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A REFEREED PAPER

PESTICIDE SUPPRESSION OF *DIAPREPES ABBREVIATUS* (L.) (COLEOPTERA: CURCULIONIDAE) PROMOTED DIFFERENTIAL GROWTH AND SURVIVAL OF 'HAMLIN' ORANGE TREES BUDDED TO FIVE ROOTSTOCKS IN A PHYTOPHTHORA INFESTED GROVE

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Abstract. **A pest management study of Diaprepes root weevil (DRW), *Diaprepes abbreviatus* (L.), was initiated in a bedded planting of 2-year-old 'Hamlin' orange trees budded on five rootstocks: Swingle citrumelo, Cleopatra mandarin, C-22, C-32, and C-35 citrange. The experimental site was located within a declining mature 'Hamlin' grove harboring a high DRW population. In 2003, after 2 years on a young tree care program that included insect and mite control, we compared the effect of foliar and soil-applied chemicals to no pesticides in a seasonal management program. DRW adult emergence from the soil and abundance in the trees was monitored and the incidence of *Phytophthora nicotianae* Breda de Haan in the soil was assessed. Foliar and soil-applied chemicals reduced adult DRW populations significantly for trees on all rootstocks. Treated trees had a faster rate of growth (except Cleopatra mandarin), larger tree canopies, fewer adult weevils, and less tree decline than untreated trees, but no significant difference in leaf injury was detected. Trees on C-32, C-35, and Swingle citrumelo had higher growth rates, canopy volumes, leaf injury, and weevil populations, but less tree decline than those on C-22 and Cleopatra mandarin. It appeared that root injury by DRW larvae created sites for infection and bark damage by *Phytophthora*. Tree decline was reduced overall by chemical treatments for DRW control and was lower for the *Phytophthora* resistant rootstocks, C-35 citrange and Swingle citrumelo.**

The *Diaprepes* root weevil (DRW), *Diaprepes abbreviatus* (L.), is one of many large polyphagous tropical weevil species known to infest citrus, many ornamental plants, and some agronomic crops in the Caribbean region (McCoy, 1999; O'Brien and Kovarik, 2000; Simpson et al., 1996). Since its introduction into Florida from the Caribbean region in 1964 (Woodruff, 1964), it has emerged as a major localized pest of commercial citrus (McCoy, 1999). Annual losses and cost of control in Florida citrus currently are thought to exceed $72 million, while losses in ornamentals and vegetables are estimated at $2 million (Peña et al., 2000).

The adult, egg, and neonatal life stages of DRW appear on above-ground parts of the host plant and all larval stages, pupae, and teneral adults occur below ground (Wolcott, 1936). Although DRW can be univoltine on citrus, overlapping generations, cause different life stages to be present simultaneously. Upon hatching, neonates fall from the tree and enter the soil. Early instars feed on fibrous roots, whereas later instars strip the bark from the taproot and structural roots, causing deep grooves as they consume the outer bark and cambium layer. Oomycetes in the genus *Phytophthora* (Graham and Menge, 1999) can invade feeding sites, infecting the bark and leading to girdling and subsequent tree death (Graham et al., 2003). Tree decline caused by the Phytophthora-Diaprepes (PD) complex is of particular importance when rootstocks are susceptible to bark infection and where trees are planted in poorly drained, fine-textured soils common to some areas of the flatwoods. Management of the PD complex and reducing tree decline requires both seasonal DRW control and rootstock resistance.

Current DRW management practices target eggs, larvae, and adults using: 1) foliar chemical sprays, 2) chemical soil barriers, and 3) soil treatments with entomopathogenic nematodes (McCoy and Duncan, 2000; McCoy et al., 2004). The latter method has been least effective in fine-textured soils (Duncan et al., 2002). Although these approaches to DRW suppression have effectively reduced pest density in the short term, there are no data on field efficacy in a season-long control program where tree health is the primary concern. To address this issue, a field experiment was initiated in a grove with a high infestation of DRW. Our objective was to compare the effect of a combination of foliar and soil-applied chemicals versus no chemicals on the control of DRW, adult and larval populations and protect the health of 'Hamlin' sweet orange trees budded to five rootstocks of variable resistance to *P. nicotianae*. This seasonal management program included monitoring adult emergence from the soil and abundance in the tree.

Materials and Methods

Experimental site. Research was conducted in the Southport Ranch Grove located 9.7 km (6 miles) east of Poinciana, Fla., in Osceola County. The declining grove consisted of 20-ha (50-acre) of mature 'Hamlin' trees budded to Swingle citrumelo rootstock and planted at 6.1 × 8.5 m (20 × 28 ft) in two-row beds. The primary soil at the site is Floridana fine sand, a loamy, very poorly drained Arenic Argiaquoll, with a dark colored mollic epipedon (surface horizon) and an argillic (clay) horizon between 50.8 to 101.6 cm (20 to 40 inches) from the soil surface. Pineda sand, a poorly drained Arenic

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Glossaqualf, also occurs at the site and has an argillic layer at the same depths. The root zone pH of these soils in their natural state normally is <6.0, but can range to above 8.0. According to previous survey estimates conducted around the state and local reports, this grove was infested with DRW at planting about 20 years ago and currently has one of the highest populations of DRW in Florida.

Experimental design. A field experiment was implemented in Sept. 2001, following tree removal from 2.6 ha (6.5 acres) on the north end of the mature 'Hamlin' grove in Feb. 2001. 'Hamlin' orange trees [0.84-0.94 ± 0.13 cm (0.33-0.37 ± 0.05 inch) trunk diameter] were budded to five rootstocks, C-22, C-32, C-35 citrange, Cleopatra mandarin, and Swingle citrumelo. Cleopatra mandarin was selected because of its susceptibility to *P. nicotianae* and the remaining rootstocks for their varying levels of *P. nicotianae* resistance (Graham and Menge, 1999). The trees were planted 3.7 × 8.5 m (12 × 28 ft) in nine alternate beds along with other experimental rootstocks included for observation. The experiment was arranged in a split plot design of two factors: chemical control of DRW and rootstocks. There were 90 replications in the trial, each one consisting of 10 trees (five trees/row in two adjacent rows on a bed). Each row was the main plot and was either treated to control DRW or not treated. The five trees within each row were single-tree subplots of each of the five rootstocks. In May 2003, the number of replications for tree evaluations was reduced from 90 to 55 based on plot completeness. Henceforth, we distinguish the initial experiment (90 replications) from the field trial (55 replications). In addition, 24 replications were randomly selected from the 55 for monitoring adult DRW populations on the chemically treated or untreated trees.

Horticultural care of mature grove. The declining 'Hamlin' grove was maintained as a reservoir of DRW to infest the new rootstock experiment. The grove received minimum care and no pesticides were applied to control arthropods or fungal diseases throughout 2001-2002. The grove was equipped with microsprinkler irrigation, and water was applied as needed. Weed control was maintained along row middles by mowing or by herbicide application (usually glyphosate) beneath the tree canopy. Soil samples were collected systematically each year to determine pH and nutrient levels. The mature trees received dolomite at a rate of 2721.5 kg/acre (3 tons/acre) in Jan. 2002 and Oct. 2003 to elevate soil pH. A band application of 16N-1P-16K fertilizer with micronutrients was made three times per year to the mature 'Hamlin' planting at a rate of 0.9 kg/tree (2 lb/tree).

Horticultural care of experimental planting. From the fall of 2001 to May 2003, the experimental planting was irrigated regularly by microsprinkler and weeds were controlled using the same program as in the mature 'Hamlin' grove. Fertilizer (10N-2P-10K plus micronutrients) was applied at 0.63 kg per tree (1.4 lb per tree) four times in 2002 and three times in 2003 to all trees. Dolomite was applied at 4535.9 kg (5 tons/acre) in Jan. 2002 and in combination with HiCal at 2268.0 kg (2.5 tons/acre) in Oct. 2003 to all trees.

Pesticide performance against life stages of DRW. From the time of planting in Sept. 2001 to May 2003, 10 foliar or soil insecticides were applied to the young trees using a high-pressure sprayer to control DRW and various foliar-feeding arthropods such as citrus leafminer, citrus psyllid, orangedog larvae, katydids, and aphids. If adult DRW were detected on new leaf-flushes, they were removed and the surrounding leaves carefully examined for egg masses. Based on overall tree health, it appeared that few, if any, DRW adults reached the young trees from the time of planting through the fall of 2002.

After 2 years controlling adult DRW on the young trees, the weevil was allowed to infest the young trees and chemical applications were henceforth limited to the designated main plots of the 55 replications of the field trial. For ease of application, the chemical treatments were applied to the same main plot in each replication. The remaining replications remained untreated. Foliar chemicals were applied for DRW in a seasonal control program (Table 1). Timing of application and choice of chemicals were determined by monitoring the emergence of adult DRW from the soil and their abundance on the trees. All foliar and soil-applied chemicals were applied with a high-pressure sprayer using a handgun. Foliar sprays were applied to the tree canopy to runoff, and soil surface application was confined to ca. 0.9 m^2 (10 ft^2) area beneath the tree. Petroleum oil (FC #455) was included in all foliar sprays at 3.8 liters (1 gal/acre) as a spreader.

From late May through early July 2003 when emerging adult populations were at a peak, we applied three foliar sprays, Sevin F 4 at 7.6 L (2 gal)/acre with oil, a combination of Danitol EC 2.4 at 0.5 L (16 oz)/acre, and Micromite WG 80 at 0.19 L (6.25 oz)/acre with oil, and Imidan W 70 at 0.9 kg (2.0 lb)/acre with oil. Sevin, Danitol, and Imidan are contact toxicants with little residual effect that kill a high percentage of the adult population thereby limiting the number of gravid females and egg deposition. Micromite is an egg sterilant that affects egg viability of the female and egg masses upon contact with foliar residues. According to Schroeder et al. (1976) and Schroeder (1996), the residual effect of Micromite can be up to 8 weeks, particularly on hardened off flushes. Since Micromite is also effective for control of citrus rust mite in the summer, its dual action makes it a more cost effective IPM tactic. Admire 2 L was applied to all trees for Asian citrus psylla, *Diaphorina citri* Kuwayama, control in the spring, despite the possibility that its systemic activity could affect the survival of neonate DRW feeding on roots (McCoy et al., 1995). Capture E 2 was applied in the fall as a chemical soil barrier to kill invasive neonates, however, weevil populations failed to devel-

Table 1. Pesticides applied for control of adult and larval *Diaprepes abbreviatus* and other foliar pests at Southport Ranch Grove, 2003.

Pesticide	Field rate/acre	Spray vol. gal/acre	Application date	Target stage	Other controlled pests
Admire L 2	1.0 L (32 oz)	227.1 L (60)	5/13/03	Citrus psyllid	DRW neonates
Sevin F 4	7.6 L (2 gal)	757.1 L (200)	5/28/03	DRW adults	Scale insects
Danitol 2.4 EC + Micromite WG 80	473 ml (16 oz) 177.2 g (6.25 oz)	757.1 L (200)	6/14/03	DRW adults and eggs	Citrus leafminer
Imidan W 70	0.9 kg (2.0 lb)	473.2 L (125)	7/9/03	DRW adults	
Capture E 2	0.9 L (32 oz)	75.7 L (20)	10/7/03	DRW larvae	Fire ants

op in the fall, suggesting the soil treatment with Capture had little value as a pest control.

Monitoring adult weevil emergence. Adult emergence from the soil in the mature 'Hamlin' grove surrounding the rootstock experiment was monitored weekly by recording the numbers of adults captured in 200 cone-shaped, screened, ground traps [0.9 m (3.0 ft) base diameter] placed along eight of the 2-row beds (McCoy et al., 2003). A single trap was placed midway between the tree trunk and the canopy dripline of selected trees. Traps were monitored from 1 April through 30 November 2003. Captured adults were released back into the grove at the site of capture.

Monitoring adult weevil abundance. The seasonal abundance of adult DRW in the young trees was monitored weekly in 24 of the 55 replications of the field trial, on the same day that adult emergence was recorded in the mature grove. Adult weevils infesting a tree were estimated by counting the number of dislodged weevils dropping to the ground after vigorously shaking a tree for 3 s using a hooked pole [1.5 m (5 ft) in length] placed around the main trunk at 1.2 m (4 ft) above the soil surface.

Monitoring the incidence of Phytophthora nicotianae. The incidence of *P. nicotianae* in the soil was estimated in 2001-2002 by determining the density of fungal propagules per cm^3 (0.06 $inch^3$) soil in the area of the field experiment. Soil samples were collected from nine, 2-row beds, every fifth tree in a row, 10 trees per row, 20 trees per bed. One sample per tree was collected about 30 cm (12 inches) from the tree trunk to a depth of 6 inches using a standard soil probe. Soil samples from each row (10 cores) were pooled and placed in a Ziplock® bag in a cooler for transport to the laboratory. In the laboratory, a 250 cm^3 (15.3 $inches^3$) sample was taken from each bag and a soil suspension was prepared for each sample. An estimate of fungal propagules per sample was determined by serial dilution and counting colonies formed on a selective PARPH agar medium (Graham and Menge, 2000). In 2003, a summer survey was not performed because of the very low numbers recovered in the two previous years. However, additional samples were taken from the rhizosphere of declining trees in Dec. 2003 and Feb. 2004.

Evaluation of tree canopy and trunk growth. Leaf-notching caused by adult DRW feeding during the year was rated in 24 replications of the field trial in early Dec. 2003. Each tree was examined visually for overall damage and then ranked on a scale from 1 to 4: 1 = no leaf injury, 2 = <25% injury, 3 = 25-50% injury, and 4 = >50% injury.

In Jan. 2002, 2003, and 2004, tree trunk diameter ca. 7.6 cm (3 inches) above the bud union was measured and converted to cross-sectional area for all trees in the 55 replications. Relative growth rates were calculated by comparing the changes in trunk cross-sectional areas between 2002 and 2004. Tree canopy dimensions were measured for all trees in the 55 replications in Jan. 2004 and canopy volume was estimated (Albrigo et al., 1975).

Evaluation of tree decline and root health. The first evidence of tree decline was observed in the field trial in Jan. 2004 in the form of and was manifest as leaves with prominent yellow veins, premature leaf drop, and trunk lesions near the soil line. Trees in the 55 replications were surveyed visually on 6 May 2004 for decline and trunk symptoms of *Phytophthora* infection. Soil and bark samples were collected from all decline trees, and 22 decline trees were randomly selected for removal from the soil. Removed trees were taken to the laboratory where the root systems were washed clean, examined for DRW root injury and *P. nicotianae* infection, and bark samples taken.

Statistical analysis. Data on the seasonal abundance of adult weevils in the field trial were compared using 4-factor ANOVA (PROC GLM, SAS, 1990) in which there were two levels for chemical treatment (main plot factor), five levels for rootstock (subplot factor), 18 levels for sampling date (May through November), and 25 replications. Weevil population data were square root transformed prior to analysis because count data typically violate parametric assumptions. Means separation used LSMEANS. Similarly, tree trunk growth, canopy volume, and tree canopy rating for leaf injury caused by DRW were compared using a series of 3-factor ANOVAs (PROC GLM, SAS, 1990) in which treatment, rootstock, and replicate were the main effects. The proportions of treated and untreated trees on different rootstocks that showed symptoms of decline were compared using contingency table analysis and the X^2 test (PROC FREQ, SAS, 1990).

Results and Discussion

Monitoring adult DRW emergence and density. Cone-shaped ground traps (n = 200) located in the mature 'Hamlin' grove captured 1,775 weevils throughout 2003. The greatest number emerged from the soil from late May through the first week of July (Fig. 1), at the beginning of the rainy season, concurring with previous research showed that the onset of adult emergence coincided with an increase in soil moisture and temperature (McCoy et al., 2003).

Previous ecological studies performed in the adjacent mature 'Hamlin' orange grove, revealed a second peak in adult abundance in the fall (McCoy et al., 2003). No explanation can be given for this variation in adult abundance from year to year, although it has been suggested that peak abundance of adults in the fall is caused by weather factors or adult migration from alternate host plants.

Weekly adult abundance in the tree canopy, monitored in both the chemically treated and untreated plots, showed a similar seasonal trend, with a peak in June (Fig. 2). The mean number of adult DRW dislodged from trees ranged from 2.8 to 6.8 in the untreated plots during June (Fig. 2).

Pesticide performance against life stages of DRW. All foliar treatments targeting adults and eggs reduced adult abundance in the 'Hamlin' rootstock experiment for about 3 weeks (Fig. 2). The ANOVA for adult abundance produced significant results for all four main effects (treatment, rootstock, sampling date, and replicate) (Table 2a). Only the interactions between chemical treatment and rootstock and between chemical treatment and date were highly significant; the interactions between rootstock and date or between treatments, rootstock, and date were not. Mean separation using LSMEANS indicated significant differences in adult abundance between chemically treated and untreated trees for various sampling dates (Fig. 2), for all rootstocks (Fig. 3), and in adult abundance among rootstocks for both treated and untreated trees (Fig. 3).

As mentioned above, foliar sprays applied to five of each ten-tree plot reduced adult DRW populations significantly for about 2 weeks post-treatment (Fig. 2). This short residual effect was probably influenced by adult immigration from untreated trees within the small plots. If this speculation is true, the estimated benefits of foliar sprays may be somewhat conservative, and residual control will improve as area sprayed is increased.

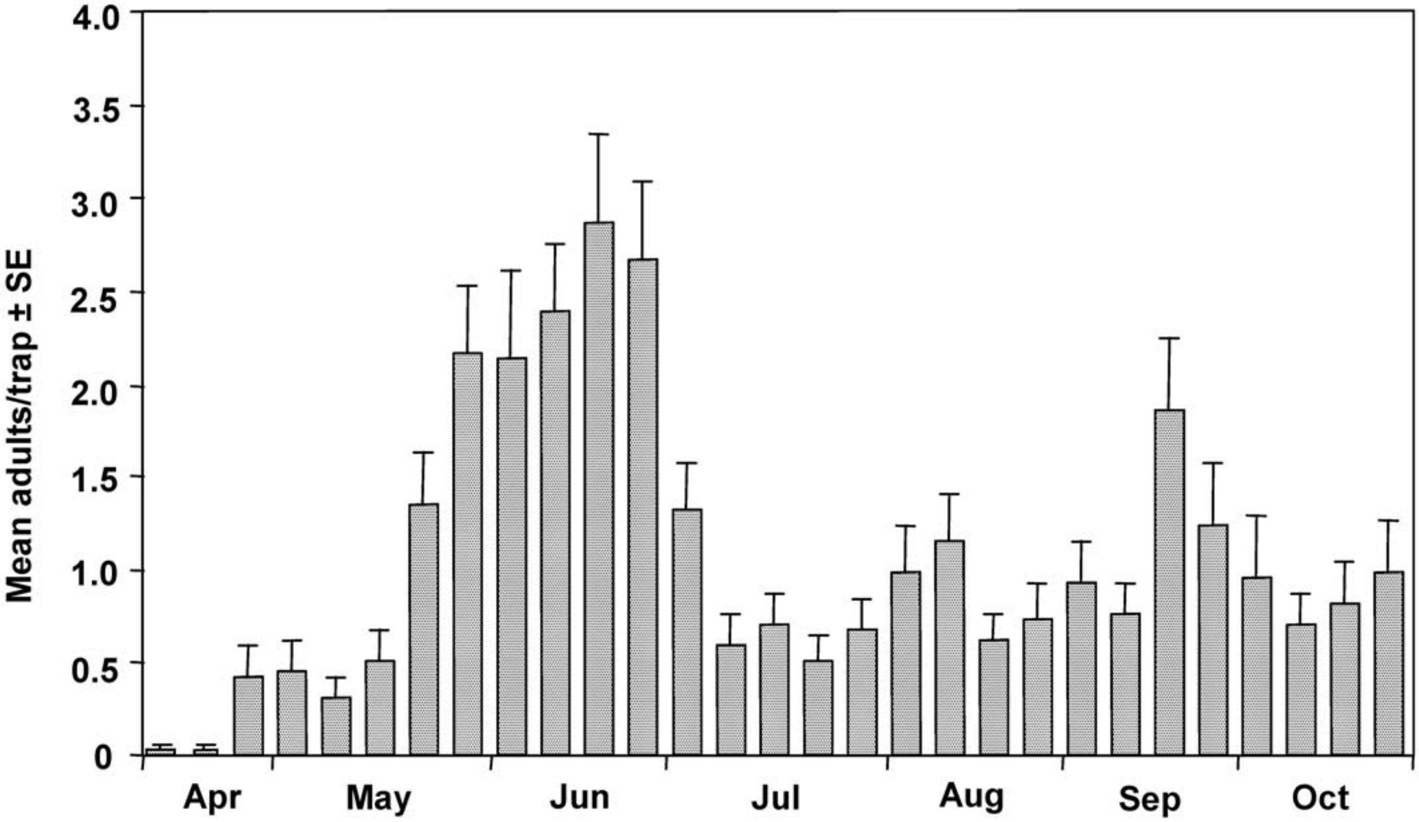

Fig. 1. Weekly abundance of adult weevils captured in cone traps in the mature 'Hamlin' grove (mean + SE).

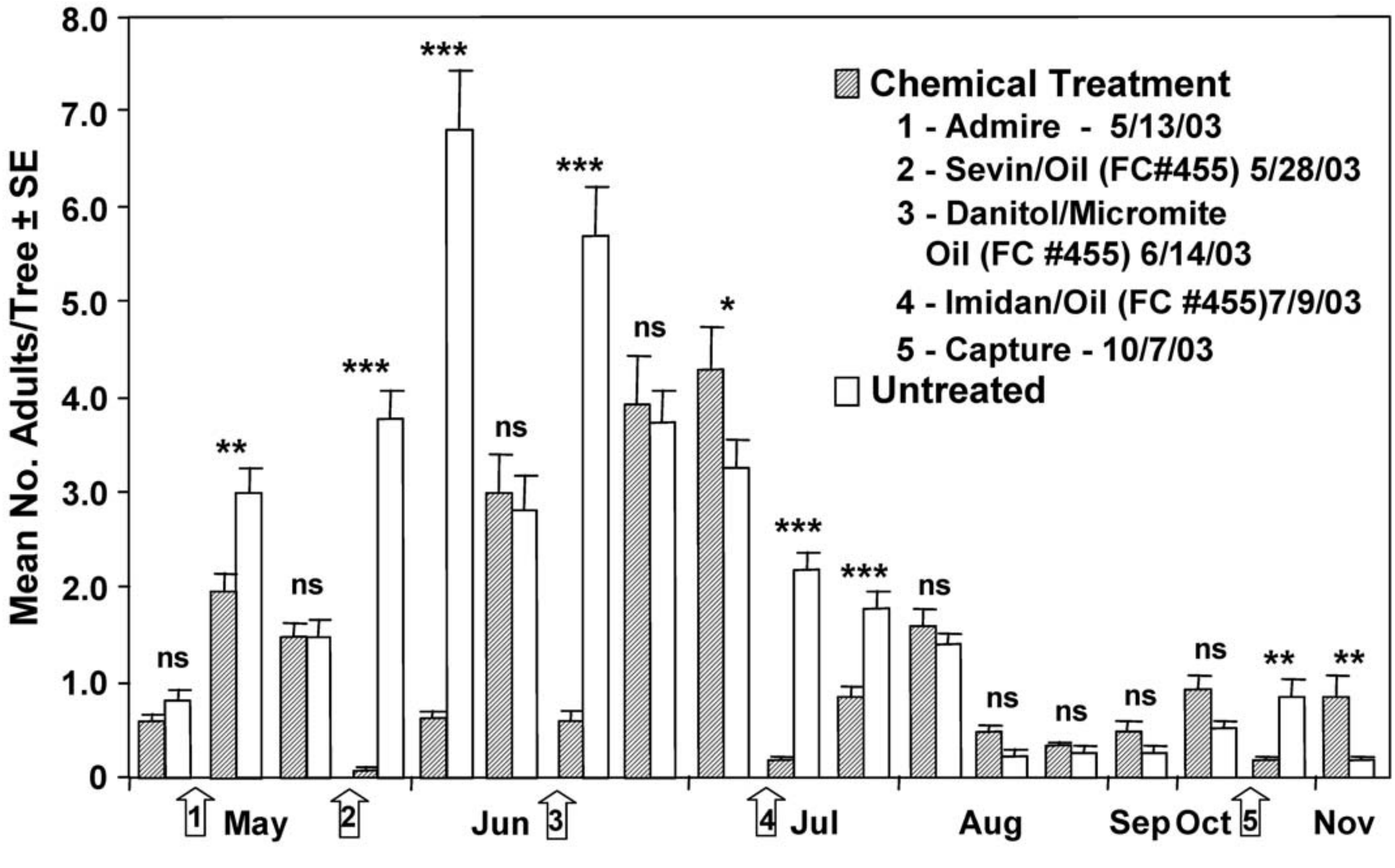

Fig. 2. Weekly abundance of adult weevils (mean + SE) in the canopy of young trees in treated and untreated plots of the field trial. Arrows with numbers indicate when various chemical treatments (see legend) were applied to the treated plots. Statistical comparison of the number of weevils in treated and untreated trees on various dates was by ANOVA (see Table 2a) and are indicated as: ns, $P > 0.05$; $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

Table 2. Results of ANOVAs comparing adult weevil abundance, tree trunk relative growth rate, canopy volume, and leaf injury rating for the young trees in the field trial.

	F	*df*	*P*
a) Adult Abundance			
Model	12.89	227, 4009	<0.0001
Replicate	10.91	24, 4009	<0.0001
Date	76.52	17, 4009	<0.0001
Treatment	79.78	1, 24	<0.0001
Rootstock	26.30	4, 4009	<0.0001
Treatment × Date	45.08	17, 4009	<0.0001
Rootstock × Date	1.24	68, 4009	0.0936
Treatment × Rootstock	9.53	4, 4009	<0.0001
Treatment × Rootstock × Date	1.10	68, 4009	0.2612
b) Tree Trunk Relative Growth Rate			
Model	2.52	117, 404	<0.0001
Replicate	1.81	54, 404	0.0008
Treatment	45.43	1, 54	<0.0001
Rootstock	15.16	4, 404	<0.0001
Treatment × Rootstock	2.60	4, 404	0.0358
c) Tree Canopy Volume			
Model	2.51	117, 404	<0.0001
Replicate	2.25	54, 404	<0.0001
Treatment	5.64	1, 54	0.0211
Rootstock	24.40	4, 404	<0.0001
Treatment × Rootstock	0.41	4, 404	0.7995
d) Leaf Injury Rating			
Model	1.67	55, 172	0.0069
Replicate	1.89	23, 172	0.0116
Treatment	0.55	1, 23	0.4666
Rootstock	3.70	4, 172	0.0064
Treatment × Rootstock	1.14	4, 172	0.3390

Chemical treatment and rootstock effect on rate of tree trunk growth. The ANOVA for tree trunk relative growth rate produced a highly significant result (Table 2b). The main effects for chemical treatment, rootstock, and replicate were also highly significant, as was the interaction between chemical treatment and rootstock. Mean separation using LSMEANS indicated significant differences among rootstocks in trunk relative growth rate for both treated and untreated trees (Fig. 4). Chemically treated trees grew at a significantly faster rate than untreated trees on all rootstocks except for Cleopatra mandarin (Fig. 4).

The ANOVA for tree canopy volume produced a highly significant result (Table 2c) with all three main effects being significant. The interaction between treatment and rootstock was not significant. Mean separation using LSMEANS indicated significant differences in canopy volume between chemically treated and untreated trees (Fig. 5A) and among rootstocks (Fig. 5B).

Treatment and rootstock effect on leaf injury rating. The ANOVA for the rating of leaf injury from adult DRW feeding was significant (Table 2d). The main effects for rootstock and replicate were significant, but the main effect for treatment and the interaction between treatment and rootstock were not. Mean separation using LSMEANS indicated significant differences among rootstocks for the severity of leaf injury (Fig. 6). Leaf injury was higher on the tree canopy of the faster growing rootstocks such as C-32 citrange, C-35 citrange, and Swingle citrumelo (Fig. 6) suggesting that the DRW feeding response was related to the quantity of vegetative growth.

Treatment and rootstock effect on tree decline. A tree decline survey conducted on 6 May 2004, revealed that 96 of the 743 trees (12.9%) on the five rootstocks currently in the grove were showing decline symptoms. The proportion of trees showing decline varied among rootstocks with Cleopatra mandarin and C-22 citrange showing the greatest decline and Swingle and C-35 citrange showing the least (Fig. 7A; 2 × 5 contingency table, $\chi^2 = 34.4261$, $df = 4$, $P < 0.0001$). Overall, 25 of 367 treated trees (6.8%) and 71 of 376 untreated trees (18.9%) showed decline, a highly significant difference (2 × 2 contingency table, $\chi^2 = 24.0521$, $df = 1$, $P < 0.0001$). A comparison of the proportional decline for individual rootstocks indicated that C-35 showed the weakest response to chemical treatment with rela-

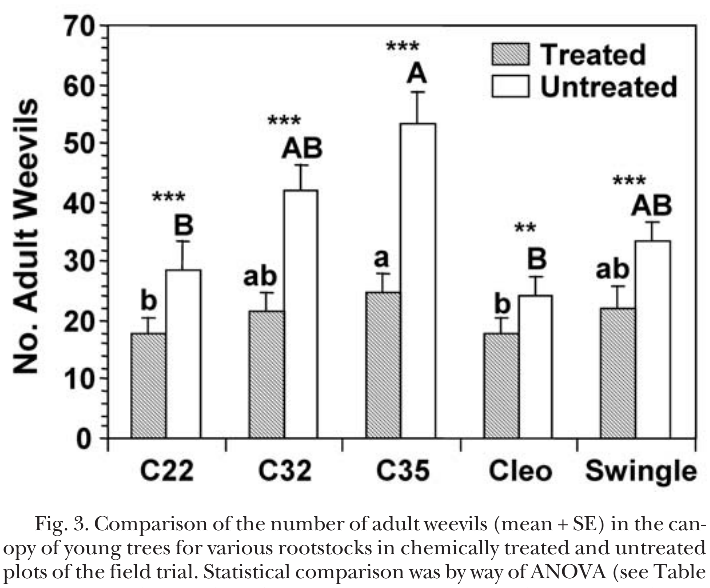

Fig. 3. Comparison of the number of adult weevils (mean + SE) in the canopy of young trees for various rootstocks in chemically treated and untreated plots of the field trial. Statistical comparison was by way of ANOVA (see Table 2a). Common letters above bars indicate no significant difference at the $P = 0.05$ level for treated trees across rootstocks (lower case letters) and untreated trees across rootstocks (upper case letters). Statistical comparisons for treated and untreated trees within rootstocks are indicated as: $^{**}P < 0.01$; $^{***}P < 0.001$.

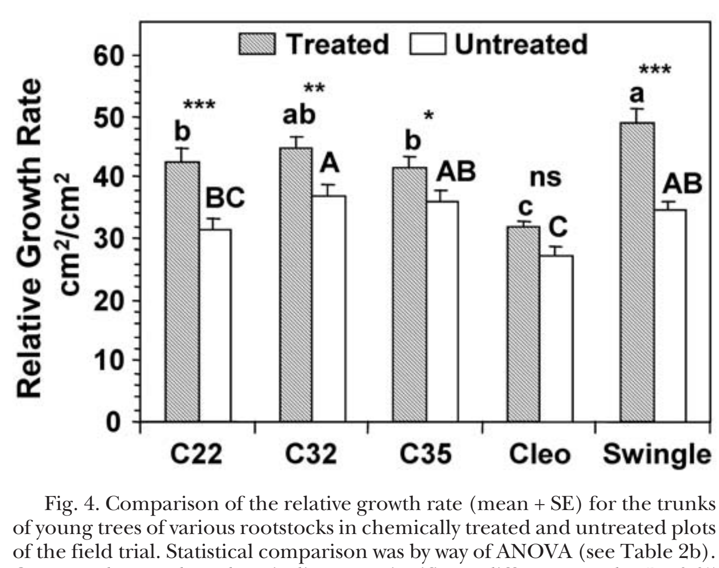

Fig. 4. Comparison of the relative growth rate (mean + SE) for the trunks of young trees of various rootstocks in chemically treated and untreated plots of the field trial. Statistical comparison was by way of ANOVA (see Table 2b). Common letters above bars indicate no significant difference at the $P = 0.05$ level for treated trees across rootstocks (lower case letters) and untreated trees across rootstocks (upper case letters). Statistical comparisons for treated and untreated trees within rootstocks are indicated as: ns, $P > 0.05$; $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

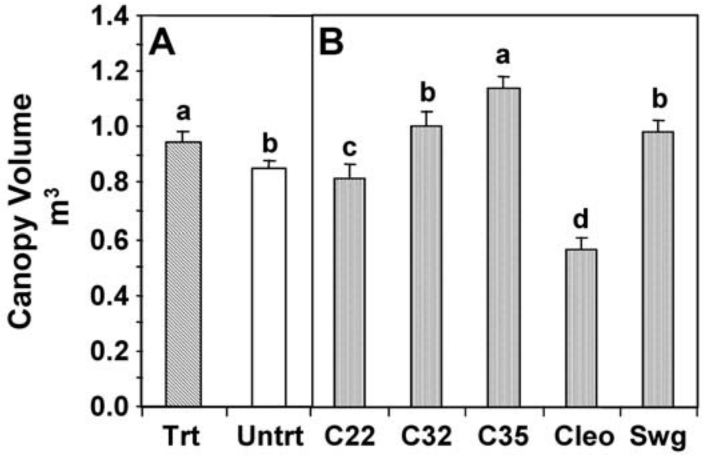

Fig. 5. Comparison of the canopy volume (mean + SE) of young trees in chemically treated and untreated plots (A) and of various rootstocks (B) in the field trial. Statistical comparison was by way of ANOVA (see Table 2c). Common letters above bars indicate no significant difference at the $P = 0.05$ level for treated and untreated trees (A) and across rootstocks (B).

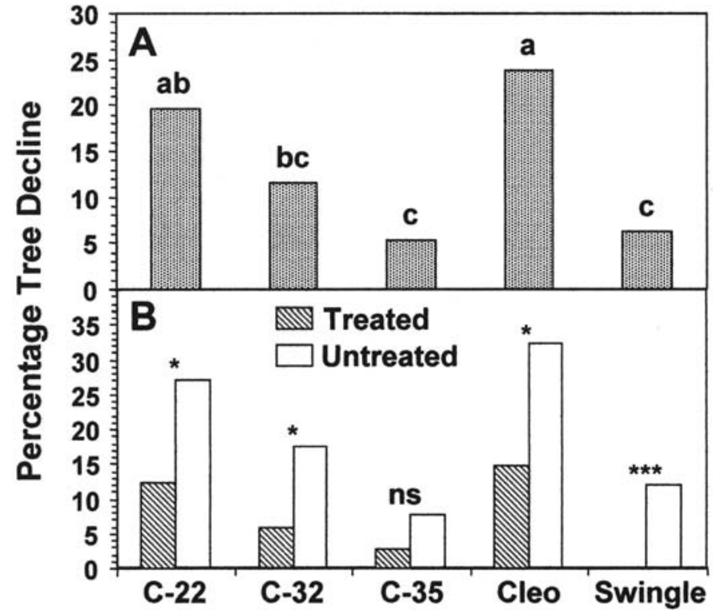

Fig. 7. Comparison of percentage tree decline of young trees of various rootstocks (A) in chemically treated and untreated plots (B) in the field trial. Statistical comparison used contingency tables and the Chi-square test. Common letters above bars indicate no significant difference at the $P = 0.05$ level across rootstocks (A) and for treated and untreated trees within rootstocks (B).

tively little decline in both treated and untreated groups (2 × 2 contingency tables, χ^2 tests; Fig. 7B), and not significantly different. However, a test of heterogeneity for decline for treated and untreated trees of the different rootstocks was not significant ($\chi^2 = 4.1255$, $df = 4$, $P > 0.05$), indicating an overall benefit of chemical treatment across rootstocks.

Assessment of root health in chemically treated and untreated plots. Based on soil samples taken in June 2001 and July 2002, the incidence of *P. nicotianae* in the soil, expressed as CFU's (colony-forming units), was very low throughout the experimental site. In 2001, three of 50 soil samples were positive for *P. nicotianae*, with a range of 0-18 CFU's/cm^3. In 2002, one of 160 soil samples was positive for the fungus. According to soil and bark samples collected in January 2004, when bark lesions on the tree trunk and tree decline was first detected, *P. nicotianae* populations on fibrous roots remained low (<5 CFU's/cm^3 soil). Yet, DRW injury was sufficient to initiate PD interaction. A contributing factor was the fine-textured sandy clay loam soil that was conducive to the onset of bark infection when infective propagules were available.

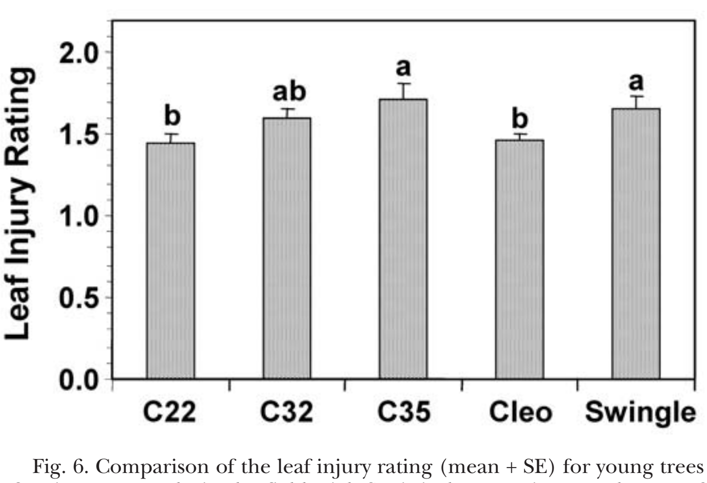

Fig. 6. Comparison of the leaf injury rating (mean + SE) for young trees of various rootstocks in the field trial. Statistical comparison was by way of ANOVA (see Table 2d). Common letters above bars indicate no significant difference at the $P = 0.05$ level across rootstocks.

Shortly after tree decline was first detected in the young planting, 17 decline trees from the untreated plots and five from the treated plots were removed to assess root health. Of the five trees that had received treatment for DRW control, one Cleopatra mandarin, one C-22, and one C-32 citrange had root damage caused by both DRW and *Phytophthora nicotianae*, the other two trees, one C-35 citrange and one Cleopatra mandarin, were positive for *P. nicotianae* only. None of the treated trees were positive for DRW root injury alone. Of the 17 decline trees removed from the untreated plots and examined for root injury, only two, one C-22 and one C-32 citrange, were positive for DRW root injury alone and only one Cleopatra mandarin rootstock was positive for *P. nicotianae* alone. However, six Cleopatra mandarin, three C-22 citrange, two C-32 citrange, and one C-35 citrange were diagnosed with both weevil root injury and *P. nicotianae* infection. As of Jan. 2004, no trees budded to Swingle citrumelo rootstocks showed tree decline, but some did show decline by May 2004 (Fig. 7). The large proportion of declined rootstocks diagnosed with both DRW and *P. nicotianae* injury suggests that DRW larval feeding on the roots contributed to decline either directly by impairing root function or indirectly by providing sites for *Phytophthora* invasion (Graham et al., 2003). In addition, Graham et al. (2003) demonstrated that DRW injury must exceed a threshold before infection by *Phytophthora* is promoted above the background activity, which was low in this grove with limited irrigation.

Conclusions

The foliar application of sterilant and toxicant chemical mixtures with biological activity against the egg and adult stages of DRW that were timed according to 1) adult emergence from the soil, 2) adult abundance on the tree, and 3) the development of the summer flush stimulated by frequent rainfall were effective in suppressing weevil populations in 2003. Treated trees on all rootstocks except Cleopatra exhibited greater trunk and/or canopy growth and less tree decline. This field trial presents the first supportive information on the positive effect of foliar chemical sprays in reducing plant injury from DRW. In addition, the data suggest that the Phytophthora/Diaprepes complex can kill trees on susceptible rootstocks such as Cleopatra mandarin, regardless of weevil control, and that vigorous rootstocks with resistance to *Phytophthora*, such as Swingle citrumelo and C-35 citrange, can tolerate high weevil populations. This study will continue through 2005.

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