Response of Mamey Sapote (Pouteria sapota) Trees to Flooding in a Very Gravelly Loam Soil in the Field

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Mamey sapote trees are periodically subjected to flooding in southern Florida but their flood-tolerance is not known. 'Magaña' mamey sapote (Pouteria sapota) trees were planted on 11 May 2006 in the field in mounds of Krome very gravelly loam soil at the Tropical Research and Education Center in Homestead, FL. Before planting, the soil was scraped to the bedrock, and a water-resistant tarp and plastic sheet (barrier) was placed on the bedrock. Native soil was mounded on each barrier for each tree. The barrier edges were raised above the soil surface to form a pool so that trees could be individually flooded. The response of trees to flooding was tested in two separate trials on 6 Nov. 2006 to 9 Jan. 2007 (Fall–Winter) and 23 Apr. to 11 June 2007 (Spring–Summer). Trees were divided into control (nonflooded) and flooded treatments. In the Fall–Winter Trial, flooding resulted in leaf epinasty after 2 weeks and reductions in net CO2 assimilation (A) after 3 weeks; however, leaf abscission was not higher for flooded trees than nonflooded trees. By the end of 70 days of flooding, only one tree (12%) died. In the Spring–Summer Trial, A was significantly lower for flooded trees than nonflooded trees by the beginning of week 2. By the end of week 4, four out of eight flooded trees had no leaves and one had wilted leaves, while three trees were still in good condition. Six of the flooded plants were infected with Pythium splendens root rot, which was likely the cause of death. Therefore, mamey sapote appears moderately tolerant to flooding in a very gravelly loam soil. However, more work is needed to separate tree decline due to flooding from that due to P. splendens infection in this soil.

Mamey sapote [Pouteria sapota (Jacq.) H.E. Moore and Stearn] is a commercially grown tropical fruit crop that is popular among the Latin community. The center of origin for mamey sapote is the humid lowlands of southern Mexico and Central America (Verheij and Coronel, 1992) and extends south to northern Nicaragua (Balerdi and Shaw, 1998). Mamey sapote requires a hot climate with a relatively even rainfall distribution and grows best in the lowland humid tropics. Mamey sapote is seldom planted above 1000 m elevation (Verheij and Coronel, 1992). There are between 131 and 196 ha of mamey sapote grown in Miami–Dade County. The crop is estimated to be worth at least $6.5 million annually (Degner et al., 2002). The Miami–Dade County agricultural area is subjected to periodic flooding during high water table conditions that coincide with periods of heavy rainfall and/or hurricanes. Flooding in mamey sapote orchards observed in this area has generally resulted in tree decline and death (Crane et al., 1997; Degner et al., 2002). The objective of this study was to investigate the physiological responses and survival of mamey sapote subjected to flooding under field conditions in very gravelly loam soil.

**Materials and Methods**

A single row of 60 grafted 3-year-old mamey sapote cv. Magaña trees was planted on 11 May 2006 at the University of Florida, Tropical Research and Education Center in Homestead, FL. Trees were obtained from Lara Farm Nursery, Homestead. The row was prepared by scraping the native Krome very gravelly loam soil (loamy-skeletal carbonatic, hyperthermic lithic Rendoll) (Burns et al., 1965; Leighty and Henderson, 1958; Nobel et al., 1996) down to the bedrock with a front end loader. Then 3.2 × 3.2 m (10 × 10 ft) water-resistant tarps were sandwiched between two black groundcloths of the same size to form a water-resistant barrier. The groundcloth layers were used to protect the plastic tarps from puncturing. A mound of soil approximately 1.5 × 1.5 m (4 × 4 ft) and 1 m (3 ft) high was placed on top of each barrier. Trees were planted in the mounds of native soil and allowed to establish in the field for 6 months before the first flooding trial. During this establishment period, the trees were irrigated using microsprinklers according to the irrigation schedule used for the rest of the orchard that was planted with avocado (Persea americana Miller) and carambola (Averrhoa carambola L.) trees. Two separate trials were conducted from 6 Nov. 2006 to 9 Jan. 2007 (Fall–Winter) and from 23 Apr. to 11 June 2007 (Spring–Summer). The Fall–Winter trial was flooded for 70 d and the Spring–Summer trial was flooded for 50 d. A fungicide was applied to the soil around each plant 1 to 2 weeks prior to each trial (Ridomil Gold EC®, Syngenta Crop Protection, Inc., Greensboro, NC) for the purposes of controlling phytophthora and pythium root rots.

Sixteen healthy trees were selected for each trial and divided into two treatments: flooded (FL) and nonflooded (NF), with eight single-tree replications per treatment. The trees were randomly

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assigned to each treatment. For the trees to be flooded the edges of the tarp and plastic were raised above the soil surface and soil was backfilled behind the raised barrier using a backhoe and shovels. Water was applied using a water wagon to form a pool.

**Data Collection.** Leaf gas exchange [net CO₂ assimilation (A), stomatal conductance of water vapor (gₛ), internal CO₂ concentration (Cᵢ), and transpiration (E)], stem water potential (Ψₛ), soil redox potential, and soil and canopy temperature data were collected during the Fall–Winter trial. Leaf gas exchange, leaf chlorophyll index using a SPAD chlorophyll meter (Minolta, Inc., Osaka, Japan), soil redox potential and soil and canopy temperature data were collected during the Spring–Summer trial. Leaf gas exchange was monitored using a CIRAS-2 portable photosynthesis system (PP Systems, Amesbury, MA). Leaf gas exchange measurements were made at a photosynthetic photon flux (PPF) of 1000 µmol·m⁻²·s⁻¹, a reference CO₂ of 375 µmol·mol⁻¹, and a flow rate of 200 mL·min⁻¹ into the leaf cuvette. Leaf gas exchange monitoring took place every 2 to 4 d during the first 3 weeks and at varying intervals thereafter. One fully mature, sun-exposed leaf on the west side of the plant was measured between 1100 and 1400 HR (EST). If any reading was suspect as being low due to windy conditions, leaf damage, or other factors, another leaf was selected to either confirm or replace that particular reading. During the Fall–Winter trial measurements were made on days 0, 2, 5, 7, 9, 11, 14, 16, 20, 23, 28, 34, 39, 53, and 71 and during the Spring–Summer trial on days 0, 4, 8, 10, 14, 17, 21, 25, and 30.

During the Fall–Winter trial, Ψₛ was measured on days 1 and 7. One leaf per plant from about the middle of the canopy was covered with a zip lock bag that was covered with reflective aluminum foil for 1 h. Subsequently, each leaf petiole was cut with a razor blade and placed into a styrofoam cooler, with the bag still surrounding the leaf. Stem water potential was measured immediately after harvest with a pressure chamber (Plant Water Status Console 3000 Series, Soilmoisture Equipment Corporation, Santa Barbara, CA) in a laboratory.

During the Spring–Summer trial SPAD readings were taken to assess the effect of flooding on leaf greenness (chlorophyll index) as a general indication of plant vigor. In previous flooding studies with potted plants, leaves in the lower canopy were observed to undergo epinasty and chlorosis, and had reduced SPAD values several days prior to leaves in the upper canopy (M.T. Nickum, University of Florida, personal communication). Therefore three leaves in the upper canopy and three leaves in the lower canopy of each tree were tagged and monitored to make comparisons between treatments, plants and canopy levels. SPAD readings were made on days 0, 4, 8, 10, 14, 17, 21, 25, and 30.

In the Spring–Summer trial, root samples were taken from all flooded trees to determine if root rot fungal pathogens were involved in the observed plant symptoms. The samples were analyzed at the Plant Diagnostic Clinic at the University of Florida, Tropical Research and Education Center in Homestead.

Soil redox potential was measured in the flooded plots using a metallic ORP indicating electrode (Accumet Model 13-620-115, Fisher Scientific, Pittsburgh, PA) connected to a voltmeter. Redox potential readings below +200 mV indicate that soil conditions are anaerobic (Ponnamperuma, 1984). In Fall–Winter, redox potential was measured on days 2 and 39 and in Spring–Summer, redox potential was measured on days 4 and 24. A large spike was driven into the soil of each flooded tree to form a hole, which immediately backfilled with soil water solution when the spike was removed. The redox potential probe was then inserted into the hole and gently moved up and down until a stable reading was obtained. In both experiments, soil temperature was monitored with a HOBO Water Temp Pro (Onset Computer Co., Bourne, MA) and canopy temperature was monitored with a StowAway TidbiT (Onset Computer Co.). The University of Florida, IFAS FAWN weather station at TREC (http://fawn.ifas.ufl.edu) was also utilized to fill in temperature data when noted. Observations of the overall plant condition including leaf epinasty, wilting, leaf drop, and mortality were recorded.

Data were analyzed by ANOVA to test for interactions between treatment and measurement date and standard t-test (P ≤ 0.05) to compare gas exchange data between treatments.

**Results and Discussion**

**Fall–Winter Trial.** Tree canopy temperatures ranged from about 10 to 30 °C and soil temperatures from 15 to 25 °C from 6 Nov. 2006 to 9 Jan. 2007 (Fig. 1). The mean soil redox potential for the FL treatment was 128 mV by day 2 and by day 29 was −107 mV. Net CO₂ assimilation, gₛ (Figs. 2 and 3), and E (data

![Fig. 1. Air temperature of tree canopy and temperature of nonflooded and flooded soil.](http://fawn.ifas.ufl.edu)
not shown) decreased for both FL and NF trees beginning on day 2. By day 5, gs of FL plants was significantly lower than NF plants \((P \leq 0.01)\). By day 8, epinasty was visible on two flooded trees. On day 16, A for both FL and NF trees approached zero. The reduced A may have been due to a week of relatively low temperatures which ended on day 16 with 13 °C soil temperatures and 6 °C canopy temperatures. After that cool period, the A and gs for NF trees increased and was significantly greater than FL plants. Trees in the NF treatment reached an A of 9 µmol CO\(_2\)·m\(^{-2}\)·s\(^{-1}\) by day 39 and this level was maintained or slightly increased throughout the remaining 32 d of flooding. The A of FL trees was about half that (4 µmol CO\(_2\)·m\(^{-2}\)·s\(^{-1}\)) at the end of 39 d, and that level of A was maintained or slightly increased throughout the last 32 d of monitoring (Fig. 2). After the low temperature period, Ci became nearly the same in both FL and NF trees for at least 1 week, even though the other gas exchange variables became significantly different between treatments. Then on day 34 the FL treatment had a significantly higher Ci than the NF treatment \((P \leq 0.01)\).

Measurements of A, gs, and Ci are important because combined they begin to provide an indication of the physiological condition of a plant’s vigor and overall physiological status (Schaffer et al., 1992). Stomatal conductance showed the earliest response to flooding. Net CO\(_2\) assimilation showed the next observable change related to treatments. Finally, Ci increased in the FL tree leaf compared to the NF tree leaf. The rise in Ci suggests that the photosynthetic apparatus may have been damaged or its capacity compromised. If the photosynthetic apparatus was not damaged and A was reduced due to low gs, then Ci would be expected to drop as well, since the available CO\(_2\) inside the leaf mesophyll would be assimilated (Schaffer et al., 1992).

There was no significant difference in Ψs among treatments (data not shown). Mean Ψs for FL and NF trees was –0.32 and –0.41 MPa, respectively, on day 1 and –0.67 and –0.515, respectively, on day 7. No leaves on NF trees exhibited chlorosis or epinasty. On day 8 the first signs of slight epinasty were observed on two FL trees, and only those two trees had epinasty by day 39. By day 70, one FL plant died (12% of all flooded plants); all other plants survived and maintained their canopy.

**SPRING–SUMMER TRIAL.** Tree canopy temperatures ranged from about 17 to 40 °C and soil temperatures from 22 to 27 °C from 23 Apr. 2007 to 11 June 2007 (Fig. 4). The mean soil redox potential for FL plots was 141 mV on day 4 and –12 mV by day 24, indicating that the soil in the FL treatment was anaerobic. In general A, gs (Figs. 5 and 6), and E (data not shown) were significantly greater for trees in the NF treatment than the FL treatment. After day 17, leaf wilting and abscission on FL trees precluded further gas exchange measurements. On day 17, leaves on two of the FL trees were dead. Further leaf desiccation and death occurred, one tree at a time every 4 d, on days 21, 25, and 29 for a total of five dead trees. Of the eight flooded trees, five (63%) exhibited this rapid 1- to 2-d decline noted on each day listed above. In contrast, all NF trees survived. *Pythium splendens* Braun was found infesting six of the eight FL trees and may have been the cause of the rapid decline and death of these trees.

There was no significant difference between SPAD values for upper and lower canopy leaves, therefore the data were combined. In general, there was a significant difference in SPAD values between the FL and NF treatments. This condition existed prior to the beginning of the experiment. During the first 30 d of the Spring–Summer trial SPAD values fluctuated only slightly and remained consistent within each treatment (Fig. 7).

Previous anecdotal evidence suggested that mamey sapote trees were intolerant of flooded conditions. However, young (~3
years-old) non-root rot infested plants appear to possess moderate to good flood tolerance under orchard conditions during the fall and winter months having survived about 70 d of continuous flooding until the water was removed. One possible explanation for this tolerance is the type of rootstock. During the past 15 to 30 years, seed from various locally grown cultivars (mostly ‘Pantin’ and ‘Magaña’) was used to produce rootstocks. More recently, a large amount of seed for rootstock has been imported from the Dominican Republic (J.H. Crane, University of Florida, personal communication). The variability in rootstocks and potential shift in the source of rootstocks used in mamey sapote grafting may explain in part the relative tolerance to flooding observed in these field flooding experiments compared to lower flooding tolerance of older orchards in the area.

Compared to other tropical and subtropical fruit crops grown in south Florida, mamey sapote’s flood tolerance may lie somewhere between that of the moderately flood-tolerant carambola (Schaffer et al., 1992; 2006) and the flood-sensitive avocado (Schaffer et al., 1992; 2006). Carambola has been capable of withstanding continuous flooding for periods of up to 18 weeks,
in container-grown plant studies in alkaline soil, although there were reductions in gas exchange and dry weights compared to nonflooded trees (Joyner and Schaffer, 1989). Soil type was found to strongly influence avocado flooding survival. Healthy container-grown avocado trees in organic soil with high water-holding capacity showed a reduction in net photosynthesis after 5 d of flooding (Ploetz and Schaffer, 1989), while there was no effect on net photosynthesis after 28 d for trees with healthy roots grown in a porous, limestone soil (Schaffer and Whiley, 2002). Consequently, even flood-sensitive species are capable of surviving extended flooding in calcareous soils if roots are disease free. If, however, the roots are not disease free or are infected by a root rot pathogen, rapid decline and death may occur within 1 to 2 weeks. For example, it was demonstrated in containerized studies with calcareous soil, that when avocado trees were inoculated with Phytophthora cinnamomi Rands prior to flooding, a reduction in A within 3 d and reached nondetectable levels in 7 to 9 d, followed by tree death within 2 weeks (Ploetz and Schaffer, 1989).

Other experiments with flooded mamey sapote trees in containers in Krome, very gravelly loam soil (conducted Apr. to June 2005) also showed A reduced to near nondetectible levels in 7 to 10 d, and typical flooding symptoms of leaf epinasty, leaf chlorosis, and leaf abscission began at the end of the first week of flooding (M.T. Nickum, University of Florida, personal communication). By contrast, in the Fall–Winter field trial, only about 25% of FL trees showed some level of leaf epinasty after 2 months; thus, practically no visible tree decline occurred. In the Spring–Summer field period, FL trees did show a reduced A level by day 10. However, FL trees did not exhibit the visible progression of decline (i.e., leaf epinasty, chlorosis, desiccation, abscission), nor did they decline rapidly during the first 1 to 2 weeks of flooding, which can indicate a preexisting infestation of root rot. Instead, it was not until day 17 when two trees died (25%), followed by one more tree every 4 d until five total trees died (63%). This may have been due to the pre-flooding soil application of a systemic fungicide which provided some measure of root protection. However, it may be speculated that as new root growth occurred and/or the efficacy of the systemic fungicide decreased or was possibly leached from the soil throughout the course of flooding, pythium root rot infestation increased and eventually caused the observed rapid decline in tree health.

Based on the above results and comparisons, non-root rot infested mamey sapote trees appear to exhibit good tolerance to flooding conditions during the fall-winter period and less tolerance during the spring-summer period in the field. Young trees or recently planted orchards on currently available rootstocks and/or treated with systemic fungicides may be able to survive 1 week of sustained flooding with minimal effect on tree health beyond reduced A. However, higher temperatures during the summer and/or root rot infestation may reduce the length of this time frame dramatically. Also, if trees are not treated regularly with soil fungicides during the season when flooding is more likely (i.e., hurricane season) then flooding will likely lead to rapid and irrecoverable tree decline and death due to root rot, as has been found in other tropical fruit species in Miami–Dade County, such as avocado (Ploetz and Schaffer, 1989). In summary, the results of this study indicate that mamey sapote is moderately tolerant to flooding in a very gravelly loam soil. However, more work is needed to separate tree decline due to flooding from that due to P. splendens infection in this soil.

**Literature Cited**


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