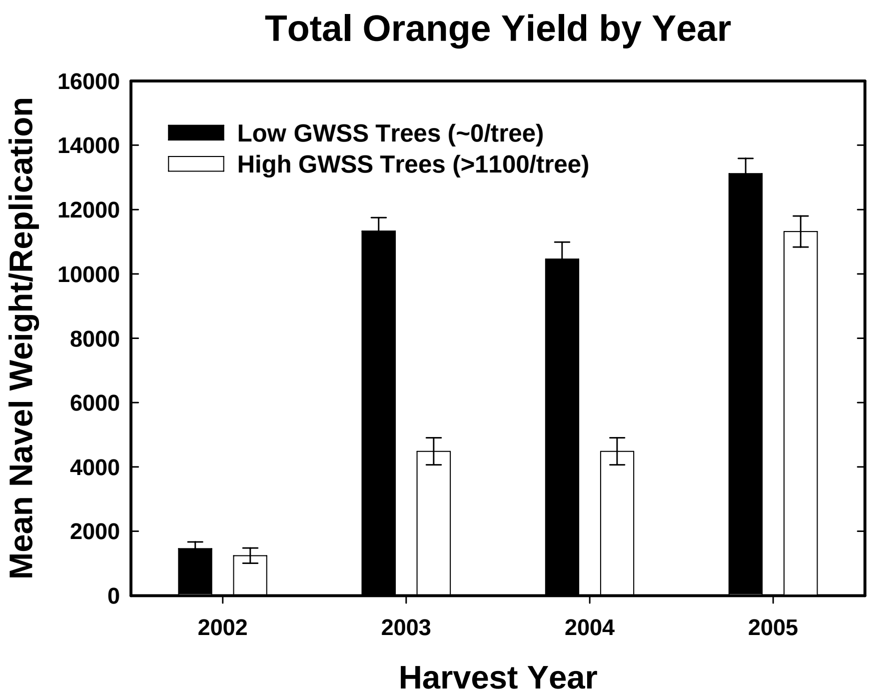

Figure 2. The low population trees produced more gross weight (pounds) of navels than the high population trees. N = 5 ± SEM. 1 replication = 37 trees.

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