oping *P. nicotianae* populations, increasing the probability of infection at root locations distal from the insect feeding locations.

Root rot disease indicators increase in the presence of weevil injuries; thus, increased emphasis should be placed on the proper dual management of root rot when subterranean insect injuries are likely on susceptible rootstocks. Presently, however, there are no clearly defined tactics for managing *P. nicotianae* in such plantings. Further, it is possible that other, less virulent microbial pathogens may become of concern due to the weakening of root defense systems by larval feeding. The preliminary results of this study suggest that *P. nicotianae* management considerations should be more actively integrated into IPM programs on *P. nicotianae*-sensitive and -tolerant rootstocks in *D. abbreviatus*-infested groves.

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FEEDING RESPONSE OF FIRST INSTAR LARVAE OF *DIAPREPES ABBREVIATUS* TO DIFFERENT NOVEL INTERGENERIC CITRUS SOMATIC HYBRIDS

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Additional index words. Citrus rootstocks, citrus relatives, citrus tissue culture, protoplast fusion, root weevil.

Abstract. **The larvae of the citrus root weevil, *Diaprepes abbreviatus* (L.) will inflict severe injury to young tree roots of all rootstocks grown commercially in Florida. In an attempt to find germplasm with resistance to larval feeding, the following intergeneric somatic citrus hybrids were screened in the greenhouse using first instar larvae as an inoculum source: 'Succari' sweet orange + *Citropsis gilletiana*, 'Succari' + *Microcitrus papuana,* 'Succari' + 'Meiwa' kumquat, 'Succari' + *Atalantia ceylanica*, 'Nova' tangelo + *Citropsis gilletiana,* and 'Nova' + *Citrus ichangensis* (an interspecific hybrid). Sour orange and Swingle citrumelo rootstocks served as standards. Cohen citrange (a triploid) and 'Limon Gigante' (provided by W. S. Castle) were also included in the study. Somatic hybrids, other test plants and controls planted in plastic containers in Fafard Citrus B soil mix were exposed to larvae for 45-70 days in two completely randomized experiments. Larval weight and survival, root biomass consumption, and gross root injury ratings were per-**

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formed on all treatments. Results of these studies are discussed.

The citrus root weevil, *Diaprepes abbreviatus* L., is a destructive pest of citrus that was first identified in Florida in Orange County during 1964 (Woodruff, 1964). Since this time, it has spread to 19 other counties, and has caused severe production losses, primarily in Orange, Lake, Polk, Indian River, and Hendry counties (McCoy et al., 1996). More than 152,900 acres of commercial agriculture have been affected. Economic damage to trees is caused by larval feeding on roots, and secondary damage caused by *Phytophthora*-induced diseases and moisture stress (Rogers et al., 1996). Once established in an area, elimination of this pest appears to be impossible due to its wide host range (Simpson et al., 1996). The ultimate solution to this problem is to identify rootstock germplasm that will allow adequate citrus production in infested areas. All commercially available rootstocks appear to be susceptible to this problem, and no source of resistance to larval feeding has been identified within the genera *Citrus* or *Poncirus*. Citrus relatives (related wild genera) are considered to be a vast but largely untapped reservoir of genetic diversity with potential for improved disease and insect resistance (Grosser et al., 1996; Louzada and Grosser, 1994). For example, *Citropsis gilletiana* is known to be resistant to feeding by larvae of the longicorn beetle (*Monohammus* sp.) (Swingle and Reece, 1967). The same mechanism responsible for this may also prevent feeding of *Diaprepes* larvae. Most citrus relatives are not horticulturally acceptable when used directly as rootstocks, and in many cases, hybridization with citrus has been either difficult or impossible. In efforts to transfer useful traits of wild relatives into useful citrus hybrids, we have used the technique of protoplast fusion (that bypasses genetic mechanisms that inhibit successful hybridization) to produce hybrids of *Citrus* with several related species including *Citropsis gilletiana, Severinia buxifolia, Atalantia ceylanica, Feronia limonia, Microcitrus papuana, Fortunella crassifolia,* and *Citrus ichangensis* (Grosser et al., 1995; 1996). These hybrids have been propagated and entered into commercial trials to determine their rootstock potential. The present study reports on the screening of some of these wide somatic hybrids and other selected germplasm for resistance to feeding by *Diaprepes* first instar larvae in an effort to identify potential rootstock sources for use in infested areas of Florida citriculture. The wild relative parent providing resistance to a resistant hybrid could be further hybridized with complementary citrus parents to provide a range of resistant hybrids.

Materials and Methods

Propagation of Test Material. All somatic hybrids and Cohen citrange were propagated using a routine rooted-cutting method (Sabbah et al., 1991). Healthy cuttings of these selections were dipped in an alcohol based solution containing 1000 ppm NM (naphthalene-acetic acid) and 1000 ppm IBA (indole-butyric acid), and placed upright into 38-welled containers that were placed on a heated mist-bed to induce rooting. After 8-12 weeks, containers were removed from the mist-bed and allowed to acclimate to normal greenhouse conditions. Healthy rooted plants were stepped up to 7.5" diameter plastic pots. Seedlings of sour orange, Swingle citrumelo, and ‘Limon Gigante’ were used in the study. The study was broken up into two experiments, based on plant availability. The first experiment included sour orange, Swingle citrumelo, and the following somatic hybrids: ‘Nova’ tangelo [‘Clementine’ × ‘Orlando’ tangelo] + *Citropsis gilletiana* Swingle & M. Kell.; ‘Succari’ sweet orange (*Citrus sinensis* (L.) Osbeck) + *Microcitrus papuana;* ‘Succari’ sweet orange + *Atalantia ceylanica* (Arn.) Oliv.; ‘Succari’ sweet orange + *Citropsis gilletiana;* and ‘Succari’ sweet orange + ‘Meiwa’ kumquat (*Fortunella crassifolia* Swing.). The second experiment included the triploid Cohen citrange (Grosser et al., 1993), ‘Limon Gigante’ (*Citrus limon*, provided by W. S. Castle) and the ‘Nova’ tangelo + *Citrus ichangensis* Swing. somatic hybrid.

Assay of Test Material. For the first experiment, 10 plants of each selection were established in 7.5" diameter plastic pots (one plant/pot) containing Fafard Citrus Mix B potting soil. Plants were established for 12 weeks in a greenhouse at a mean daily temperature of 27°C. Plants were watered and fertilized as needed. Eight pots of each selection were inoculated with neonate larvae of *Diaprepes abbreviatus* at 15 larvae per container. The two remaining pots of each selection served as un-inoculated controls. After 45 days, the experiment was concluded, and the number of larvae recovered per pot was recorded. Root biomass and fibrous root dry weights of each plant were determined. Root damage was rated subjectively by visual observation and scoring using the following scale: 1 = no visible injury; 2 = fibrous root loss; 3 = severe fibrous root loss/cortical injury; and 4 = stem girdling. Representative control and test plants of each selection were photographed. The second experiment was conducted the same way except that three uninoculated control plants of each selection were maintained, pots were inoculated with 10 larvae per pot, and the challenge by *Diaprepes* larvae was maintained for a period of 70 days.

Table 1. Average root rating, average root weight, and total # larvae recovered per genotype for Experiment 1.

Rootstock genotype	Treatment/ Reps	Root rating*	Root weight	No. of larvae
Sour orange	Control/2	1.0	2.93	—
	Test/8	1.9	1.84	27
Swingle citrumelo	Control/2	1.0	2.66	—
	Test/8	1.9	1.36	51
Nova + Citropsis	Control/2	1.0	1.67	—
	Test/8	2.9	0.74	41
Succari + Atalantia	Control/2	1.0	1.78	—
	Test/8	3.5	0.25	32
Succari + Atalantia	Control/2	1.0	1.15	—
	Test/8	3.0	0.53	26
Succari + Citropsis	Control/2	1.0	2.70	—
	Test/8	3.8	0.78	35
Succari + Meiwa	Control/2	1.0	2.27	—
	Test/8	3.2	0.41	37

*Root rating: 1 - no visible injury; 2 - fibrous root loss; 3 - severe fibrous root loss/cortical injury; and 4 - stem girdling.

Table 2. Average root rating, average root weight, and total # larvae recovered per genotype for Experiment 2.

Rootstock genotype	Treatment/ Reps	Root rating*	Root weight	No. of larvae
Limon Gigante	Control/3	1.0	2.77	—
	Test/8	4.0	0.01	32
Cohen citrange	Control/3	1.0	1.74	—
	Test/8	4.0	0.14	27
Nova + *C. ichangensis*	Control/3	1.0	1.96	—
	Test/8	4.0	0.02	22

*Root rating: 1 - no visible injury; 2 - fibrous root loss; 3 - severe fibrous root loss/cortical injury; and 4 - stem girdling.

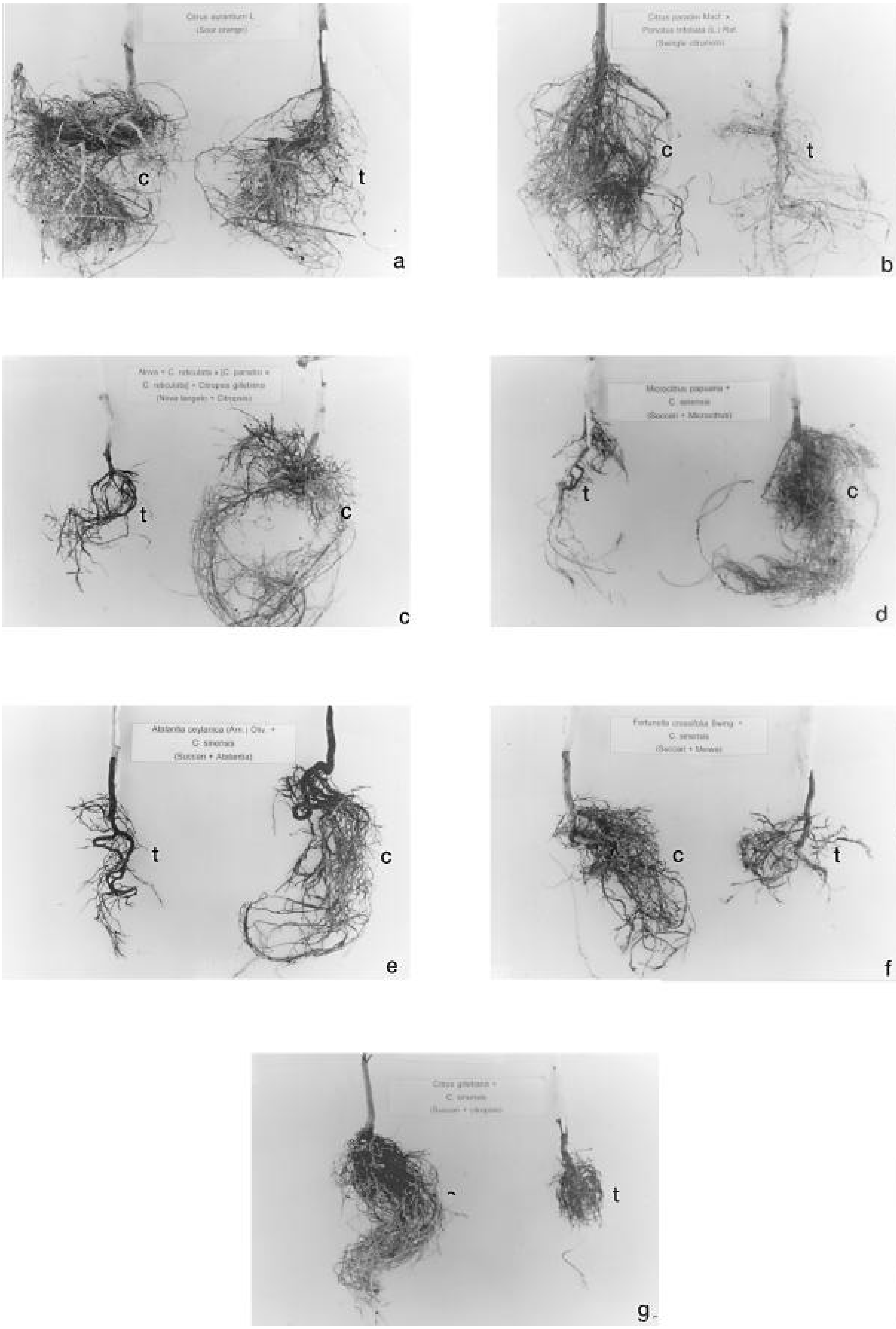

Figure 1. Comparison of roots from test (t) and control (c) plants in Experiment 1. a) sour orange, b) Swingle citrumelo, c) 'Nova' tangelo + *Citropsis gilletiana,* d) 'Succari' sweet orange + *Microcitrus papuana,* e) 'Succari' + *Atalantia ceylanica,* f) 'Succari' + *Citropsis gilletiana,* and g) 'Succari' + 'Meiwa' kumquat.

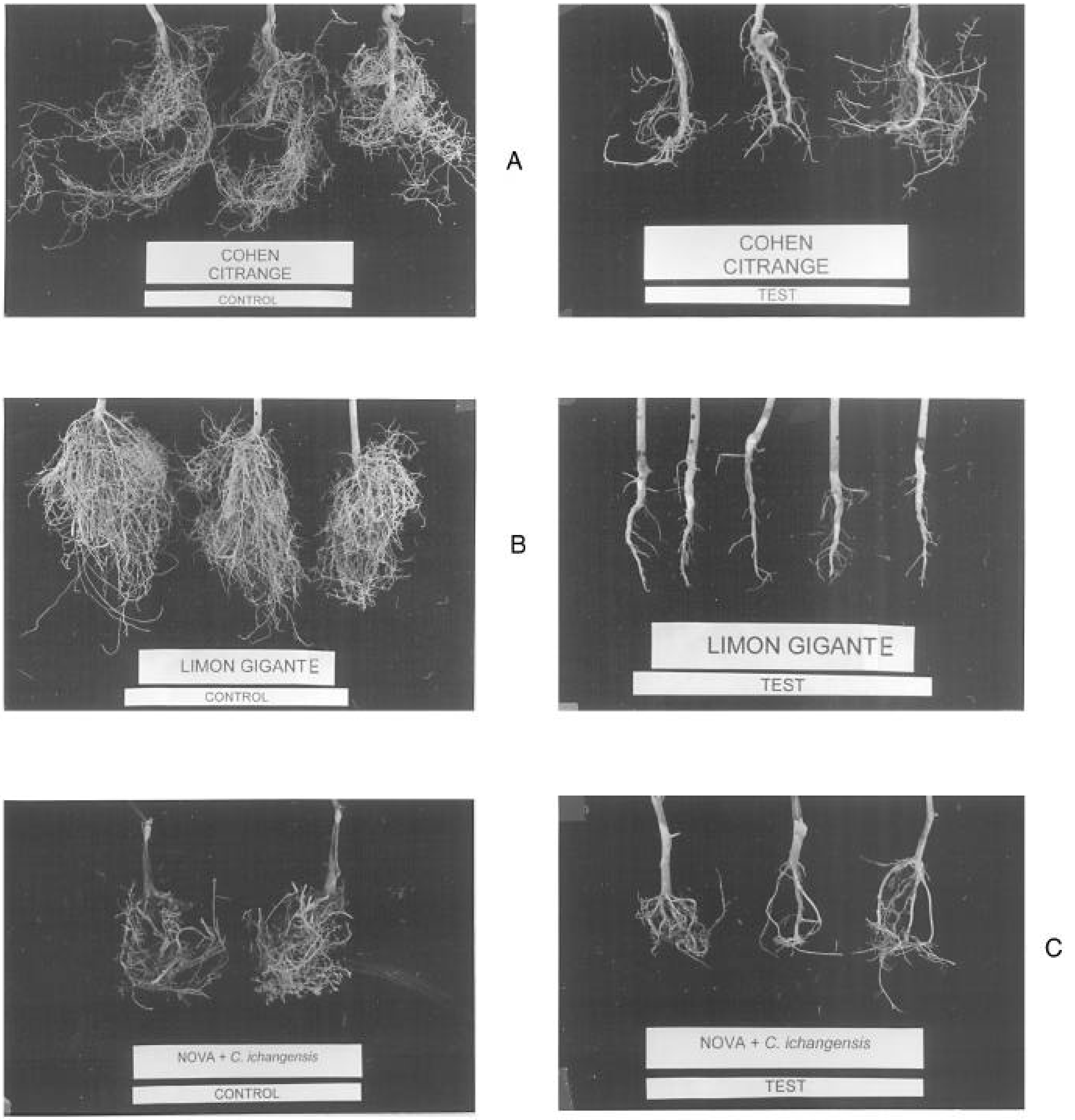

Figure 2. Comparison of roots from test and control plants in Experiment 2. a) 'Limon Gigante', b) Cohen citrange, and c) 'Nova' tangelo + *Citropsis gilletiana.*

Results and Discussion

Average root rating, average fibrous root dry weight, and total number of larvae recovered per plant selection are provided in Tables 1 and 2, for Experiments 1 and 2, respectively. Photographs of root systems of test and control plants following breakdown of Experiments 1 and 2 are provided in Figs. 1 and 2, respectively. Results clearly show that larvae of *Diaprepes abbreviatus* fed readily and caused significant damage to all genotypes included in this study. This supports previous studies that demonstrated an extremely wide host-range for *Diaprepes* (Beavers and Hutchison, 1985; Schroeder et al., 1979; Simpson et al., 1996). Beavers and Hutchison (1985) reported that seedlings of *Microcitrus australasica* and *Severinia buxifolia* were extremely susceptible to feeding by *Diaprepes* root weevil larvae. The somatic hybrid of 'Succari' sweet orange + *Microcitrus papuana* included in this study was equally susceptible. The *Citrus* related genera *Citropsis*, *Atalantia*, and *Fortunella* also failed to provide any resistance, as genetically additive somatic hybrids including these species as parents were severely damaged by larval feeding. Simpson et al. (1996) recently reported that adult *Diaprepes abbreviatus* weevils did not feed on leaves of *Citrus ichangensis* in a forced no-choice feeding experiment. However, the 'Nova' tangelo + *C. ichangensis* included in this study was severely damaged by larval feeding. Shapiro and Gottwald (1995) suggested that Swingle citrumelo may offer some resistance to root weevil larval feeding, but this was not supported by the present study, as Swingle was also badly damaged. 'Limon Gigante' was reportedly showing field resistance to *Diaprepes* root weevil feeding in the Dominican Republic, but it was severely damaged in this study. Although significantly damaged, the commercial rootstocks Swingle citrumelo and sour orange showed less damage than any of the wide hybrids tested. This can be attributed to the generally reduced vigor in the wide hybrids. The wide hybrids also had lesser developed root systems going into the experiment because they were propagated as cuttings, whereas the commercial rootstocks were seedlings. Root damage across all genotypes was much more severe in the second experiment than in the first. This can be explained by the fact that the second experiment was carried out for an additional 25 days (70 versus 45), giving the larvae more time to feed and cause damage. The results from these two experiments demonstrate that *Diaprepes* root weevil larvae readily feed and cause extensive damage to a wide range of hybrid *Citrus* germplasm.

Conclusion

Diaprepes abbreviatus larvae exhibit non-discriminatory feeding on young tree roots of *Citrus* and its wide hybrids. Somatic hybrids of *Citrus* with related genera are apparently not going to provide growers with an acceptable rootstock alternative. It is our opinion that future research should focus on the testing of vigorous rootstocks with excellent regrowth capacity and resistance to *Phytophthora*-induced diseases. Such rootstocks may have potential to overcome damage by root weevil larval feeding and grow into productive trees. Such trees could be profitable if maintained under an appropriate management scheme.

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EVALUATION OF FUNGICIDES FOR MANAGEMENT OF DEFOLIATION CAUSED BY *MYCOSPHAERELLA CITRI* (GREASY SPOT) IN 'HAMLIN' ORANGE

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Abstract. **Our objective was to compare the effectiveness of an experimental bicarbonate-based fungicide alone and in combination with benomyl, with two standard emulsified oil formulations in managing defoliation by *Mycosphaerella citri* Whiteside (greasy spot) in orange [*Citrus sinensis* (L.) Osbeck]. The experimental site was in a commercial grove of 6-year-old 'Hamlin' orange trees in southwest Florida. Fungicide treatments, a novel formulation of ammonium bicarbonate [(AB) 0.5% w/v], benomyl (2.2 kg a.i./ha), a reduced-rate combination of bicarbonate and benomyl (0.25% w/v + 1.1 kg a.i./ha), and petroleum distillates FC-435-66 (70 l/ha) or FC-455-88 (70 l/**

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