68. Wood, B. W. 1988. Fruiting affects photosynthesis and senescence of pecan leaves. J. Amer. Soc. Hort. Sci. 113:432-436.
69. Wood, B. and J. Payne. 1984. Influenoe of single applications of insecticides on net photosynthesis of pecan. HortScience 19:265-266.
70. Xiloyannis, C., S. Natali, S. Fregni, and L. Botrini. 1986. The effect of relative humidity on transpiration in kiwifruits and olive trees and leaf desiccation in kiwifruits. Rivista di Fruticoltura e di Ortofloricoltura 48:43-47.
71. Xiloyannis, C., K. Uriu, and G. C. Martin. 1980. Seasonal and diurnal variations in abscisic acid, water potential and diffusive resistance in leaves from irrigated and non-irrigated peach trees. J. Amer. Soc. Hort. Sci. 105:412-415.
72. Young, E., J. M. Hand, and S. C. Weist. 1981. Diurnal variation in water potential components and stomatal resistance of irrigated peach seedlings. J. Amer. Soc. Hort. Sci. 106:337-340.

Proc. Fla. State Hort. Soc. 102:234-236. 1989.

PERFORMANCE OF CLONAL AVOCADO ROOTSTOCKS IN DADE COUNTY, FLORIDA[1]

RANDY C. PLOETZ, JOSÉ L. RAMOS, JORGE L. PARRADO, BRUCE SCHAFFER, AND S. PABLO LARA
University of Florida, IFAS
18905 SW 280th Street
Homestead 3303

Abstract. **Six clonal rootstocks of *Persea americana* ('Bo Borchard', 'Duke 7', 'G1033', 'Parida', 'Thomas', and 'Toro Canyon') and two clonal rootstocks of *P. americana* X *schiedeana* ('G755b' and 'G755c') were obtained from a commercial nursery in California and tested under conditions found in production areas of Dade County, FL. Rootstocks were grafted with 'Choquette' scions and planted in pots filled with Rockdale fine sandy loam infested or not infested with *Phytophthora cinnamomi.* After about four months, a portion of the plants in infested and noninfested soil were flooded for one week. At the end of the flooding period net CO_2 assimilation (photosynthesis), percent root necrosis, and root, shoot, and total plant dry weight were determined for flooded and nonflooded plants. All plant responses were significantly influence by rootstock cultivar, and these responses were generally not affected by flooding or challenge with *P. cinnamomi.* 'Parida', 'G1033', 'Toro Canyon', and 'Duke 7' exhibited reduced photosynthesis and biomass accumulations, as well as foliar symptoms of Fe-deficiency and poorly formed and necrotic root systems. Although these results are from a single experiment, it appears that adaptation to alkaline soils may be a primary determinant of the performance of these rootstocks in Dade County.**

The Florida avocado industry is based on cultivars of the West Indian (WI) and Guatemalan (G) races of *Persea americana* and their hybrids. During standard cultural practices, scions of these cultivars are grafted onto seedlings of either 'Lula' (G X WI) or 'Waldin' (WI) (4). The large seed of the latter cultivars produce vigorous, uniform rootstocks which are well-adapted to the calcareous soils in which avocados are grown in Dade County, FL. However, both cultivars are suceptible to phytophthora root rot which is caused by *Phytophthora cinnamomi* (3). The pathogen is widespread in Dade County, and in combination with flooding, phytophthora root rot can cause severe damage to avocado trees in the area (2, 3, 5).

Avocado rootstocks that resist phytophthora root rot have been identified at the University of California at Riverside (1, 8). The program started by Dr. George Zentmyer has produced several tolerant clones and the best of these are now available through commercial nurseries in California.

Our research on the root rot X flooding interaction has focused on identifying responses of avocado in Florida to these factors and on controlling root rot in the presence or absence of flooding. In the present study we assessed eight different cultivars of rootstock developed in the California program under conditions found in avocado production areas in Dade County; rootstock performance was determined with host parameters that are affected by root rot and flooding (3, 5).

Materials and Methods

Rootstocks were clonally propagated by Brokaw Nursery, Inc., Saticoy, CA and air-freighted to Homestead. According to instructions provided by the nursery, rootstocks were grafted within 2-3 days of arriving in Homestead; scions of 'Choquette' were used on all plants. After roots on the clonal rootstocks were well-established, the nurse seed was cut from the clone, the cut surface was treated with Captan fungicide (Captan 50W, Stauffer Chemical Co., Mountain View, CA), and plants were transferred individually to 15 cm-diameter pots filled with a peat-perlite potting medium. After about two months, they were transplanted into 20 cm-diameter pots filled with Rockdale fine sandy loam either infested or not infested with sorghum seed that was colonized by *P. cinnamomi* (3). Plants were incubated in a non-air-conditioned greenhouse in which temperatures ranged from 20-39 C, watered as needed, and drenched about every 2-3 weeks with a commercial 20-20-20 fertilizer. Label rates of a commercial sequestered Fe formulation (Sequestrene 138 Fe, Ciba-Geigy Corp., Greensborough, NC) were applied to all plants one and two months after transplanting, and foliar symptoms of Fe-deficiency were rated visually with the scale devised by Young (7) about one month after each Fe application.

After four months, half of the infested and noninfested plants were flooded for one week in fiberglass reservoirs such that water levels were maintained about 2 cm above the soil surface. Net CO_2 assimilation (net photosynthesis) was determined at the end of the week with a portable gas and water vapor exchange analyzer and a Parkinson leaf

This work was supported, in part, by grants from the Florida Avocado Administrative Committee and the Cooperative State Research Service, USDA, Agreement no. 88-34135-3567. The authors thank Brokaw Nursery, Inc., Saticoy, CA for the generous donation of rootstocks used in the study.
[1]Florida Agricultural Experiment Station Journal Series No. N-00046.

chamber described previously by Schaffer and Ploetz (5). A slide projector was used to illuminate leaves in the chamber to insure that photosynthetic photon fluxes exceeded saturation for avocado (6).

Root systems were harvested after the measurement of photosynthesis and washed free of soil under flowing water. Percent root necrosis was determined visually and necrotic roots were assayed for colonization by *P. cinnamomi* by plating on a selective medium (3). Roots and shoots were dried at 70 C for dry weight determinations.

Results

Of the variables tested, only rootstock cultivar had a consistent effect on host responses tested (Tables 1 and 2). Flooding and infestation of soil with *P. cinnamomi* had no or minor effects on net photosynthesis, root necrosis, and dry matter accumulation of plants in the study. Rootstock cultivar had a significant effect ($P < 0.05$) on net photosynthesis, dry matter accumulation, root necrosis, and foliar symptoms of Fe-deficiency (Tables 1 and 2).

Phytophthora cinnamomi was not recovered from plants in noninfested soil. In infested soil, *P. cinnamomi* was never recovered from 'Duke 7', 'G1033', 'Parida', and 'Thomas', was recovered infrequently from 'G755b', 'G755c', and 'Toro Canyon' (i.e., < 1% of all assayed roots), and from about 9% of the necrotic roots of 'Bo Borchard'; rates of recovery for the different cultivars were not significantly different.

Discussion

To a limited or great extent, each host response tested gave an indication of the probable performance of each cultivar in avocado-production areas of Dade County. For example, 'Parida' had significantly lower rates of photosynthesis and dry matter accumulations, and higher levels of root necrosis and foliar Fe-deficiency than some or all of the other cultivars tested; it would probably not be a good rootstock for the area. In contrast, other cultivars such as 'G755b', 'G755c', 'Bo Borchard', and 'Thomas' appear to be well-adapted to soil and conditions in the area (i.e., flooding) and further work may demonstrate their value in Dade County.

Table 1. Response of plants on different avocado rootstocks to growth in Rockdale fine sandy loam.[w]

Rootstock cultivar[x]	Botanical description[y]	Mean Pn[z]	Mean dry weight (g) shoot	root	total
Bo Borchard	*P. americana* M	5.4 ab	169.7 a	39.5 a	209.2 a
Duke 7	*P. americana* M	5.1 ab	95.2 bc	20.7 c	115.9 bc
G755b	*P. americana* G X *P. schiedeana*	6.3 a	116.2 b	31.0 ab	147.2 b
G755c	*P. americana* G X *P. schiedeana*	3.5 ab	170.9 a	30.8 ab	201.8 a
G1033	*P. americana* G	3.5 ab	59.3 bc	17.1 c	76.3 bc
Parida	*P. americana* G X M	1.3 b	45.6 c	17.6 c	63.2 c
Thomas	*P. americana* M	2.0 ab	121.8 ab	25.5 bc	147.3 ab
Toro Canyon	*P. americana* M	3.2 ab	76.8 bc	16.4 c	93.1 bc

[w]Rootstocks were grafted with scions of 'Choquette' and planted in Rockdale fine sandy loam. Plant responses were tabulated after about 4 months. Since neither infestation of soil with *Phytophthora cinnamomi* nor flooding significantly ($P < 0.05$) affected these host responses, responses for each cultivar were pooled across treatments for analysis. Means in columns followed by the same letter are not significantly different according to Tukey's studentized range test at $P < 0.05$.
[x]Rootstocks were clonally propagated by Brokaw Nursery, Inc., Saticoy, CA.
[y]The rootstocks of *Persea americana* are either of the Mexican (M) or Guatemalan (G) race, or are G X M hybrids. 'G755b' and 'G755c' are interspecific crosses between *P. americana* G and *P. schiedeana*. This information was kindly provided by Dr. Bob Bergh, University of California at Riverside.
[z]Mean Pn = net assimilation of CO_2 in µmols m^{-2} s^{-1} for all leaves assayed for a given cultivar.

Table 2. Recovery of *Phytophthora cinnamomi* from and root necrosis and foliar symptoms of Fe-deficiency for avocado plants on different rootstocks planted in Rockdale fine sandy loam.

Rootstock cultivar	Mean % root necrosis[x] Flooded	Nonflooded	Fe-deficiency[y]	Mean % recovery of *P. cinnamomi*[z]
Bo Borchard	30.3 b,e	22.3 b,e	0 b	9.4
Duke 7	24.0 b,e	21.7 b,e	0 b	0
G755b	29.0 b,e	15.8 b,f	0.1 b	0.2
G755c	33.3 b,e	27.1 b,e	0.1 b	0.3
G1033	33.8 b,e	20.0 b,e	0.3 b	0
Parida	68.3 a,e	58.0 a,e	0.7 a	0
Thomas	28.8 b,e	22.0 b,e	0 b	0
Toro Canyon	45.0 ab,e	27.5 b,e	0 b	0.3

[x]Since the *Phytophthora cinnamomi* X flooding interaction was not significant ($P < 0.05$), infested and noninfested values were pooled for analysis. Means followed by the same letter within a column (a-b) or row (e-f) are not significantly different according to Tukey's studentized range test and t-tests, respectively, at $P < 0.05$.
[y]Foliar Fe-deficiency was rated with the system described by Young (7). Mean ratings followed by the same letter are not significantly different according to Tukey's studentized range test at $P < 0.05$.
[z]Mean recovery of the pathogen is from necrotic roots of plants in flooded and nonflooded, infested soil; means were not significantly different at $P < 0.05$ according to Tukey's studentized range test.

Performance of the rootstocks was influenced greatly by their tolerance of the alkaline, calcareous soil that was used in the experiment. Since the parent material of Rockdale fine sandy loam is oolitic limestone, the pH of this soil averages about 7.6 and Fe-deficiencies develop easily in avocados grown in the soil (4, 6). Some of the cultivars in the present study developed symptoms of Fe-deficiency, even though the plants were treated with supplemental Fe. For example, 'Parida' often developed conspicuous interveinal chlorosis in young foliage and had poorly formed and often very necrotic root systems (Table 2). Significantly smaller root and shoot systems for 'Parida', 'G1033', 'Toro Canyon', and 'Duke 7' may have also been caused, in part, by nutritional imbalances (Table 1).

All of the cultivars tested except 'Bo Borchard' are moderately to highly resistant to phytophthora root rot (1). That 'Bo Borchard' was not affected by *P. cinnamomi* was somewhat surprising and probably indicates that plants in the experiment were not challenged greatly by phytophthora root rot. Temperatures ranged as high as 39 C in the greenhouse that was used in the study, and it may have been too hot for significant disease development under these conditions. Zentmyer (8) determined that optimal temperatures for disease development range from 15-27 C and that a sharp decrease in the effects of the disease occurs at 33 C. Thus, high temperatures in the present study probably influenced disease development and a significant influence of root rot on 'Bo Borchard' rootstocks may have been detected if these plants had been incubated under more moderate temperatures. This work should be repeated under conditions in which temperature can be better controlled.

Literature Cited

1. Coffey, M. D. 1987. Phytophthora root rot of avocado: An integrated approach to control in California. Plant Dis. 71:1046-1052.
2. Ploetz, R. C. and Parrado, J. L. 1988. Quantitation and detection of *Phytophthora cinnamomi* in avocado production areas of south Florida. Plant Dis. 72:981-984.
3. Ploetz, R. C. and Schaffer, B. 1989. Effects of flooding and Phytophthora root rot on net gas exchange and growth of avocado. Phytopathology 79:204-208.
4. Ruehle, G. A. 1963. The Florida Avocado Industry. Univ. Florida Agr. Expt. Sta. Bull. No. 602.
5. Schaffer, B. and Ploetz, R. C. 1989. Net gas exchange as a damage indicator for Phytophthora root rot of flooded and nonflooded avocado. HortScience 24:653-655.
6. Scholefield, P. R., J. J. Walcott, P. E. Kriedemann, and A. Ramadasan. 1980. Some environmental effects on photosynthesis and water relations of avocado leaves. Calif. Avocado Soc. Yrbk. 64:93-105.
7. Young. T. W. 1969. Response of iron chlorotic avocado trees on Rockdale soil to certain iron treatments. Proc. Fla. State Hort. Soc. 82:328-333.
8. Zentmyer, G. A. 1980. *Phytophthora cinnamomi* and the diseases it causes. Monog. No. 10. Amer. Phytopathol. Soc., St. Paul, MN. 98 pp.

Proc. Fla. State Hort. Soc. 102:236-239. 1989.

FLOODING TOLERANCE OF 'GOLDEN STAR' CARAMBOLA TREES

M. E. B. JOYNER AND BRUCE SCHAFFER
IFAS, University of Florida
Tropical Research and Education Center
18905 S.W. 280 Street
Homestead, FL 33031

Additional index words. Averrhoa carambola, net CO_2 assimilation, transpiration, stomatal conductance, flowering, fruiting.

Abstract. **Young carambola (*Averrhoa carambola* L.) cv. Golden Star grafted one to two years previously on 'Golden Star' seedling rootstock and grown in containers in a slightly alkaline nursery potting media were subjected to continuous and intermittent flooding for a minimum of three weeks and a maximum of 18 weeks. Net CO_2 assimilation, transpiration, and stomatal conductance were determined periodically for flooded plants and nonflooded controls. At the end of the eighteen-week flooding period, tissue dry weights and root:shoot ratios were determined. There was a significant reduction in net CO_2 assimilation, transpiration, and stomatal conductance 5 weeks after continuous flooding was imposed. Trees which were intermittently flooded generally exhibited decreased net CO_2 assimilation, transpiration, and stomatal conductance at the end of each flooding period. After unflooding, net CO_2 assimilation, transpiration, and stomatal conductance increased to rates nearly or equal to those of the control plants. Flooding stress also appeared to result in an increased number of fruit per tree. At the end of the experiment, reductions in leaf, shoot, and root dry weights of continuously flooded trees were correlated with the length of the flooding period. Tissue dry weights of intermittently flooded trees were also less than those of the unflooded controls. The data indicated that carambola trees are able to recover from continuous and intermittent flooding, although flooding damage is reflected in reduced dry weights.**

Until recently, fruit groves in Dade County were primarily sited east of the extensive canal system built to better control the seasonal water table extremes. Recently, due to urbanization in southern Dade County, growers have begun to cultivate land in the 5 mile-wide zone between the canals and the Everglades National Park. A system of mounds and drainage ditches partially compensate for the seasonal flooding which occurs in groves in that area. Despite this, crops such as mango (*Mangifera indica*), 'Tahiti' lime (*Citrus aurantifolia*), and carambola, among others crops grown in the area are subjected to periodic flooding where high seasonal water tables can result in standing water in excess of 75 cm in the groves for upwards of 6 to 8 weeks in the spring.

Many woody plants respond to flooding much as they do to drought (14, 16). Symptoms of flooding damage include reduced growth (4, 12, 17, 22), chlorosis and reddening of leaves, often followed by leaf drop (1, 2, 8, 11, 22, 23, 28), root die-back, and an altered root:shoot ratio (22, 23, 31), as well as changes in leaf gas exchange characteristics (2, 24, 32). Flooding stress can also result in increased or unseasonable flowering and fruiting (18, 26, 34).

Little has been published about flooding tolerance of tropical and subtropical fruit trees, with the exception of citrus (29, 33). To our knowledge, nothing exits in the literature about flooding tolerance of carambola (*Averrhoa carambola* L.). Therefore, we conducted preliminary studies of the tolerance and response of carambola trees to flooding.

Florida Agricultural Experiment Station Journal Series No. N-00131.

Materials and Methods

Carambola trees cv. Golden Star grafted on 'Golden Star' seedling rootstock were grown in a commercial peat:perlite potting mix in 5 l plastic pots. The rootstock for this study was selected because it is vigorous in local limestone soils (5, 20, 21), and is the first choice of rootstock among local growers (6). A total of 102 trees were divided into several treatments (Fig. 1): five continuously flooded treatments, continuously flooded for 3, 5, 7, 9, or 18 weeks; two intermittently flooded treatments, flooded for 3 weeks unflooded for 3 weeks, repeated twice; and flooded for 3 weeks, unflooded for 6 weeks, repeated once; and the nonflooded controls. Plants were flooded by placing the entire pot in a plastic tub filled with tap water to above the soil surface.

Net CO_2 assimilation (A), transpiration (E), and stomatal conductance for CO_2 (g_c) were determined periodically for trees in each treatment using an open gas exchange system previously described by Ploetz and Schaffer (30).

Data were analyzed by analysis of variance and Waller-Duncan K-ration T test or Duncan's Multiple Range test (3, 10, 15).