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COMMERCIAL USE OF CROSS-PROTECTION BY A MILD MUTANT OF PAPAYA RINGSPOT VIRUS FOR CONTROL OF RINGSPOT DISEASE OF SOLO PAPAYA IN THE BAHAMAS

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Abstract. **One mild nitrous acid-induced mutant (PRV HA 5-1) of papaya ringspot virus (PRV) was used in the inoculation of 1.5 ha of Solo Sunrise papaya. Seedlings were grown at the farm in a greenhouse using commercial cultural practices. The 4 to 5 leaf stage of papaya seedling was infected by applying inocula with a spray gun equipped with a 1.2 mm diameter nozzle, using pressure of 8 kg/cm at a distance of 20 cm. Each batch, enough plants for a 0.4 hectare planting, was inoculated twice before transplanting. From the 22,500 plants transplanted only 1.3% escapes were rouged with severe PRV. Papaya Ring Spot virus pressure was reduced by destroying diseased plants within an 8.0 km radius from the farm.**

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INFLUENCE OF ROOTSTOCK ON FLOOD TOLERANCE OF TAHITI LIME TREES

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Abstract. **Responses of Tahiti lime (*Citrus* x 'Tahiti') to flooding were compared among trees budded on 3 different rootstocks or propagated by marcottage. Marcots and trees budded on 1-year-old seedling rootstocks of alemow (*Citrus macrophylla* Wester), sour orange (*Citrus aurantium* L.), or grapefruit (*Citrus paradisi* Macf. 'Pine Island') were grown in an organic medium in a glasshouse and subjected to either continuous or intermittent flooding for 35 days. Percent tree survival, net CO_2 assimilation (A), transpiration (E), and water use efficiency (WUE) were determned at 7-day intervals for all trees. At the end of the experimental period, roots were assayed for *Phytophthora* spp., which was not found on any tree. After 7 days of flooding, trees grafted on sour orange had the greatest percent mortality. Twenty one days of flooding resulted in 100% mortality of all budded trees, but only 20% mortality of marcots. Net CO_2 assimilation of continuously flooded trees declined over time, but the rate of decline was greatest for trees on sour orange rootstock and least for the marcotted trees. After 35 days of intermittent flooding, tree mortality was greatest for sour orange, followed by alemow; there was no mortality of marcotted trees or those on grapefruit rootstock. For intermittently flooded trees, net CO_2 assimilation of grafted trees declined during flooding but generally increased to pre-flood rates after removal from flooding. Net CO_2 assimilation of marcotted trees was not affected by intermittent flooding. Transpiration and WUE generally declined over time for all continuosly flooded trees, but was variable for intermittently flooded trees. The data indicate that for Tahiti lime grown in an organic medium, marcotted trees are relatively flood-tolerant and trees grafted on sour orange rootstock are flood-sensitive.**

Tahiti lime (*Citrus* x 'Tahiti') has the highest total market value and, after avocado, occupies the largest land area (over 3000 hectares) of any fruit crop grown in Dade County, Florida (2). Traditionally, limes have been grown east of a canal system built to control seasonal fluctuations in the level of the water table. Recently, however, cultivation of tropical and sub-tropical fruits, including lime, has moved west of the canal system, toward the Everglades National Park. Although a system of mounds and drainage ditches partially compensates for the periodic flooding that occurs in this area, heavy rains often result in a water level that is several centimeters above the soil for prolonged periods.

Flooding detrimentally affects many tropical and subtropical fruit crops including avocado (9,10,13), mango (7), carambola (6), and citrus (8,16). Early symptoms of flooding stress include decreased net photosynthesis, stomatal conductance, and transpiration (1,9,14). Prolonged flooding usually results in a cessation of root and shoot growth, wilting, decreased nutrient uptake, and eventually tree death (14).

For grafted plants, the ability to tolerate flooding is usually related to the rootstock and not the scion (1,5,11,14). In Dade County, Tahiti limes are grown as either marcots or on one of several rootstocks (*C. macrophylla* is the most common) (3,4). Knowledge of the relative tolerance of various rootstocks and marcots to flooding may allow growers to select the best rootstock for Tahiti lime for flood-prone areas. The purpose of this study was to compare flood-tolerance among marcotted Tahiti lime trees or those budded onto 3 different rootstocks.

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Materials and Methods

Tahiti lime buds were T-budded onto seedling rootstocks of either grapefruit (*Citrus paradisi* Macf. 'Pine Island'), sour orange (*Citrus aurantium* L.), or alemow (*Citrus macrophylla* Wester), or were propagated by marcottage. Seeds, budwood, and marcots were obtained from trees at the University of Florida, Tropical Research and Education Center in Homestead. Seeds were sown in flats and transferred to 3.8 liter plastic pots containing Promix® 6 months after emergence and budded 6 months later. Marcots were made in March, 1987, removed from the tree 2 months later and planted in Promix® in 3.8 liter plastic pots. Budded trees and marcots were kept outdoors for a period of 6 and 18 months, respectively, prior to the beginning of the experiment. Plants were fertilized monthly with a 8N-3P-9K granular fertilizer and a 20N-20P-20K soluble fertilizer in the irrigation water. Trees were irrigated 2-3 times per week.

Six months after budding, plants on each of the rootstocks and the marcots were divided into 3 flooding treatments: 1) continuously flooded; 2) intermittently flooded (flooded for 7 days and then unflooded for 7 days); and 3) the nonflooded control. Each treatment consisted of 5 or 6 single-plant replications for each of the 3 rootstocks and marcotted trees in a completely randomized design.

Trees were flooded by placing pots in plastic tubs filled with tap water to about 2 cm above the top of the pot. The length of the flooding period was 35 days. The experiment was conducted in an air-conditioned glass-house; temperature was 24.5 ± 4.5°C.

Prior to flooding and at 7-day intervals thereafter, net CO_2 assimilation (A) and transpiration (E) were determined with a portable gas exchange system (Analytical Development Corp., Hoddesdon, Herts., England) as described by Schaffer and O'Hair (12). Water-use efficiency (WUE) was calculated as A divided by E. Percent tree mortality was determined at weekly intervals for plants in each treatment.

Within one week after plants died or at the end of the experimental period for surviving plants, roots were assayed for *Phytophthora*, the genus containing the fungi that cause foot rot of Tahiti lime. Trees were assayed using a modification of the procedures described by Ploetz and Schaffer (9). For fungal assays, 6 randomly selected root segments (about 1 cm long) were rinsed in tap water, surfaced sterilized in 95% EtOH for 30 sec, rinsed in sterile, deionized water and placed on a semi-selective agar medium (15) on petri plates (3 stem segments per plate) and incubated in the dark for at least 3 days. Plates were then examined for the presence of *Phytophthora* spp.

Results

Throughout the experiment, there were no visible signs of stress or mortality of the nonflooded (control) trees. Prior to flooding (Figs. 1 and 2) and throughout the experiment for nonflooded trees (data not shown), A and E were lowest for limes on *C. aurantium* rootstock; there was no difference in A and E among plants in the other treatments on any measurement date. Generally, there was no difference in WUE among rootstocks for the nonflooded trees (data not shown).

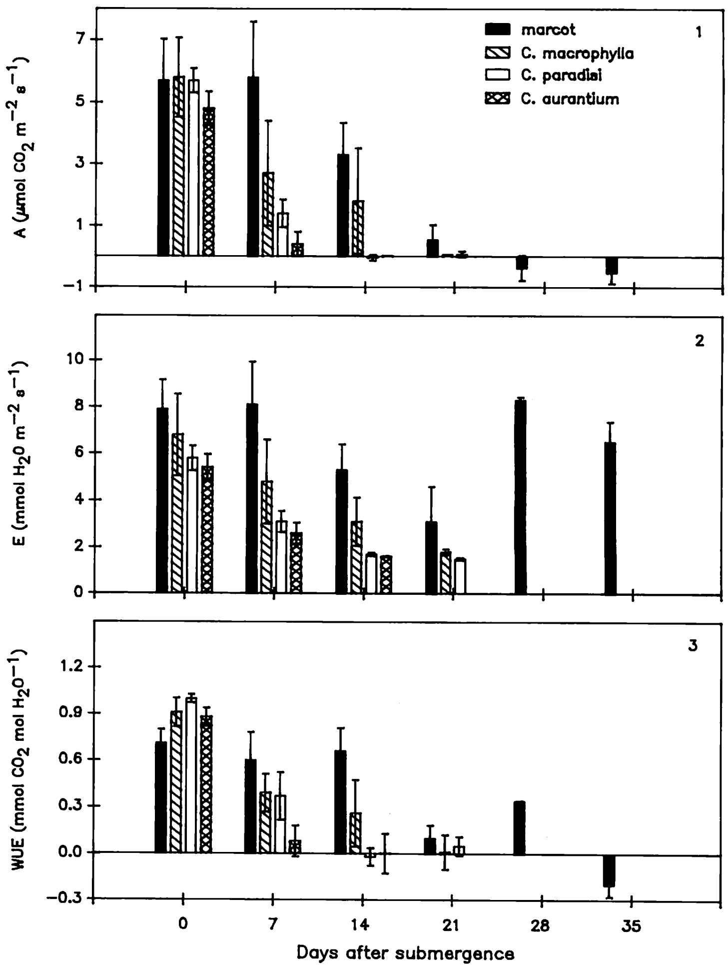

Fig. 1. Effect of continous flooding on 1) net CO_2 assimilation (A), 2) Transpiration (E), and 3) water-use efficiency (WUE) of Tahiti lime on four rootstocks. Wide bars represent means and narrow bars represent ± 1 SE.

After 7 days continous flooding, trees on *C. aurantium* rootstock had the greatest percent mortality and some of the trees on *C. paradisi* rootstock also died (Table 1). After 21 days of continous flooding, mortality was 100% for all budded trees, whereas marcots exhibited only 20% mortality. After 35 days of continous flooding, mortality of the marcots had risen to 83 percent.

Fourteen days after submergence, mortality of intermittently flooded trees on *C. aurantium* and *C. macrophylla* rootstock was 67% and 33%, respectively (Table 1). By day 35, mortality for plants on *C. aurantium* and *C. macrophylla* rootstock was 83% and 50%, respectively. No intermittently flooded marcots or trees on *C. paradisi* rootstock died by the end of the study (Table 1). No *Phytophthora* spp. were detected in any of the roots samples examined from trees in any of the treatments.

Seven days after submergence, A, E, and WUE were generally greater for marcotted trees than for budded trees (Figs. 1 and 2). At that time, trees on *C. aurantium* rootstock tended to have the lowest A, E, and WUE. Although only the marcots survived more than 28 days of continous flooding, mean A rates of these trees were below zero on days 28 and 35 (Fig. 1).

Although there was weekly variation in A, E, and WUE, there was no significant effect of intermittent flooding on these variables for marcotted trees (Fig. 2). Net CO_2 assimi-

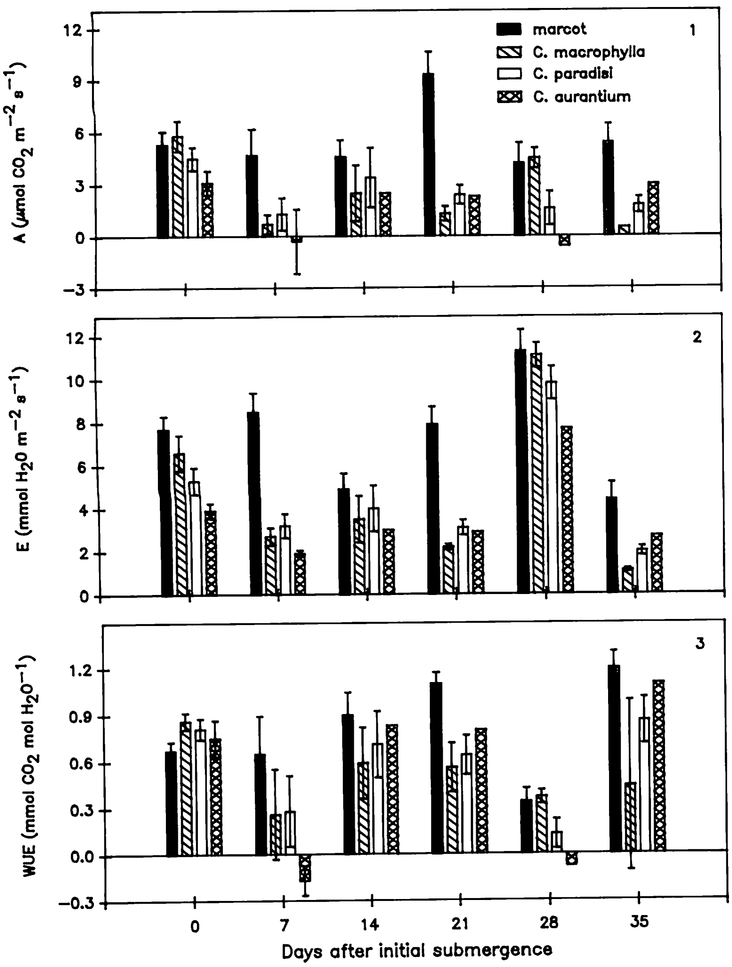

Fig. 2. Effect of intermittent flooding (repeatedly flooded for 7 days and then unflooded for 7 days) on 1) net CO_2 assimilation (A), 2) Transpiration (E), and 3) water-use efficiency (WUE) of Tahiti lime on four rootstocks. Wide bars represent means and narrow bars represent ± 1 SE.

lation of budded trees was generally reduced by intermittent flooding (Fig. 2). Transpiration of budded trees was lower than that of the marcots after 7 days of flooding, but 7 days after unflooding, E of budded trees recovered to rates similar to those of the marcotted trees (Fig. 2). There were no consistent effects of intermittent flooding on WUE of budded trees or marcots (Fig. 2).

Discussion

The data from this study indicate that although Tahiti lime trees are susceptible to long-term flooding, marcotted trees are more flood-tolerant than trees budded on any of the 3 rootstocks tested. *Citrus macrophylla* and *C. aurantium* are generally thought to be flood-tolerant rootstocks (C. W. Campbell, personal communication). However, this is based on the fact that these two rootstocks are resistant to foot rot caused by *Phytophthora* spp. (3,17). Studies on the interaction between flooding and *Phytophthora cinnamomi* on avocado have shown that the combination of flooding and the pathogen result in a synergistic or additive decline in tree vigor (9,10,13). Campbell (4) observed that while Tahiti lime on *C. macrophylla* and *C. aurantium* rootstock had good growth and yield under nonflooded conditions in southern Florida, limes on *C. paradisi* rootstock performed poorly, and were highly susceptible to

Table 1. Effect of continuous or intermittent flooding on percent mortality of young Tahiti lime (*Citrus* x Tahiti) trees on marcots and 3 different rootstocks.

Roots	Days after submergence 0	7	14	21	28	35
	Percent Mortality					
	Continuously flooded					
Marcot	0[1]	0	20	60	83	
C. macrophylla	0	0	0	100	–	–
C. paradisi	0	17	17	100	–	–
C. aurantium	0	60	60	100	–	–
	Intermittently flooded[2]					
Marcot	0	0	0	0	0	0
C. macrophylla	0	33	33	50	50	50
C. paradisi	0	0	0	0	0	0
C. aurantium	0	50	67	83	83	83

[1]At the beginning of the experiment N = 5 or 6
[2]Intermittently flooded plants were alternately flooded for 7 days and unflooded for 7 days.

phytophthora foot rot. Therefore, in *Phytophthora*-infested soil, *C. macrophylla* and *C. aurantium* would be a better choice of rootstock than *C. paradisi*. However, since Tahiti lime trees are rarely affected by phytophthora foot rot in southern Florida (3), the performance of these plants may be more related to soil conditions.

Marcotted and budded lime trees both appear to adapt to intermittent, short-term flooding, typical of that which occurs in southern Florida, although marcots tolerated intermittent flooding better than budded trees. Repeated flooding cycles reduced the vigor of budded trees, as indicated by reduced photosynthesis, whereas net CO_2 assimilation of marcotted trees was virtually unaffected. Thus, under conditions typical of flood-prone areas in southern Florida, marcotted trees may be a better choice than budded trees.

An additional advantage of marcotted trees is that they are relatively easy to produce and come into bearing early (4). However, as marcotted trees mature, their productivity may decrease relative to budded trees (4). Therefore, for adequately drained soils, budded trees may be preferential.

Although Tahiti lime marcots were more flood-tolerant than budded trees, it is important to point out that this study was conducted in an organic media with a good water-holding capacity. The soils in southern Florida, are very porous with a poor water holding capacity. Therefore, further investigations in soil types native to southern Florida are needed to confirm the effects of long-term and cyclical flooding on the flood-tolerance of Tahiti lime trees on various rootstocks.

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BUD FORCING METHOD AFFECTS EARLY SCION DEVELOPMENT OF CONTAINER-GROWN 'HAMLIN' NURSERY TREES

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Abstract. **Greenhouse-grown Carrizo citrange [*Citrus sinensis* (L.) Osb. x *Poncirus trifoliata* (L.) Raf.] seedlings were budded with 'Hamlin' orange [*Citrus sinensis* (L.) Osb.]. Three treatments were used to force bud growth: (a) cutting off [C] the seedling above the bud union; (b) lopping [L] by cutting half way through the seedling above the bud union and breaking the seedling top over; or (c) bending [B] the seedling top over and tying it to the base of the plant. Plants were harvested, dried and weighed as scions grew following forcing. Seedling tops of L and B plants were labeled with $^{14}CO_2$ at 3 stages of scion development and plants were harvested 24 hr after labeling. Plants with seedling tops attached (L,B) gained more scion and whole plant dry weight than C plants. Root dry weight gain, shoot length, leaf number and leaf area were greater for B plants than for C plants. During early stages of scion development, a greater percent of labeled photosynthate was translocated from seedling leaves of B plants than from seedling leaves of L plants. Movement of ^{14}C photosynthate within nursery plants was primarily to shoots during growth flushes, and to roots during periods between growth flushes.**

Reducing, or eliminating, rootstock apical dominance is a standard nursery practice which allows the bud, inserted during grafting, to develop the upper portion of the tree. The methods commonly used in citrus nurseries to force scion bud growth are: (a) cutting off, (b) lopping and, (c) bending/tying (looping). While each method is used in Florida, lopping and "cutting off" are most popular in field and greenhouse nurseries, respectively (1,5). Claims have been made that bending/tying and lopping are superior to "cutting off" because the rootstock top may serve as a source of photosynthate for developing scions (2,3). Moore (2) reported faster growth from bending/tying and lopping than from "cutting off", and described scion growth as continuous rather than cyclic as with "cutting off". However, Moore reported no data. Amih's (1) studies of the effects of forcing method on nursery tree growth were inconclusive. Amih suggested that such factors as scion and rootstock cultivar, environment, and season may affect plant response to forcing method. Rouse (4) reported that bending/tying with seedling leaves remaining below the bud union was superior to other forcing methods for 'Rio Red' grapefruit [*Citrus paradisi* (Macf.)] budded on sour orange [*Citrus aurantium* (L.)] rootstock. Bending/tying has resulted in lower percent bud break than has "cutting off" when seedling leaves below the bud were removed (4).

Bud forcing method probably affects many physiological processes which may directly, or indirectly, influence growth and development of nursery trees. Understanding the contributions of seedling tops to the growth of citrus nursery plants may enable nursrey managers to achieve more rapid and uniform growth of nursery scions following bud forcing. The purpose of this study was to quantify the effects of seedling tops on the dry weight gain and scion development of nursery plants and to evaluate the extent of photosynthate transfer from seedling tops to other plant parts at several stages of scion growth following bud forcing.

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