MONTGOMERY BOTANICAL CENTER PROJECT REPORT

Cycad Savannah (CSAV) Soil/Drainage Testing Project
to Support the Development of a New Cycad Ecologic Garden

EXECUTIVE SUMMARY

Organization and Contact Information

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Purpose of Project

To augment an already existing six-acre Cycad Geographic Collection, MBC is developing a seven-acre Cycad Ecologic Garden. Together the two displays will provide the largest research and educational collection of cycads in the United States. The Cycad Ecologic Garden is being designed to showcase the broad range of taxa in the three primary habitats in which cycads are found—savannah, tropical forest, and oak woodland. The largest section of the new Cycad Ecologic Garden will feature cycads native to grasslands and savannahs as well as dry, rocky deserts. While generally hardy, the roots of these plants are very sensitive to moisture. The large majority of cycad species designated for this area would not be able to tolerate the amount of water that the existing soil structure retains from Florida's abundant rainfalls. This is an unsolved problem shared with other botanical gardens and institutions in tropical/subtropical areas who wish to grow taxa that demand this horticultural requirement.

In 2003, MBC brought together a team of experienced biologists, horticulturists, landscape designers, and soil scientists. From this collaboration came an innovative concept that combines a "designer" soil mix and a subsurface drainage system that may effectively address this problem. Because the soil/drainage system is innovative and untried, our environmental consultant recommended conducting a research test plot before planting the entire four acres of the savannah area with the rare, valuable cycads we grow from wild-collected seeds. MBC sought and obtained external funding from The Central Florida Palm and Cycad Society, The Cycad Society, The Stanley Smith Horticultural Trust, and a number of private donors to design and conduct this experiment to ensure the long-term health of plants in our developing Cycad Ecologic Garden that require dry soils, and to provide a solution to others who share this soil structure / drainage problem.

Overview of MBC's Cycad Ecologic Garden

In 2003, MBC completed the Cycad Geographic Collection, a six-acre research collection of more than 2,600 cycads. In a 15-minute stroll, a visitor can view cycads grouped according to the four continental regions of the world in which they are native: the Americas, Asia, Africa, and Australia. Rigorous scientific standards in population sampling and data collecting add value to this unique collection. Utilized by students, educators, and leading cycad researchers and horticulturists, the Cycad Walk is also a popular feature of our educational tours for the general public.

Because native habitats of cycads throughout the world are rapidly yielding to commercial agriculture, urban encroachment, and over-harvesting, many wild cycad populations are considered threatened or endangered. With a long-established commitment to the preservation of this remarkable plant group, MBC continues to develop and maintain one of the world's major *ex-situ* collections of cycads by committing to an addition of approximately 3,000 plants to our collection over the next 10 years—broadening the collection's diversity of both populations and taxa.

At the same time, cycads have gained increased attention and popularity in ornamental horticulture. Often confused with palms, cycads represent one of earth's most ancient surviving plant groups, providing a window to the evolutionary past of all other living seed plants. Because of their association with the Age of Dinosaurs, their unusual beauty, and their general hardiness, cycads have become an appealing addition to contemporary landscape and interior design.

The Cycad Savannah (CSAV) Soil/Drainage Testing Project is a vital step in developing a new seven-acre Cycad Ecologic Garden at MBC. It is a long-term project that will serve as a multi-level resource for scientific and horticultural research, conservation, and education.

Our Cycad Ecologic Garden project, encompassing all three major habitats in which cycads grow—tropical forest, oak woodland, and open savannah—addresses various issues in the following ways:

0. Each area will incorporate grasses, trees, and other plants that make up the respective habitats. A series of paths and roads will provide the framework for uniting the collection with two botanically designed gateways at the north and south ends. The garden design will demonstrate the ornamental landscaping potential of cycads by showcasing their large diversity of size, shape, color, and form using a full palette of species from different geographical regions.
0. Seeds produced from mature plants will substantially add to the cycad seeds currently distributed annually through the MBC SeedBank Program. In this way, more diversity of taxa can be supplied to other botanical gardens and institutions to enhance their botanical educational displays. A greater variety of cycad taxa and a greater quantity of seeds will also enter into the U.S. nursery industry for ornamental landscaping. History has shown that an increased abundance of cycads in cultivation has had a positive effect in decreasing pressure on unsustainable harvesting in the wild and reducing black-market activities.
0. The creation of specialized habitats for taxa with particular horticultural requirements will help ensure the healthy growth of the endangered cycads in the world *ex-situ* collections and, ultimately, preservation of their germplasm.

The Cycad Savannah (CSAV) Soil/Drainage Testing Project

Background

Of the three habitats within the Cycad Ecologic Garden, the four-acre Cycad Savannah (CSAV) is the only area requiring modification of its soil structure. Cycads targeted for this area thrive in seasonally arid grasslands and savannahs, as well as xeric, rocky environments of Australia, Africa, and Mexico that are dry for more than 46 days of the year. In contrast, the designated CSAV area—like most of South Florida—is situated over limestone bedrock that quickly becomes saturated after a long rainy season drenches the ground with almost daily occurrences of one to three inches of precipitation. This horticultural conflict has discouraged other gardens, parks, and institutions in tropical/subtropical regions of the world from developing outdoor educational displays of cycads and other plants with similar requirements. This challenge provides us with an opportunity to develop an innovative solution with a scientific approach of experimentation and documentation that can be shared with others facing this issue.

During the first half of 2004, we initiated and completed a series of evaluations, testing, and design processes in the CSAV area that formed the hypothesis for conducting a study of an appropriate growing medium that will not retain water and a subsurface drainage concept designed to quickly move water away from the root zone—referred to as the CSAV Soil/Drainage Testing Project.

We currently have more than 850 cycads growing in our nursery from previous seed-collecting expeditions that are designated for the CSAV area as soon as the ground is prepared. Considering the amount of time and money already invested in these accessions, we have a considerable responsibility in assuring their health and survivability. The CSAV Soil/Drainage Testing Project was designed to test the effectiveness of a proposed soil/drainage system to provide a sustainable growing environment and will allow for modifications before the entire four-acre CSAV is developed and planted.

2003-2005: Initial Evaluation and Recommendations

The following objectives were completed in 2003-05:

- Conducted an intensive three-day CSAV Workshop, during which soil types, roads, paths, and groundcovers/mulches were evaluated; the characteristics of the 300 known cycad species were examined for design possibilities and habitat requirements; and prospective geo-materials were located in the marketplace and critically reviewed and evaluated.
- Completed the landscape design for the Cycad Ecologic Garden and a planting plan for the northern half of the four-acre CSAV area.
- Completed a detailed topographical survey and calculated runoff curves and infiltration rates.
- Conducted soil analyses and percolation tests in six observation trenches, and completed an innovative design for a quick-response, passive drainage system.
- Identified soil scientist/consultant Paul Sternberg, as an expert to create the soil mix.

Core Project Team

<u>MBC Staff</u>

- Jody Haynes, Project Leader and MBC Cycad Biologist
- Christine Wiese, Project Implementation Coordinator and MBC Cycad Curator
- Dr. M. Patrick Griffith, MBC Executive Director

<u>Consultants</u>

- Paul Sternberg, Horticultural and Soil Design Consultant: soil research scientist, University of California, Riverside, and cycad horticulturist
- Loran Whitelock, Horticultural and Design Consultant: MBC member, world renowned cycad plant explorer, horticulturist, landscape designer, and author of acclaimed book entitled *The Cycads*
- Joseph Hibbard, Landscape and Drainage System Designer: senior partner, Sasaki Associates, Inc.

Project Description

I. <u>Plant Categorization</u>: Cycads currently in the MBC Nursery that are slated to be planted in the CSAV area have now been divided into “Desert,” “Savannah,” and “Parazamia” categories, defined as follows:

   A. ***“Desert” category***: Plants that typically occur in deserts or seasonally xeric areas or that experience extended drought conditions in habitat **and/or** those that have proven difficult to grow at MBC using traditional planting techniques (*i.e.*, more than 67% documented dead in the ground to date). Examples include several *Encephalartos* species from the Eastern Cape region of South Africa, *Cycas beddomei* and *C. circinalis* from India, several *Cycas* species and the larger

Macrozamia species (Section *Macrozamia*) from the most arid regions of Australia, and a few *Ceratozamia* and *Zamia* species from the drier regions of Mexico, Colombia, and the Caribbean. We currently have more than 300 plants in 20 taxa and five genera that fit into this category.

. ***"Savannah" category***: Plants that typically occur in seasonally dry—though relatively less xeric—grasslands or forest transition zones and that do not experience extended droughts in habitat **and/or** those that have not proven exceptionally difficult to grow at MBC using traditional planting techniques (*i.e.*, only 15% documented dead in the ground to date). Examples include all *Dioon* species, *Stangeria eriopus* and several *Encephalartos* species from the more mesic regions of South Africa and southern Africa, several *Cycas* species from less xeric regions of Australia, and an assortment of *Ceratozamia* and *Zamia* species that have proven adaptable to a variety of growing conditions in South Florida. We currently have more than 200 plants in 20 taxa and six genera that fit into this category.

. ***"Parazamia" category***: All *Macrozamia* species in the Section *Parazamia*; all are quite small and very difficult to grow in cultivation (*i.e.*, 84% documented dead in the ground at MBC to date). We currently have more than 100 *Macrozamia* Section *Parazamia* plants in 13 taxa in our nursery.

. <u>Experimental Methods & Sampling Design</u>

. ***Summary of Methods***

0. Soil moisture:
   - Soil moisture was tested multiple times at each test site (see below for a list of the test sites). A complete set of tensiometers was installed at one location within each site, and then the soil moisture probes were used to take readings from the other duplicate sites within each location. For each reading taken at each site, the probe was calibrated and results compared with the tensiometers installed at that particular site.
   - For the new test pits and the existing in-ground sites (see below), soil moisture readings were taken at two depths: just below the mulch (ca. 6") and within the "root zone" (ca. 12"). For the Parazamia Bed (see below), soil moisture readings were taken at depths of 6", 12", and 24".
   - Rainfall during the project duration was monitored and compiled to determine if soil moisture conditions would be considered "normal," "below normal," or "above normal" for Miami-Dade County.

0. Soil temperature was tested at three levels at each duplicate location within each site: at the surface, using a digital infra-red thermometer, and under the mulch (ca. 3-4 in.) and within the root zone (ca. 6-8 in.), using a dual probe digital thermocouple thermometer.

0. Readings were taken at regular intervals to determine the fluctuation of soil moisture and temperature both during the day and from day to day during the testing period.

0. A weather monitoring station was installed in the CSAV area to monitor fluctuations in rainfall, temperature, wind speed, etc., during the testing period.

0. After 30 days of sampling, the results from each site were compared with the assumed optimum drainage values obtained from the growing containers filled with MBC cycad nursery soil mix (see Section B.1. below). From these data, judgments were then made regarding the range of subsurface soil moisture conditions that are achievable in the field at MBC, and how the range might be best matched to the moisture and drainage requirements of the "Desert," "Savannah," and "Parazamia" cycads we intend to plant in the CSAV area.

B. ***Summary of Test Sites***:

0. *Cycad growing containers*:
    - A 1-gallon size container filled with cycad nursery soil mix currently being used to grow "Desert" category species in the MBC Nursery was used to define moisture conditions in a soil environment known to support "Desert" cycads in South Florida.
    - A 95-gallon size container filled with cycad nursery soil mix provided information on temperature and moisture retention properties of larger volumes of cycad nursery mix.
    - A 95-gallon size container filled with CSAV designed soil mix provided comparative results of soil moisture retention and temperature properties.
    - All containers were placed in full sun and soil moisture and temperature readings were taken at the surface, at the center, and at the bottom of the containers immediately following irrigation and at regular intervals over a period of several days.

0. *Existing in-ground sites*:
    - Australia 1 bed – 3 locations within the bed.
    - Australia 3 bed – 3 locations within the bed.
    - Duplicate (3) Gateway bed west existing plant pits – immediately above dry well containing ballast rock.
    - Duplicate (3) Gateway bed west existing plant pits – immediately above native rock.
    - Duplicate (3) South Palmetum existing cycad plant pits – replaced organic mulch with decomposed granite.
    - Duplicate (3) South Palmetum existing cycad plant pits – left organic mulch in place.

0. *New in-ground sites to be constructed*:
    - Duplicate (5) CSAV test pits – CSAV soil mix, lined with plastic.
    - Duplicate (5) CSAV test pits – CSAV soil mix, not lined with plastic.
    - "Parazamia" bed – two locations within the bed.

Revised Timeline

As a result of the damage inflicted on MBC during last year's hurricane season, the timeline for this project had to be altered slightly from the revised timeline outlined in the previous status report. The final timeline was as follows:

Jul–Sep 2005	• Purchased and tested required equipment and supplies for monitoring test sites. • Reviewed and confirmed monitoring and testing procedures with consultants.
Jan–Mar 2006	• Purchased materials and supplies for Parazamia Bed. • Purchased and installed rain gauges and the permanent weather monitoring station. • Paul Sternberg (soil consultant) completed design specifications for CSAV soil mix. • Constructed (and began monitoring) Parazamia Bed according to soil consultants' specifications.
Apr–Jun 2006	• Conducted soil moisture and temperature testing in the cycad growing containers in the MBC Full Sun Nursery (as discussed in Section B.1. above). • Constructed CSAV Test Pits according to soil consultant's specifications. • Monitored existing and newly constructed in-ground test sites. • Evaluated monitoring data for all test sites and wrote final report.
Jul-Sep 2006	• Refine soil and/or drainage specifications, if necessary, in collaboration with CSAV Core Project Team. • Complete a final plan of action for continuation of phased testing and future development of the CSAV area in 2006 and beyond.

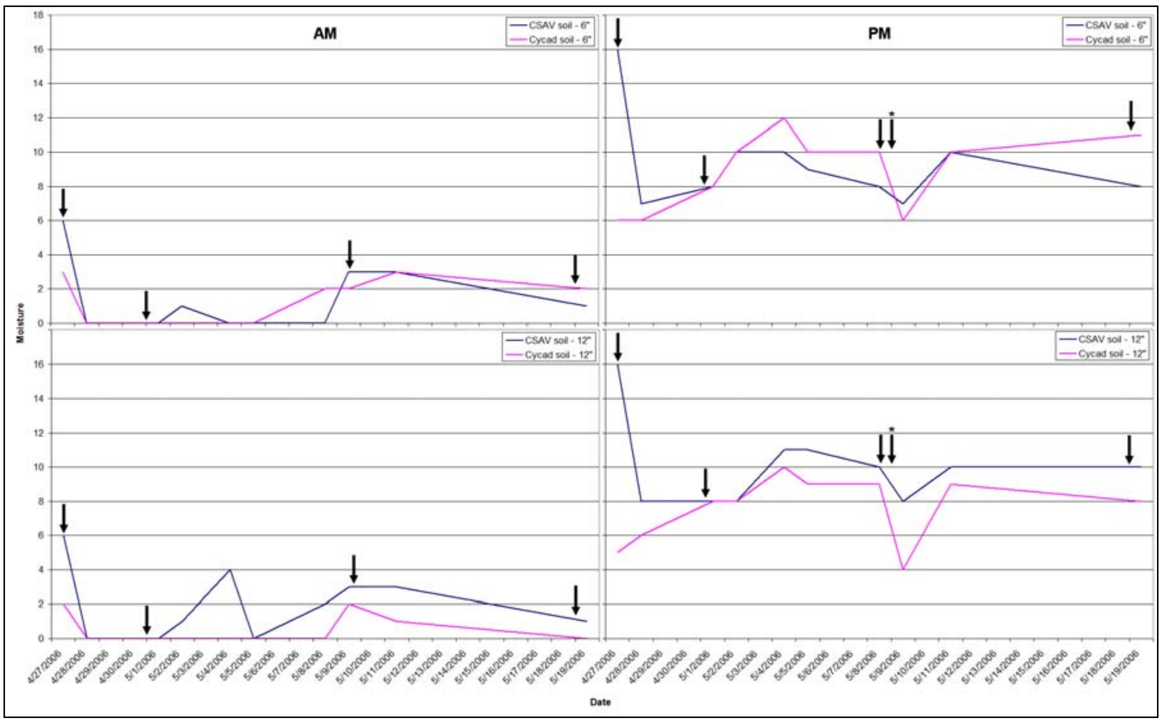
Results

Soil Moisture

Cycad Growing Containers

At the beginning of this project an assumption was made that MBC's nursery cycad soil mix could be used as a baseline with respect to drainage and moisture retention. This assumption was based on many years of successfully growing "Savannah" and "Desert" type cycads using this mix in the nursery. The results of the experiment designed to compare soil moisture retention of MBC's nursery cycad mix to the designed CSAV soil mix indicate that the CSAV soil performs equally well or better than the nursery soil (see graph below). Thus, with respect to soil moisture alone, we believe the CSAV soil mix will be quite suitable for growing "Savannah" and "Desert" cycads in the CSAV area.

Notes pertaining to this and all future graphs: (1) Tensiometers read "0" when the soil is completely saturated and the readings increase in value as the soil dries; (2) arrows indicate rain events totaling 1" or more.



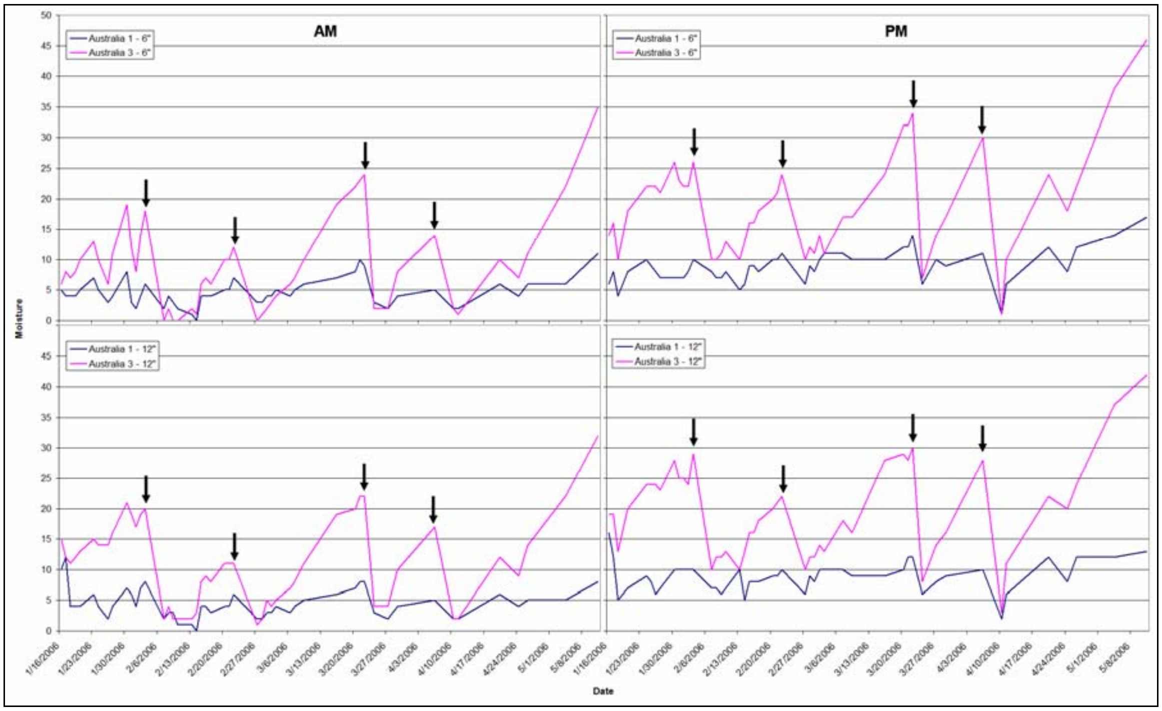
Existing In-ground Sites

Monitoring procedures for existing in-ground sites were designed to focus on three primary factors: (1) soil particle size, (2) presence or absence of a dry well, and (3) organic vs. granite mulch. This section will present the results of these monitoring efforts.

0. Soil Particle Size

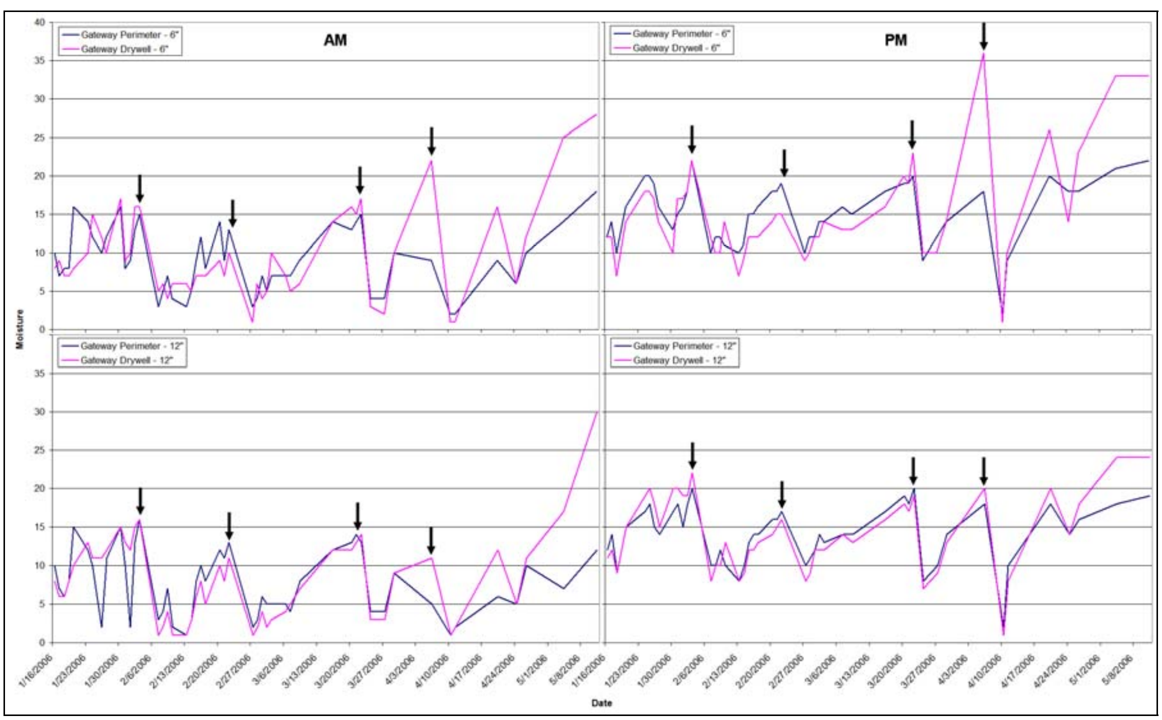
   The existing Australia 1 and Australia 3 beds were chosen to examine soil particle size as it relates to drainage and moisture retention. During the monitoring period, the beds were treated exactly the same: they received no supplemental irrigation and both were covered in granite mulch (which has proven to dramatically increase survival and growth rates of Australian cycads here at MBC).

   As can be seen in the graph below, the bed with the coarsest sand (Australia 3) dries out much more quickly following rain events and becomes markedly drier than the bed with the finer sand (Australia 1). This graph also indicates that moisture levels are fairly consistent at 6" and 12" depths, which is where the roots of growing plants would be localized.



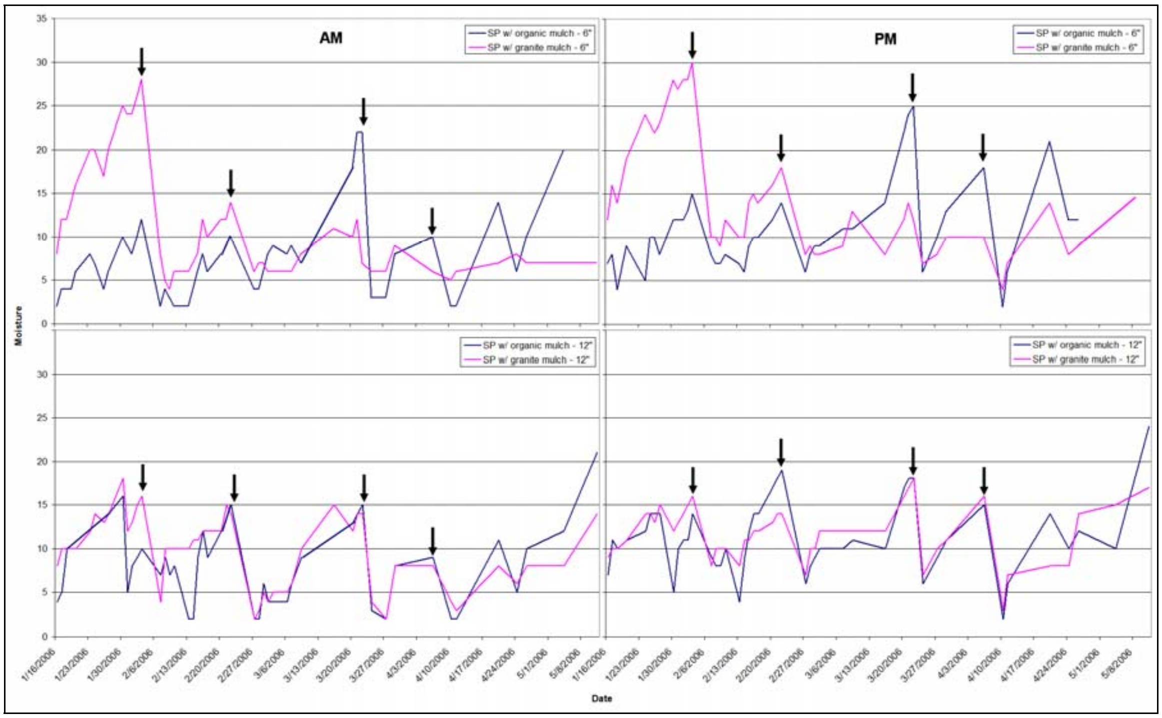
0. Presence/Absence of Dry Well

The existing west side of the North Gateway to the Cycad Ecologic Collection was chosen to examine the effect of the presence or absence of a dry well below the planting area as it relates to drainage and moisture retention of the soil. The graph below shows that the soil above the drywell is nearly always as dry or drier than the soil around the perimeter of the bed, where there is no dry well underneath. The dry well was originally constructed in this area because water was known to stand here following heavy rains. Since the drywell was constructed, however, there has been no evidence of standing water even after the heaviest of rain events.



3. Organic vs. Granite Mulch

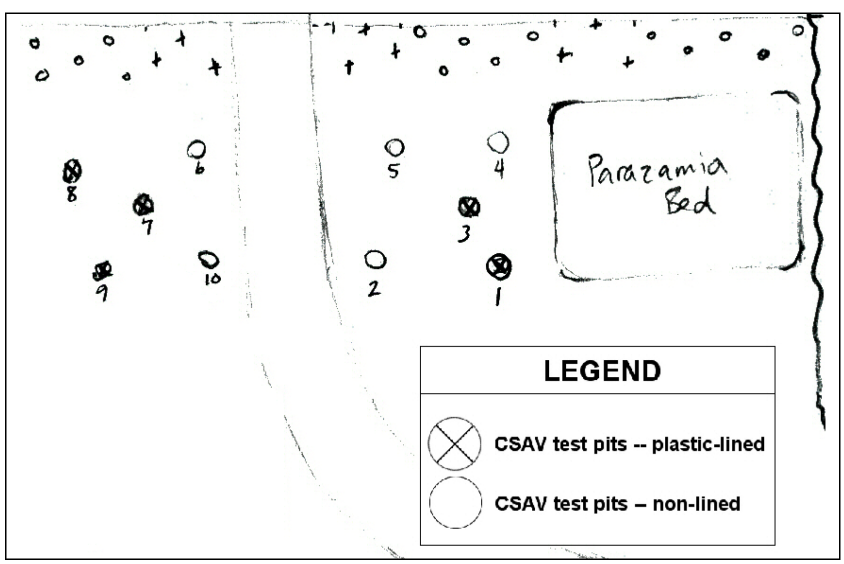
The South Palmetum area of the MBC property was chosen to examine the effect of the replacement of organic mulch with granite mulch as it relates to drainage and moisture retention of the soil beneath it. Although this graph is somewhat noisy, it does indicate that granite is at least as good as organic mulch with respect to soil moisture retention at 12" below the surface (as shown in the bottom panels). The top panels seem to indicate that the soil at 6" below the surface is sometimes drier and sometimes wetter under the granite mulch compared to the organic mulch. The lower "pink" peaks from mid-March to early May, however, may actually represent an artifact of a malfunctioning tensiometer, as the soil moisture meter indicated that the soil was always drier below the granite mulch at the 6" level.



New In-ground Sites

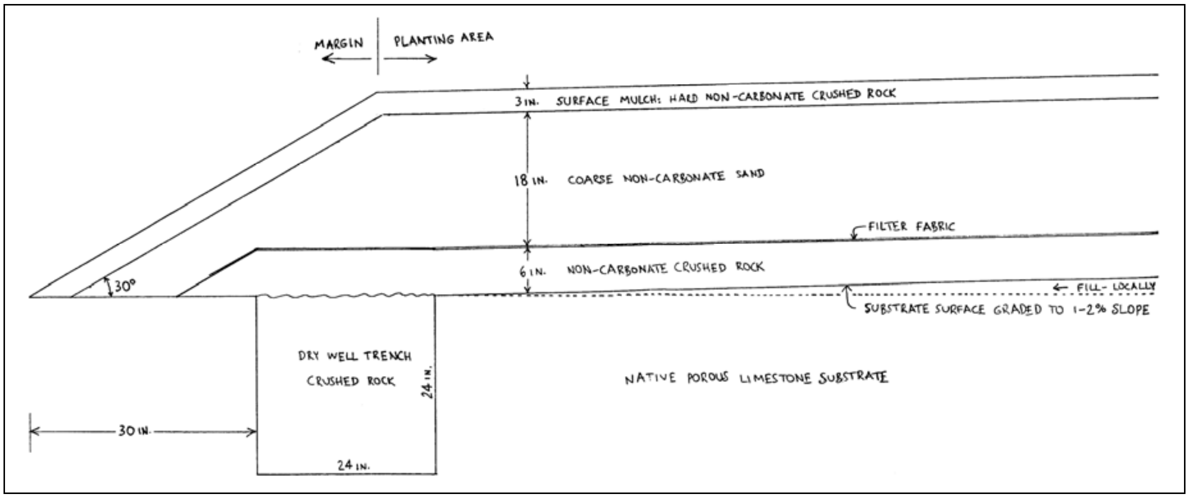
The sketch at right shows the relative placement of the Parazamia Bed and the CSAV Test Pits at the north end of the CSAV area. As indicated, the pits were numbered from 1 to 10, and half of them were lined with plastic (per our consultant's recommendation) and the other half were not. All pits were approximately four feet in diameter, approximately two feet deep, and include a 1-foot by 2-foot dry well.

Results from monitoring soil moisture in the Parazamia Bed and CSAV Test Pits will be discussed separately below.



0. <u>Parazamia Bed</u>

The Parazamia Bed was constructed based on recommendations from the soil consultant (as shown in the drawing below), with additional input from others on the Core Project Team.



The following photos illustrate the progression of Parazamia Bed construction. It should be noted that the site for this bed was chosen because of its natural slope toward the dry well; thus, no additional native fill was necessary to create the slope (as indicated in the drawing above).

A. Dry well trenches and flat drainage pipe.

B. Granite drainage layer (6”).

C. Filter fabric over drainage layer.

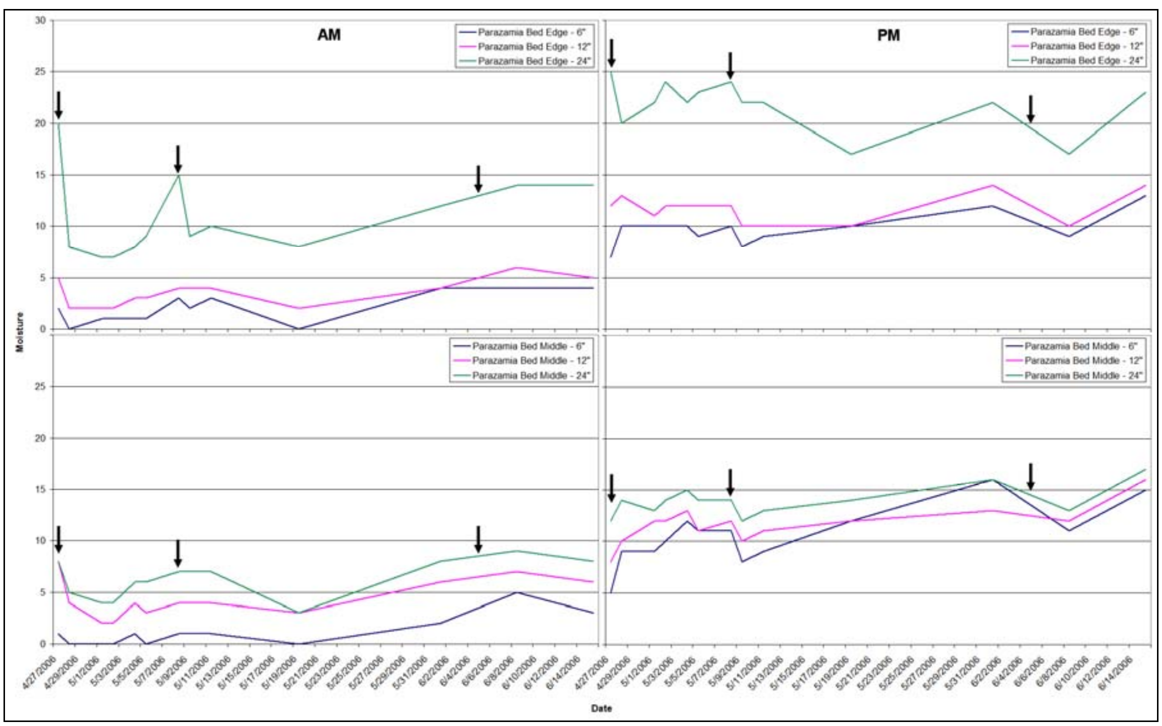
D. Coarse sand over filter fabric (18”).

E. Granite mulch (3") and tensiometers.

F. Close-up of tensiometer arrays.

Tensiometers installed in the Parazamia Bed monitored the soil moisture at three soil depths: 6", 12", and 24". Readings were taken in the morning and the afternoon. As the graph below indicates, soil moisture was greatest closest to the surface and in the morning.

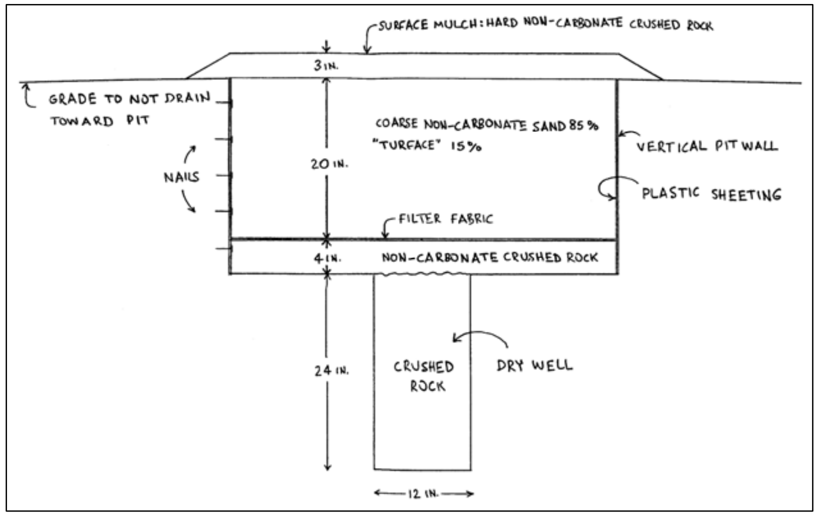
Although more data will be needed to make any definitive conclusions (see Conclusion section below), it seems as though the coarse sand in this bed does allow the moisture to drain down into the dry well. The graph also indicates that there is a noticeable edge effect, because the moisture levels were nearly always lower (represented by higher tensiometer readings) at the bed perimeter (top panels) compared to the bed interior (bottom panels).



2. <u>CSAV Test Pits</u>

The ten CSAV Test Pits were constructed following the soil consultant's recommendations (as shown in the drawing at right). All ten pits were constructed similarly, except that five were lined with plastic and the other five were not. The soil mix for the pits was comprised of 85% coarse sand and 15% Turface® MVP® inorganic soil modifier (Profile Products LLC).

Below are some photos illustrating the construction of the CSAV Test Pits.



A. Representative pit showing dry well.

B. Gravel drainage layer (4") and filter fabric.

E. Plastic-lined pit.

F. Non-lined pit.

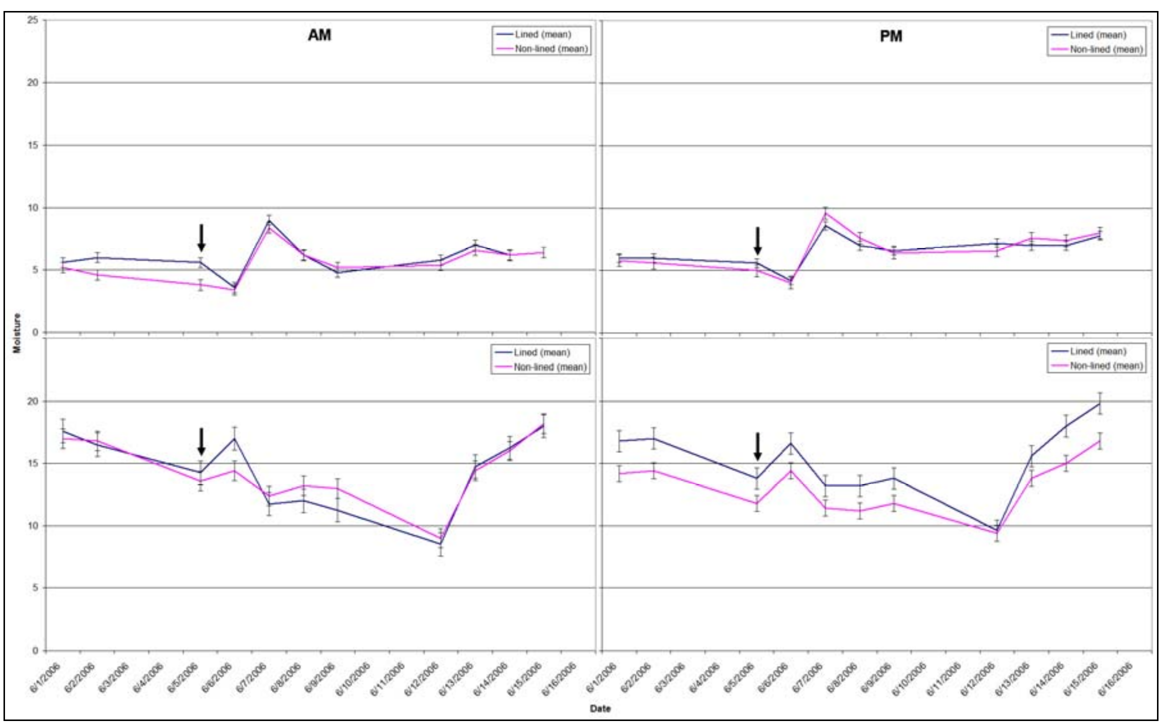
G. Preparing sand for mixing with Turface®.

H. Mixing CSAV Test Pit soil.

I. Completed pit with gravel mulch (3”).

J. Five of the pits with tensiometers.

The number and arrangement of tensiometers in the CSAV Test Pits allowed for the generation of standard error bars around the mean moisture values, as indicated in the graph below. These results suggest that moisture levels in the CSAV soil mix within the pits were higher in the morning (left-hand panels) and closer to the surface (top panels represent values from the 6” tensiometers).



The soil moisture values from the 12” tensiometers (bottom panels in the above graph) revealed a somewhat surprising result—which is that the plastic-lined pits seem to be providing better drainage and less moisture retention than the non-lined pits. If examined logically, however, this is actually not all that surprising if one considers that the plastic is most likely reducing the lateral transport of moisture into the pits from the surrounding native soil.

Soil Temperature

Although it seems unnecessary to show the graphs of the soil temperature data collected during this study, some general comments of the results may prove useful. As would be expected, the temperature of the surface of the ground (at mulch or soil) as well as below the ground was lower in the morning and higher in the afternoon. The highest temperature recorded at the surface was 60°C (141°F); this occurred in the middle of the Parazamia Bed with the granite mulch covering. At that time, the temperatures below the surface were 38°C (101°F) at 6” and 35°C (94.5°F) at 12”.

Although temperatures this high were not necessarily expected, surface readings well above 38°C (100°F) were recorded in the Australia 3 bed, where the plants have improved dramatically since the introduction of the granite mulch. Furthermore, temperatures above 53°C (128°F) were recorded at the surface of the nursery cycad soil mix in this study, yet even temperatures this high do not seem to adversely affect the cycads growing in the Full Sun Nursery at MBC.

While the granite mulch tends to heat up in the full sun during the day, it actually cools off quite quickly and tends to trap the heat in the soil below. For example, the surface temperature in the middle of the Parazamia Bed (same location as discussed above) one morning was 25°C (77°F), while the temperatures below the surface were 32°C (89.5°F) at 6” and 33°C (91.2°F) at 12”.

Conclusion and Path Forward

Conclusions from CSAV Soil/Drainage Testing Project

Parazamia Bed

The Parazamia Bed will need to be continually evaluated throughout this year’s rainy season to determine whether or not it will be able to provide adequate drainage and sufficiently low moisture retention to allow the “Parazamia” type cycads to grow and thrive. Additional data from the Parazamia Bed should also be accompanied by continued monitoring data from the Australia 3 bed during the same time period. Following that, a few test cycads should be planted in the bed and carefully monitored for several months. It is quite possible that the combination of coarse sand and granite mulch in the Parazamia Bed will provide appropriate growing conditions for these plants. If this is determined not to be the case, however, then this bed will likely need to be disassembled and the sand combined with the Turface® MVP® product that was used in the CSAV Test Pits—which exhibited slightly better results with respect to drainage and soil moisture retention.

CSAV Test Pits

As mentioned above for the Parazamia Bed, the CSAV Test Pits will also need to be continually evaluated throughout this year’s rainy season to determine whether or not they will be able to provide adequate drainage and sufficiently low moisture retention to allow “Savannah” type cycads to grow and thrive. Following that, a few test cycads should be planted in the pits and carefully monitored for several months. We believe that the combination of CSAV soil mix and granite mulch in these pits will likely provide appropriate growing conditions for these plants.

Testing and Developmental Phasing

The results described above are from Phase I of the CSAV Soil/Drainage Testing Project at Montgomery Botanical Center. They represent data relevant to the successful cultivation of “Savannah” and “Parazamia” type cycad species at MBC. The “Desert” type cycads may still require additional testing due to their much stricter soil drainage requirements. Phase II may include a smaller test plot similar to the one specified in our original proposal. Additional funding will be required for Phase II.

The proposed use of individual plant pits for the “Savannah” species, along with the modular nature of the “raised bed with under-drainage system” proposed for the “Parazamia” and “Desert” species will allow for a well-designed, affordable, phased approach to the development of the entire CSAV area over the coming years.