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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ha), were applied on 6 Jul., 1994 by a commercial air-blast sprayer calibrated to deliver 1400 l/ha. Each treatment and an untreated control was replicated 6 times using ten-tree blocks arranged in a randomized complete block design. Percentages of tree defoliation were estimated on 15 Nov., 20 Dec., 1994 and 27 Jan. and 24 Feb., 1995 using the Horsfall-Barratt disease rating scale. All treatments reduced the rate of greasy spot defoliation and all but benomyl reduced the final percentage of defoliation. FC 455-88 and AB plus benomyl were generally the most effective and the other treatments were of intermediate effectiveness in reducing greasy spot defoliation.

Greasy spot caused by the fungus *Mycosphaerella citri* Whiteside (Whiteside, 1972) was first reported in Florida in 1915 (Fawcett, 1915) and remains one of the most economically significant foliar diseases of citrus in the state. The disease also occurs in the Caribbean, and in regions of Central and South America and Asia with similar warm, humid climates (Whiteside, 1988). Leaves of all commercially grown *Citrus* spp. and many related genera are susceptible to varying degrees (Whiteside, 1972).

Symptoms progress from yellow spots on the upper leaf surface to irregular greasy lesions on both sides of leaves and premature leaf drop. Symptom expression takes 3-4 months in grapefruit (*Citrus paradisi* Macf.) leaves and much longer in orange (*C. sinensis* (L.) Osbeck). Greasy spot defoliation may occur even before full leaf symptoms develop but is generally not extensive in any host until after the onset of cold weather (November-December in southwest Florida). Severe defoliation can decrease fruit production significantly and may make the tree less able to recover from cold damage (Whiteside, 1984; Whiteside, 1988).

Current greasy spot management in Florida requires the application of an emulsified petroleum oil formulation such as FC-435-66 or FC 455-88 (the numbers 435 and 455 refer to the 50% distillation temperatures of these oils as measured in °F) or, in the case of the more susceptible cultivars, a combined oil and copper fungicide mixture (McGovern and Timmer, 1996). A single application of oil or oil combined with copper in June through early August generally provides acceptable control of greasy spot in oranges under low disease pressure. Benlate was used in the past for greasy spot control, but is no longer recommended because of the development of resistance to this fungicide by *M. citri* (Whiteside, 1980).

Sporadic research conducted over the last 70 years has examined the potential of sodium bicarbonate and, to a lesser extent, potassium bicarbonate to suppress *Penicillium digitatum*, *P. italicum*, *Geotrichum candidum*, and the storage rots they cause in citrus (Arimoto et al., 1977; Barger, 1928; Homma et al., 1981a; Homma et al., 1981c; Hwang and Klotz, 1938; Xu and Hang, 1989). Sodium bicarbonate was used for commercial disinfestation of citrus against *Penicillium* spp. in California during the late 1920's (Marloth, 1931). Green rot of citrus caused by *Penicillium digitatum* was reduced by storage in air currents passed through bottles containing damp crystals of ammonium bicarbonate (Tomkins and Trout, 1931). More recently there has been a renewed interest in the evaluation of bicarbonate-based fungicides for the management of diseases of ornamentals and vegetables (Bowen et al., 1995; Homma et al., 1981b; Horst et al., 1992; McGovern, 1993; Ricker and Punja, 1991; Punja et al., 1982; Ziv and Hagiladi, 1993; Ziv and Zitter, 1992). The objective of the current research was to evaluate the effectiveness of an experimental, environmentally compatible ammonium bicarbonate formulation alone and in combination with a reduced rate of benomyl in managing defoliation caused by *M. citri* in orange.

Materials and Methods

An experimental site was chosen within a commercial grove in southwest Florida consisting of 6-year-old 'Hamlins' on 'Swingle' rootstock. The fungicides evaluated included a novel formulation capable of *in situ* generation of ammonium bicarbonate [AB (2236/2346, Church & Dwight Co., Inc., Princeton, NJ, 0.5% w/v)], benomyl (2.2 kg a.i./ha), a reduced-rate combination of AB and benomyl (0.25% w/v + 1.1 kg a.i./ha), FC 435-66 (70 l/ha), and FC 455-88 (70 l/ha). The AB formulation was specifically developed for use on citrus based on *in vitro* studies which suggested that ammonium bicarbonate more effectively suppressed *M. citri* and other citrus pathogens than either sodium or potassium bicarbonate (McGovern, unpublished data).

Fungicides were applied on 6 Jul., 1994 by a commercial air-blast sprayer calibrated to deliver 1400 l/ha. Treatments and untreated controls were replicated 6 times using ten-tree blocks arranged in a randomized complete block design. Whole-tree defoliation percentages were obtained on 15 Nov., 20 Dec., 1994 and 27 Jan. and 24 Feb., 1995 using the Horsfall-Barratt disease rating scale (Horsfall and Barratt, 1945) which correlated well with greasy spot severity on leaves of individual flushes in a previous experiment (McGovern and Sommerfeld, 1994). Square root transformation was performed on defoliation percentages prior to statistical analysis using ANOVA followed by LSD (p ð 0.01) (SAS Institute Inc., Cary, NC).

Results and Discussion

None of the treatments produced detectable phytotoxicity (dieback, foliar necrosis, etc.). All treatments including benomyl significantly reduced the rate of greasy spot defoliation as measured by calculating the area under the disease progress curve (AUDPC) (Fig. 1 and Table 1). FC 455-88 was superior to FC 435-66 in this regard, confirming the general findings of Whiteside (1989) and the trend observed by Trammel and Simanton (1966) which indicated that the effectiveness of spray oils against greasy spot was directly related to increasing distillation temperature. All treatments except benomyl significantly reduced the final defoliation percentage, suggesting that the population of *M. citri* in this grove had developed resistance to benomyl to some extent (Table 1).

Table 1. Effect of fungicides on rate of greasy spot defoliation [area under the disease progress curve (AUDPC)], and final percentage of defoliation measured on 24 Feb., 1995 in six-year-old 'Hamlin' orange in southwest Florida.

Treatment	AUDPC	Final Defoliation (%)[y]
Control	2252 a[z]	39.1 a
Benomyl	1903 b	34.1 ab
Ammonium Bicarbonate (AB)	1811 b	29.8 bc
Oil (FC 435-66)	1646 b	28.9 bc
AB + Benomyl (1/2 rates)	1599 bc	27.1 c
Oil (FC 455-88)	1331 c	26.0 c

[z]Means within columns followed by different letters are significantly different by LSD (p ð 0.01).
[y]Square root transformation was performed on percentage data prior to statistical analysis (SAS Institute, Inc.); untransformed means are presented.

It is interesting to note that the AB formulation produced a reduction in the AUDPC and final defoliation comparable with the most commonly used oil spray, FC 435-66. In addition, the reduction in the rate of greasy spot defoliation and final defoliation by the AB-benomyl mixture was significantly different from benomyl alone and equivalent in effectiveness to the most effective oil, FC

EFFECT OF FUNGICIDES ON RATE OF DEFOLIATION BY *Mycosphaerella citri* (GREASY SPOT) IN `HAMLIN' ORANGES

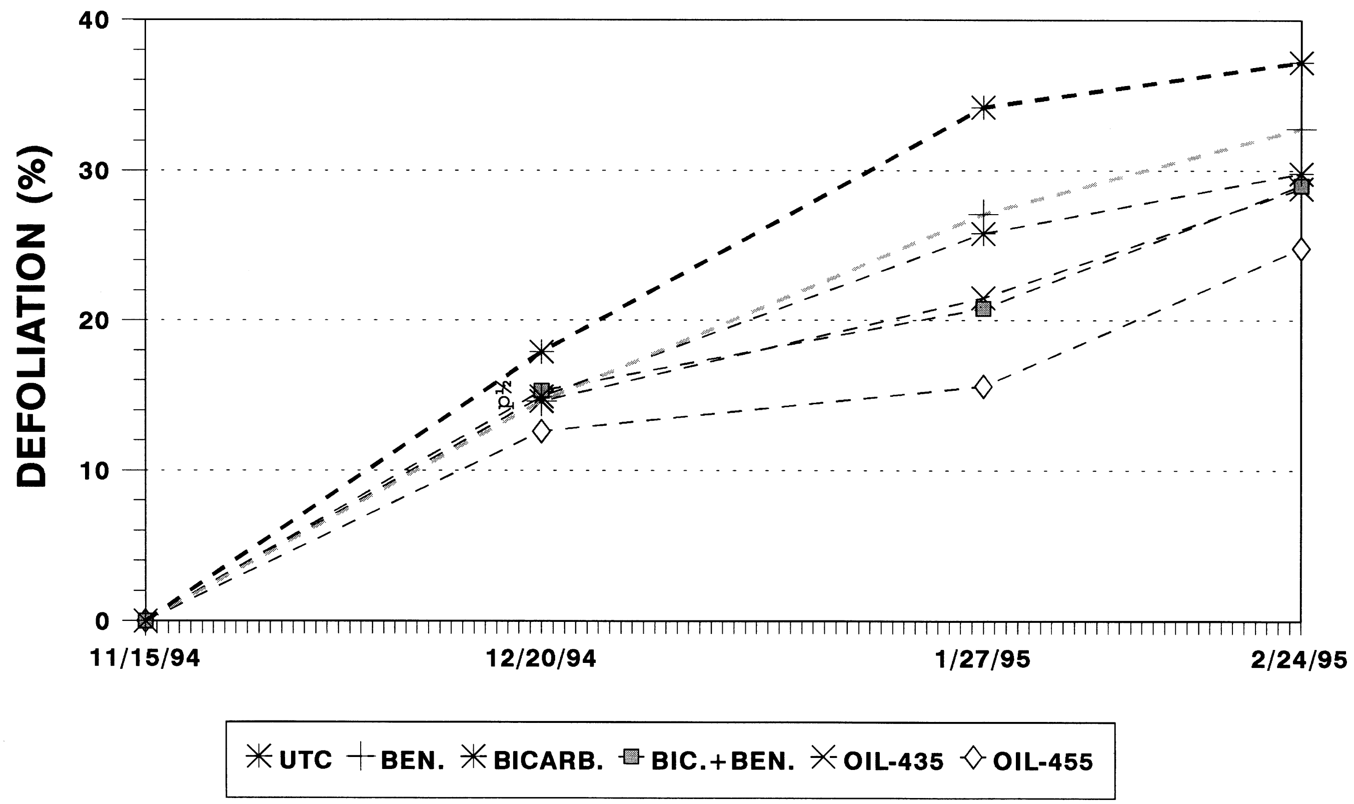

Figure 1. Effect of fungicides on the rate of greasy spot defoliation in 6-year-old 'Hamlin' orange in southwest Florida during 1994-1995. Bicarb. = ammonium bicarbonate formulation. The combined bicarbonate-benomyl combination consisted of both materials applied at half the rate at which each was used individually.

455-88, suggesting that the combination may have been synergistic. The formulation of ammonium bicarbonate evaluated in this study may have potential for the control of other plant diseases and for fungicide resistance management and rate reduction when used in combination or rotation with other fungicides.

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APHID POPULATIONS IN A FLORIDA CITRUS TRISTEZA VIRUS SUPPRESSION TRIAL

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Additional index words. Citrus Tristeza Virus, CTV, Hamlin orange, sour orange rootstock, brown citrus aphid, *Toxoptera citricida*, spirea aphid, green aphid, *Aphis spiraecola*, *Aphis citricola*, melon aphid, cotton aphid, *Aphis gossypii*, ELISA, vector.

Abstract. **Aphid populations were monitored weekly during a five-year study conducted in a sweet orange scion (Hamlin, *Citrus sinensis* (L.) Osbeck) on sour orange rootstock young tree planting. Sampling for citrus tristeza virus (CTV) was conducted once a year. Samples for CTV analysis were analyzed using an indirect double-antibody sandwich with enzyme-linked immunosorbent assay (ELISA). The presence of CTV was compared to aphid population increases found during the previous year. The 300 tree block was treated with several chemical aphid control regimes (Temik®, Meta-Systox R® and stylet oil) with little or no effect. Mild and severe isolates of CTV were observed throughout the block. Four double-sided 22.5 cm × 13.5 cm Pherocon® A.M. sticky traps posted on the borders of the block were used to catch and monitor aphids. In 88% of the weeks of observation either *Aphis spiraecola* (Patch), *Aphis gossypii* (Glover) or both species were the predominant aphids collected. These aphids were most abundant in March, April and May with a slight fall presence peaking in November. An increase in the number of *A. spiraecola* in 1993 was found to be correlated with a large increase in the presence of CTV in the block in early 1994. No distinct pattern of aphid movement was evident throughout the block.**

Introduction

Until the November 1995 discovery that the Brown Citrus Aphid (BrCA), *Toxoptera citricida* (Kirkaldy), had arrived in Florida, the state's endemic aphids most commonly found on citrus were: *Aphis spiraecola* (Patch), *Aphis gossypii* (Glover), *Aphis craccivora* (Koch), *Toxoptera aurantii* (Boyer de Fonscolombe), *Macrosiphum euphorbiae* (Thomas) and *Myzus persicae* (Sulzer) (Blackman and Eastop, 1984). The highest rate of transmission of Citrus Tristeza Virus (CTV) in Florida had been attributed to *A. gossypii*, the melon aphid, followed by *A. spiraecola* (=*citricola* van der Goot), the spiraea or green aphid (Norman and Grant, 1954; Yokomi and Garnsey, 1987). *T. aurantii*, the black citrus aphid, rarely transmits the virus (Yokomi and Garnsey, 1987), although it has been reported to do so (Simanton and Knorr, 1969; Norman and Grant, 1956). *M. persicae*, *M. euphorbiae* and *A. craccivora* have not been confirmed as vectors for CTV and are found only occasionally on citrus, preferring to colonize weed hosts (Oldfield and Yokomi, 1990; Yokomi, personal communication).

Since its discovery in Florida in the 1950's, the citrus tristeza virus has spread throughout all of the state's major growing areas (Garnsey, et al, 1980; Grant, 1952). During this time in the Indian River area, tristeza was first diagnosed as a budwood-transmitted disease which naturally spread rapidly during the late 1960's (Brlansky, et al. 1986). In 1963 Florida's budwood certification program still considered CTV-positive trees as registered, thereby causing further spread of the disease unbeknownst to nurseries involved in propagating new trees (Powell and Pelosi, 1993).

The brown citrus aphid is the most efficient known vector of CTV (Costa and Grant, 1951). Since its appearance in the New World, BrCA has quickly become the most abundant and predominant citrus-attacking species in each country it has infested (Yokomi and Tang, 1996). Because the same scenario is expected in Florida, we have summarized pre-*Toxoptera citricida* alate aphid activity (1990-1994) at the Indian River Research and Education Center on Florida's east coast at Fort Pierce.

Materials and Methods

A block of 300 CTV-free Hamlin sweet orange [*Citrus sinensis* (L.) Osbeck] trees on sour orange (*C. aurantium* L.) rootstock was planted May 1989 on double beds 9.15 m apart, 6.1 meters between rows, with between-tree spacing of 4.6 m. The block was established as an aphid/CTV chemical control experiment. The results of the natural field spread of CTV throughout the block have been reported by Powell, *et al*. (1996).

Alate aphid activity in the block was monitored using five yellow water pan traps and four yellow double-sided sticky traps. The pan traps were round, 25 centimeters in diameter, 7.5 cm deep and painted lemon yellow. Four pan traps were located between trees on the outside north and south rows of the block, three trees from

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