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# FLOODING TOLERANCE OF 'GOLDEN STAR' CARAMBOLA TREES

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*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.

## 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).

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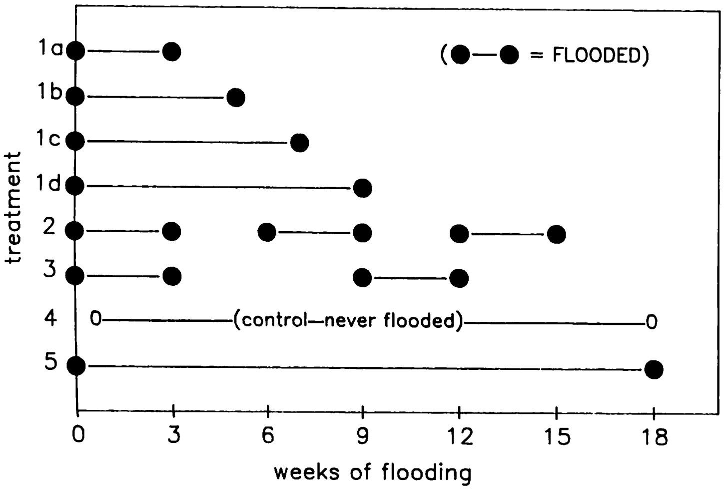

Fig. 1. Flooding schedule for 'Golden Star' carambola trees.

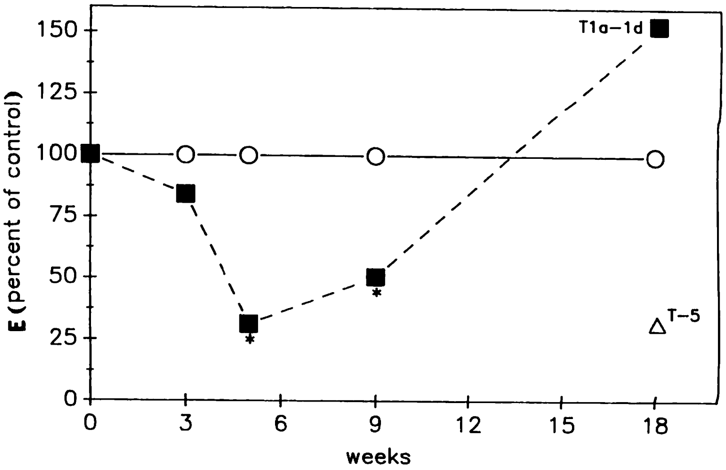

Fig. 3. Transpiration (E) for continuously flooded 'Golden Star' carambola trees (treatments la-ld). Single asterisk indicates significant difference from control ($P<0.05$); double asterisk indicates highly significant difference from the control ($P<0.01$). T-5 was flooded for 18 weeks; all other treatments were flooded for a maximum of 9 weeks, then unflooded for at least the last 9 weeks.

## Results

*Gas exchange.* Among the continuously flooded treatments (treatments la-ld), the initial response for A, E, and gc, as a percent of the control, was a decline. Each variable reached the lowest percent of the control at week 5, then increased (Figs. 2-4) At week 18, A of the continuously flooded treatments (la-ld) was almost identical to that of the controls, and E and $g_c$ were greater than that of the controls. Net $CO_2$ assimilation, E, and $g_c$ rates of trees which were continuously flooded for 18 weeks were between 25 and 30 percent of those of the controls.

For treatment 2 (intermittently flooded and unflooded for 3-week periods), A declined through the end of the second flooding cycle (week 9), recovered, declined again during the third flooding period, then recovered at the end of week 18, although not to the level of the control (Fig. 5). Transpiration showed a similar pattern (Fig. 6). Stomatal conductance for treatment 2 appeared to level off during the second flooding and recovery, declined during the third flooding period, then increased to a slightly greater level than that of the control after week 18 (Fig. 7). Net $CO_2$ assimilation, E, and $g_c$ for treatment 3 (flooded for 3 weeks, unflooded for 6 weeks) declined when plants were flooded and recovered when plants were unflooded (Figs. 5, 6 and 7).

*Biomass.* At the end of the flooding period (week 18), the mean total plant dry weight was 443.02 g for the controls. The pooled mean plant dry weight for the continuously flooded trees (treatments la-ld) was 63.9 percent of the control. For the intermittently flooded plants, plant dry weight for treatment 2 was 69.2 percent of the control, and for treatment 3 was 82.1 percent of the control. The mean total root dry weight for the control at the end of the experiment was 181.67 g. Treatments la-ad had a pooled mean root dry weight which was 61.1 percent of the control. Mean root dry weight of treatment 2 was 58.3 percent of the control, and for treatment 3 was 77.6 percent of the control. The mean dry weight of the leaves was

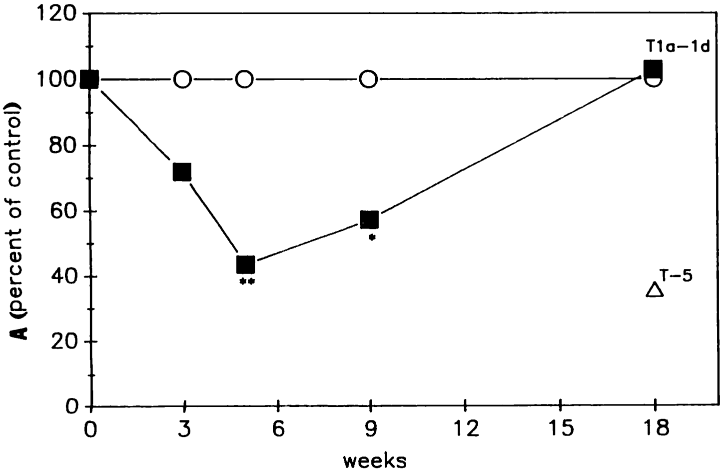

Fig. 2. Net $CO_2$ assimilation (A) for continuously flooded 'Golden Star' carambola trees (treatments la-ld). Single asterisk indicates significant difference from control ($P<0.05$); double asterisk indicates highly significant difference from the control ($P<0.01$). T-5 was flooded for 18 weeks; all other treatments were flooded for a maximum of 9 weeks, then unflooded for at least the last 9 weeks.

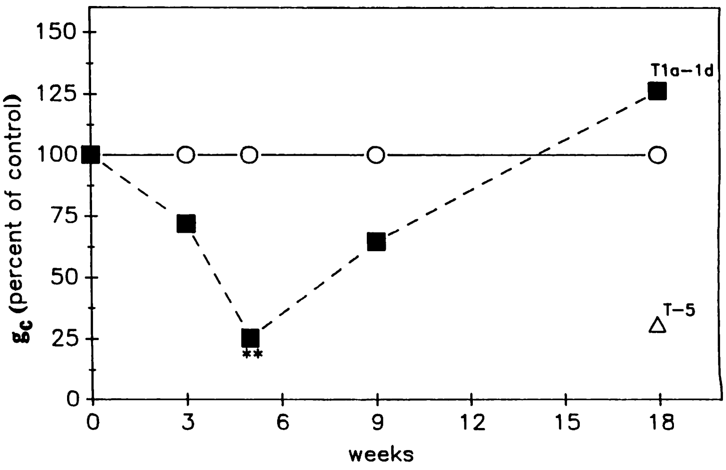

Fig. 4. Stomatal conductance ($g_c$) for continuously flooded 'Golden Star' carambola trees (treatments la-ld). Single asterisk indicates significant difference from control ($P<0.05$); double asterisk indicates highly significant difference from the control ($P<0.01$). T-5 was flooded for 18 weeks; all other treatments were flooded for a maximum of 9 weeks, then unflooded for at least the last 9 weeks.

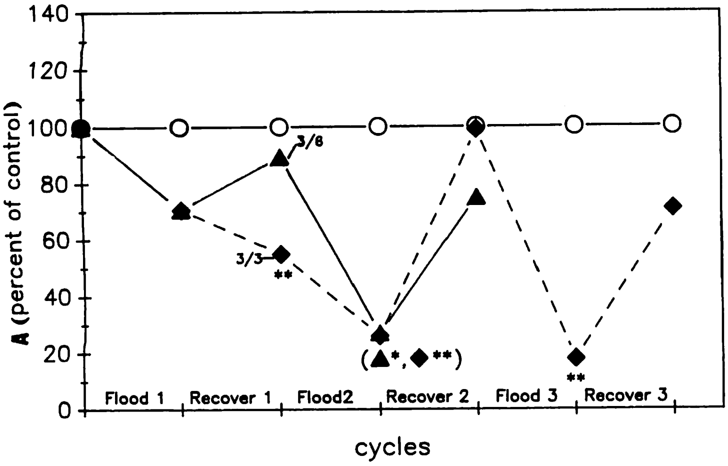

Fig. 5. Net $CO_2$ assimilation (A) for intermittently flooded 'Golden Star' carambola trees. Treatment 2 (3/3) was flooded for 3 weeks, unflooded for 3 weeks, repeated twice; treatment 3 (3/6) was flooded for 3 weeks, unflooded for 6 weeks, repeated once. Single asterisk indicates significant difference from the control ($P<0.05$); double asterisk indicates highly significant difference from the control ($P<0.01$).

112.51 g for the control. The pooled mean leaf dry weight for treatments 1a-1d was 51.1 percent of the control, for treatment 2 was 62.2 percent of the control, and for treatment 3 was 80.7 percent of the control.

*Flowering and fruiting.* During the course of the experiment, many of the trees flowered and a number of those that flowered bore fruit. None of the continuously flooded trees flowered before the seventh week. Among intermittently flooded treatments, treatment 2 had one tree flowering by the third week and additional trees flowering during subsequent weeks. Treatment 3 had one tree flowering at the end of the ninth week and two trees flowering after 12 weeks.

After 18 weeks, treatment 1c had 33 fruit, treatment 1d had 13 fruit, treatment 2 had 28 fruit, and treatment 5 had 24 fruit. All other treatments, including the control, had 6 or fewer fruit.

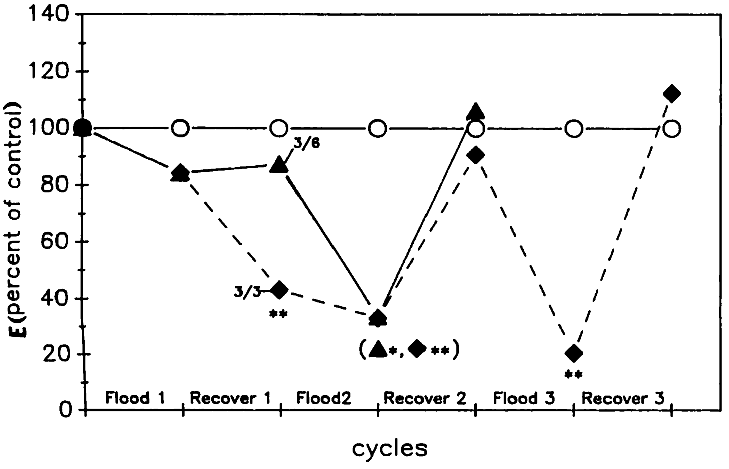

Fig. 6. Transpiration (E) for intermittently flooded 'Golden Star' carambola trees. Treatment 2 (3/3) was flooded for 3 weeks, unflooded for 3 weeks, repeated twice; treatment 3 (3/6) was flooded for 3 weeks, unflooded for 6 weeks, repeated once. Single asterisk indicates significant difference from the control ($P<0.05$); double asterisk indicates highly significant difference from the control ($P<0.01$).

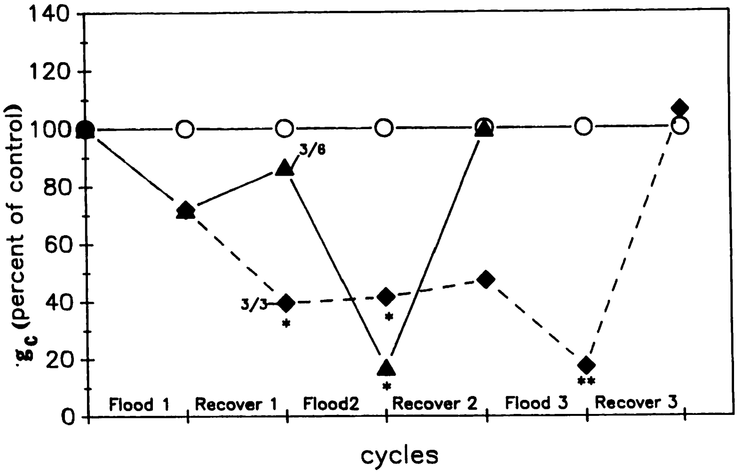

Fig. 7. Stomatal conductance ($g_c$) for intermittently flooded 'Golden Star' carambola trees. Treatment 2 (3/3) was flooded for 3 weeks, unflooded for 3 weeks, repeated twice; treatment 3 (3/6) was flooded for 3 weeks, unflooded for 6 weeks, repeated once. Single asterisk indicates significant difference from the control ($P<0.05$); double asterisk indicates highly significant difference from the control ($P<0.01$).

## Discussion

*Gas Exchange.* For continuously flooded trees, net gas exchange initially declined through week 5, then recovered when plants were unflooded. Similarly, for cyclically flooded plants, net gas exchange of flooded plants was less than that of the controls. For these treatments, net gas exchange rates recovered to rates similar to those of the controls when plants were unflooded. Other researchers have found that flooding results in decreased net gas $CO_2$ assimilation, transpiration, and stomatal conductance (2, 9, 13, 19, 22, 24, 25, 29, 32). Since leaves of 'Golden Star' carambola are able to recover from the reduction in net gas exchange rate when plants are unflooded, it appears that this species is somewhat flood-tolerant.

*Biomass accumulation.* After 18 weeks, there was a loss in plant dry weight for flooded plants. Reductions in plant biomass due to flooding was also reported by Burroughs and Carr (4), Crane and Davies (12), Hook and Scholtes (17), and Kozlowski (22). Among the continuously flooded trees, the greatest biomass reduction occurred in leaves (51.1 percent of control) followed by roots (61.1 percent of control). The intermittently flooded trees had a greater biomass reduction in the roots than the leaves. Continuous flooding appeared to have a greater effect on leaf retention while cyclical flooding appears to have a greater affect on the reduction of root biomass. Kozlowski (22), Kramer (23), Orchard et al. (27), and Sena Gomes and Kozlowski (31) found that, in general, roots sustain flooding better than do other parts of the tree. In the present study, root:shoot ratios of carambola were not significantly different among treatments, in contrast to reports by Kozlowski (22), Kramer (23), and Sena Gomes and Kozlowski (31) that root:shoot ratios of flooded plants is altered.

In this experiment, leaf drop due to flooding presumably resulted in large reductions in photosynthesis due to the decreased photosynthesizing surface area. Once trees were no longer flooded, gas exchange of the remaining leaves appeared to quickly return to rates at or near that of the unflooded controls. This implies a potential for eventual recovery of carambola from the effects of flooding. However, the reduction in net $CO_2$ assimilation on a whole plant basis is still great after unflooding due to the reduction of leaf area.

*Flowering and fruiting.* Under normal conditions, carambola fruit retention is markedly lower than fruit set (7). In this study, flooded trees retained the greatest number of fruit. Therefore, flooding stress possibly increases fruit retention of carambola. However, more research is needed in this area.

In summary, 'Golden Star' carambola appeared to be somewhat flood tolerant and has the ability to recover from flooding stress with respect to net gas exchange. However, both continuous and intermittent flooding result in decreased biomass accumulation. In addition, flooding of carambola appears to slightly increase flowering and fruit set.

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# ACREAGE AND PLANT DENSITIES OF COMMERCIAL CARAMBOLA, MAMEY SAPOTE, LYCHEE, LONGAN, SUGAR APPLE, ATEMOYA, AND PASSION FRUIT PLANTINGS IN SOUTH FLORIDA

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*Additional index words.* Tropical fruit crops, plant density.

*Abstract.* **A survey of seven commercial tropical fruit crops grown in south Florida was conducted to determine current acreage, total number of trees, primary cultivars, grove ages, and predominant plant spacings. Current acreage is as follows: carambola (*Averrhoa carambola* L.), 435; mamey sapote (*Calocarpum sapote* (Jacq.) Merr.), 267; lychee (*Litchi chinensis* Sonn.), 190; longan (*Euphoria longana* (Lour.)**

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