FINAL REPORT FOR THE STUDY

EVALUATING SALT TOLERANT ORNAMENTALS FOR A 21ST CENTURY GALVESTON

2016-2019

PRESENTED TO THE MOODY FOUNDATION

SUBMITTED BY:

DR. DAVE CREECH

PO BOX 13000

STEPHEN F AUSTIN STATE UNIVERSITY

NACOGDOCHES, TEXAS 75962

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EXECUTIVE SUMMARY

Initially, this 2016 Moody Foundation funded project had four goals: 1) create a GIS (Geographic Information Systems) map of the research plot that characterized the slopes, drainage patterns and soil nutrient levels, including sodium, 2) Develop a long term evaluation program for woody ornamental trees and shrubs, 3) Initiate a Master of Science thesis research project to study treatments that affect soil amelioration and plant establishment in the project area, and 4) Initiate a Master of Science degree to assess and characterize microbial communities in the salt affected soil on Galveston Island and the opportunities for mycorrhizal colonization of select species to enhance their salt tolerance and performance. Those goals have been achieved and other deliverables are described in this Final Report to the Moody Foundation.

A major goal of this project is to evaluate woody ornamentals in a salt and wind challenged environment. The site selected for the research plot is at the West end of Moody Gardens and North of and adjacent to the Scholes International Airport. Our footprint consists of about two acres, and we're using a nursery row strategy. Most of the plant materials are planted on a mild 6" to 1" berms of off-island sand, about four feet wide. Bark has been tilled in, and we use mulching, herbicides and base of plant hand weeding to keep the weeds at bay. Everything is drip irrigated. We have a fertilization philosophy that leans to light applications applied infrequently. The plots are only 3-4' above sea level and a couple of hundred feet from the bay. At about two feet and below you find a high salt soil environment, which means most trees and shrubs have a poor chance of thriving, or surviving. An additional challenge is wind. Plant materials tend to lean toward the north. Branches on the south side of a tree trunk find themselves soon growing to the north.

Our latest inventory reveals over 260 woody plants attempting to thrive or survive in this tough landscape situation. Most accessions are three to five plants of each. We already have winners and losers. Of course, many of the palms, both commodity and rare, are performing well. At this writing, August 2019, the SFA Gardens introduction Prunus X 'Purple Pride' seems to prosper. *Leucophyllum langmaniae* 'Lynn's Legacy' is keeping excellent form and seems to bloom all the time. Our pomegranate varieties are thriving. *Hibiscus dasycalyx*, the Neches river rose mallow, is an endangered plant with which we have considerable experience. It is surprisingly strong in our plots with great flowering, shows no salt damage and seems unaffected by the sawfly, a terrific problem in its home further north. *Grevillea robusta* and *Salix floridanus* deserve further trials on the island. We have high hopes for *Myrcianthes fragrans*, Simpson's showstopper, which features evergreen foliage, exfoliating bark, white flowers and attractive fruit. The hybrid Taxodium selections selected for salt tolerance via the Nanjing Botanical garden are growing well, but wind is the big challenge for tree form and structure. Several Poplars via the University of Florida have been surprises with fast growth and unaffected foliage. There are losers, some surprising, some not. The Mexico oaks have fought a battle with aerial salt. As candidates fall, they are being replaced with new plant materials for testing. Most important to the Moody Gardens mission, this grant has created a long term platform for evaluating plants in a windy and salt challenged landscape. Malcolm Turner is the Technician in charge of this project on the ground. He's doing a great job making things happen, and I have renewed confidence that the maintenance part is covered. Danny Carson, recently retired Moody Gardens Horticulturist, and Donita Brannon, Rainforest, have been great to work with. Sabino Bilon of Moody Gardens deserves a special thank you. He has taken a personal interest in the project and has been of great help when needed.

It should not go unmentioned that this project has been a really fine learning experience for so many undergraduate and graduate students at SFA. They have been given an opportunity for a real world environmental project. With climate change a growing reality in the scientific community, our youngest citizens have the most reason for interest and enthusiasm for a project of this nature. Facts do matter.

In addition to plant evaluation, the project has allowed other collaborative research projects. Dr. Hua Jianfeng, our visiting scientist from Nanjing Botanical Garden established a planting to test the use of *Hibiscus hamabo* as a rootstock for *Hibiscus syriacus*, Rose of Sharon. We will answer the question whether using the salt tolerant hamabo as a rootstock allow the popular Rose of Sharon to grow in a more salt challenged environment? The verdict is not in, but to date, the results are promising. Dr. Farrish and MSc candidate Daniel Morgan have some very interesting research that will help landscapers with horticultural strategies to deal with salt challenges. Drs. Wagner and Taylor are wrapping up a study on the mycorrhizal status of that portion of Moody Gardens and the opportunities for improving plant performance. These and other studies are outlined in the following annual reports for 2016, 2017, 2018, and 2019.

This research project has enjoyed good publicity and outreach. A full listing of paper presentations, publications and tours for the project can be found in Section 8, Publications and Presentations.

Everyone I've met on the island is quick to let me know we're one hurricane away from a disaster. But this is Galveston, and the Islanders know that. Ours is not a project for the timid. Still, it's an effort that can help us gain a better understanding of dealing with plants in a challenging coastal environment. If the prognostications are right on climate change, Texas is destined to be warmer in all four seasons and subject to more intense droughts and violent storms. If the predictions of sea level rise for 2050 and 2080 and beyond are correct, then finding climate change friendly plants and better strategies to grow them is indeed a prudent cause for land use planners along the coastlines.

BUDGET AND REMAINING BALANCE

Moody Grant					
265041	**Yr 1**	**Yr2**	**Yr3**	**Yr4**	**Yr5**
	4/9/15-4/8/16	4/9/16-4/8/17	4/9/15-4/8/17	4/9/16-4/8/18	4/9/19-7/3/19
Beginning Balance Forward		42,023.23	65,306.51	122,199.72	69,185.59
Revenue					
Private Grant Funds	83,989.66	83,989.66	83,989.68	0.00	0.00
	83,989.66	126,012.89	149,296.19	122,199.72	69,185.59
Expenditures					
Faculty Salaries	0.00	0.00	0.00	2,700.00	0.00
Graduate Asst Salaries	10,932.53	11,075.10	3,783.32	2,200.00	200.00
Student Wages	517.62	252.48	905.90	2,938.09	242.16
Classified Wages	8,605.72	6,446.74	7,097.90	10,025.09	2,717.27
Benefits	2,818.59	1,773.64	2,779.82	4,957.66	868.35
Travel	4,066.57	3,947.63	4,787.83	5,395.75	584.62
O&M	15,025.40	37,210.79	7,741.70	16,630.54	158.64
Capital Outlay	0.00	0.00	0.00	8,167.00	0.00
	41,966.43	60,706.38	27,096.47	53,014.13	4,771.04
Balance	42,023.23	65,306.51	122,199.72	69,185.59	64,414.55

2019 ANNUAL REPORT

WOODY ORNAMENTAL EVALUATION

Dr. Dave Creech

This project was initiated in 2016 as the result of a three year grant from the Moody Foundation. The first year was spent building the infrastructure for a two acre research plot on the west side of Moody Gardens and adjacent to the airport's north side. Over the last 4 years, SFA and Moody Gardens have collaborated to construct a "revolving door" nursery. The project acquires interesting plant materials from a wide variety of sources, plants three to five, and then evaluates their performance. Superior performers are noted and propagated for distribution; poor performers are discarded and replaced with new candidates for testing. The latest planting plan is in the Appendix of this document.

Measuring a *Populus* species

We have maintained an Excel database for plant growth (diameter, height, width) of the individual plants. The superior performers have been impressive with tree trunk diameters exceeding 6" with many species. The Taxodium collection is extensive with numerous hybrid selections included in the study in groups of five trees. 'Oaxaca Child' is a Montezuma cypress with evergreen tendencies, no knees and fine salt tolerance. It deserves greater use.

Taxodium 'Oaxaca Child'

GRAFTING STUDY: As a result of our collaboration with the Nanjing Botanical Garden and Professor Yin Yunlong's program, we are testing the efficacy of grafting Rose of Sharon (Hibiscus syriacus) on H. hamabo as a rootstock. Hamabo is extremely salt tolerant. It appears to graft easily with the popular and well know Rose of Sharon (Althaea). The grafts heal quickly and plant growth has been exceptional. We have high hopes this rootstock will allow popular Rose of Sharon varieties to move into saltier locations. We still have aerial salt issues to study and that may limit the opportunity ahead. Time will tell.

Hibiscus hamabo/H. syriacus grafted combination

Hibiscus syriacus on H. hamabo RS

Hibiscus hamabo

This winter will conclude the evaluations for a good number of the species established in 2016 and 2017.

The superior performers will be dug and planted at Moody Gardens or in nearby civic projects as it seems fit. The empty spaces will be planted in mid to late winter 2020 to new candidates and the process will begin again. Acquire, Evaluate, Propagate, Promote and Distribute is the mantra of this program.

Grivillea robusta

While we have a number of standouts, there are a few that deserve mentioning. For instance, we have multiplied *Salix floridanus*, a rarely encountered Florida coastal willow species (described in the 2018 annual report) and we now have 25 one gallons to plant in winter 2020. One of the more successful trees tested is *Grivellia robusta* (silk Oak) which is fast growing, tolerant of light freezes, with an attractive flower and form.

This project has received good publicity and outreach to future land use managers. In the past year, we presented an oral paper in Birmingham, Alabama, Feb 2, 2019 to the Southern Region of the American Society for Horticultural Science on our research work at Moody Gardens. We were pleased to host a class of 65 SFA Forestry students, a class of Dr. Pat Stephen Williams, SFA Forestry, May 22, 2019. We provided a tour and seminar for the Annual State Conference of County Extension agents which was held in Galveston, Texas, on July 30, 2019.

Soil Amelioration, Aerial Salt Deposition, and Groundwater Study

Dr. Ken Farrish

Project Overview

Two graduate students, both seeking the Master of Science degree in Environmental Science, conducted their research projects on the Moody Gardens site. Elaine Harris focused her research on soil amelioration treatments aimed at improving plant survival and growth, specifically live oak (*Quercus virginiana*), hybrid bald cypress (*Taxodium* X 'T406') and yellow hibiscus (*Hibiscus hamabo*), on the salt affected soils. Her work also sought to quantify the amount of annual aerial deposition of salts from sea spray on the study area. Daniel Morgan followed up on Elaine's work with additional plant measurements, evaluation of hybrid bald cypress (*Taxodium distichum*) foliage Na^+ concentrations and a groundwater characterization and monitoring study.

Soil Amelioration and Aerial Deposition Study, Elaine Harris

Objectives

The specific objectives of this research were to:

- Quantify the salinity of soils found at the storm surge impacted coastal site.
- Evaluate soil Na^+ amelioration practices for efficacy in displacement and reduction of soil Na+.
- Conduct a plant trial of live oak (*Quercus virginiana*), hybrid bald cypress (*Taxodium* X 'T406'), and yellow hibiscus (*Hibiscus hamabo*).
- Measure survival and growth response of the three plant species to applied soil amelioration treatments.
- Quantify the aerial input of Na^+ (sea spray) to the site through deposition during both wet and dry weather events. Current inputs of sodium salts from sea-spray aerosols and during precipitation events were also quantified using a precipitation/dry-fall automated collector at the study site over one year with monthly measurements.

Study site plantings of live oak (*Quercus virginiana*),
hybrid bald cypress (*Taxodium X 'T406')*, and yellow hibiscus (*Hibiscus hamabo*) on soil amelioration plots at the Moody Gardens study site.

Image of the Precipitation Collector used
to quantify the annual aerial Na^+ deposition at the Moody Gardens study site.

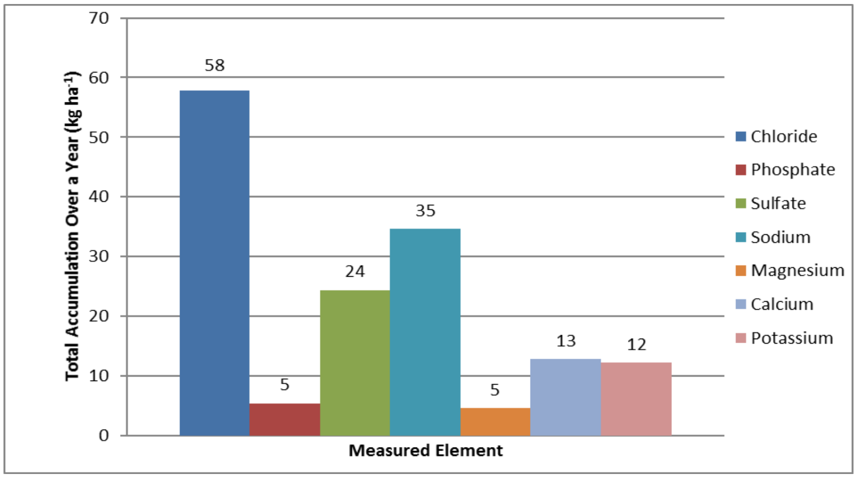
Methods

Principal methods of elevated soil sodium (Na+) amelioration include increasing sodium leaching via irrigation, incorporating organic mulches, employing elevated planting beds and adding chemical amendments. In this study, elevated beds were constructed with uncontaminated soil originating from an off-island source, pine bark was used for the incorporated mulch and the chemical amendment was calcium sulfate (gypsum). The study evaluated the effectiveness of the soil management treatments using the survival and growth of three plant species, live oak (Quercus virginiana), hybrid bald cypress (Taxodium distichum) and yellow hibiscus (Hibiscus hamabo). A randomized factorial design using the eight treatment combinations with the three plant species was replicated six times on an area that was salt affected from the hurricane storm surge near Galveston Bay.

Results and Discussion

Plant survival and growth for all three species was very good on all soil amelioration treatments and control plots. The treatments had little effect on either survival or growth, probably in part due to unrequested continued irrigation by Moody Garden's staff with reverse osmosis treated water well into the second growing season. Measurement of soil parameters indicated that Na^+ levels appeared to be somewhat reduced in the gypsum treated plots. In retrospect, a higher gypsum rate of application may have produced desirable results. Clean soil brought into the site to build the raised beds did not contain appreciable amounts of Na^+ initially, however, Na^+ levels increased within the first year in these beds to levels comparable to the native soil. Na^+ may have moved up into the beds via diffusion from below, from input of aerial deposition, or most likely both. The indication is that building raised beds with clean soil may not be an effective means of addressing high soil Na^+ concentrations.

Annual aerial deposition of Na^+ was relatively small, but also quite variable during the year. Greatest deposition of Na^+ occurred during storm events as wet deposition. However, total annual aerial deposition of Na^+ was only 0.39 percent of the Na^+ content in the top 10cm of soil, and therefore may not be a large contribution to soil Na^+, but could directly adversely impact plant foliage in the short term.



Total accumulation of Cl^- , PO_4^{3-}, SO_4^{2-}, Na^+, Mg^2+, Ca^{2+}, and K^+ on a per hectare basis deposited at the study location from May 2016 to May 2017.

Foliage and Groundwater Study, Daniel Morgan

Objectives

The purpose of this study was to develop an understanding of where Na^+ salts accumulate in the Galveston coastal system of groundwater, soil and plants, what factors affect the rate of accumulation of salts and to observe how a series of native and nonnative plants tolerate Na^+ intake through the ground and through aerial deposition.

The specific objectives of this research were to:

- Evaluate third growing season survival and growth of the three species (*Taxodium* X 'T406', *Quercus virginiana*, and *Hibiscus hamabo*) used in the soil amelioration study and to determine elemental concentrations, especially Na^+, present in the foliage of the *Taxodium* plants on the study area.

- Monitor the depth and quality of the groundwater by determining fluctuations in Na^+, Cl^-, pH, electrical conductivity (EC) and temperature through a one-year period.

- Relate the groundwater conditions with weather data and aerial deposition data to help characterize the movement of salts in the environment of the study area.

Methods

Nine piezometers were installed at the Moody Gardens site in 2017. Three of the piezometers were equipped with Solinst Leveloggers, water level dataloggers that can also detect electrical conductivity and water temperature at a predetermined interval.

Each piezometer was constructed out of 3.175 cm Schedule 40 PVC pipe. At the bottom of each piezometer, a 25 cm section of 0.25 mm-slotted PVC pipe was attached to the main body of the piezometer. The piezometers that did not contain Leveloggers were capped at the top with PVC pipe caps. The piezometers equipped with Leveloggers used a 3.175 cm to 5.08 cm coupling attached to a 15 cm 5.08 cm diameter PVC pipe, to allow the installation of the Levelogger well cap.

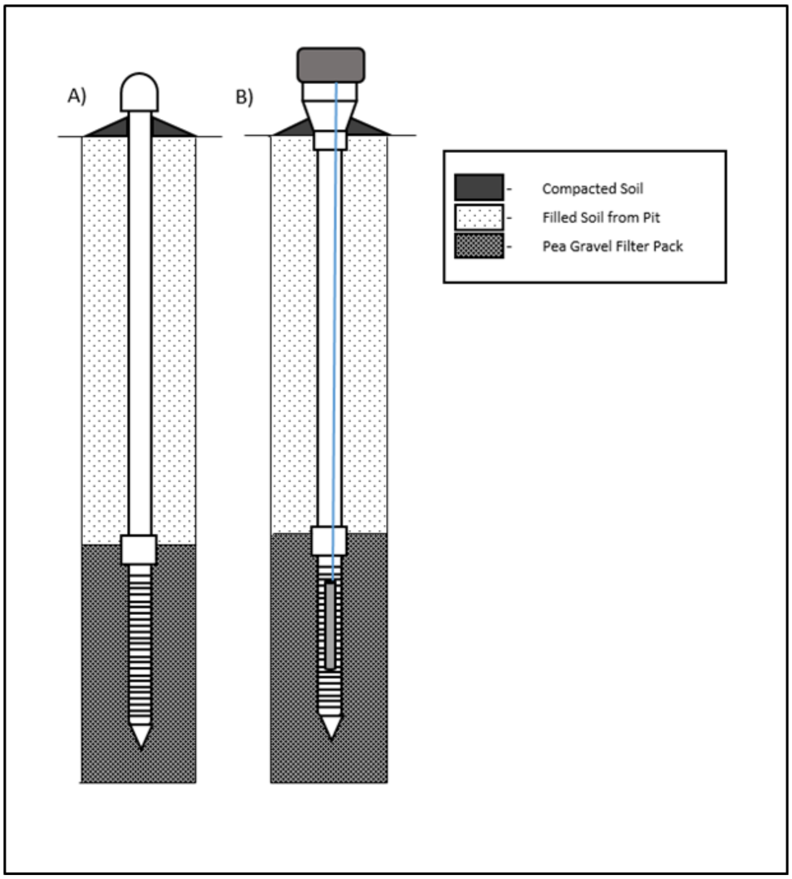


Diagram of the design of the piezometers used for collection of groundwater data, as well as the design for the piezometer pits. The dimensions of the piezometers and the pits varied based on the location of each point. Part A shows the design of a standard piezometer used for groundwater sampling and measurements. Part B shows the design for a piezometer to be used in conjunction with a Solinst Levelogger.

Image of typical installed piezometer at the Moody Gardens research site.

The Solinst Leveloggers collect data on water level, electrical conductivity and water temperature. They can be left onsite to collect continuous data readings to supplement data found from the water samples. The Leveloggers collected data at an interval of 30 minutes and ran continuously for the duration of the study. Data was collected from the loggers during the biweekly sample collections in order to ensure the safety of the data, as well as check for abnormalities. Upon completion of groundwater collection, the piezometers were used to determine soil characteristics in the study area. The Leveloggers were removed and recalibrated for the slug tests, with the sample interval being changed from 30 minutes to 2 seconds, the fastest possible sample interval. Groundwater depth data was compared to precipitation data collected from the nearby airport weather station.

Groundwater was collected from each of the piezometers every two weeks for a period of one year. Groundwater samples were tested for pH, electrical conductivity (EC), carbonates, bicarbonates, sodium, calcium, magnesium, potassium, iron, sulfate, chloride, phosphate and nitrate. To determine the presence of salts in the plants of interest, foliage samples were collected from the *Taxodium* T406 close to the end of the growing season, to allow for an adequate accumulation of salts in the leaves before fall leaf senescence. Foliage samples were dried, ground and then analyzed for select element content at the SFA Plant, Soil, and Water Analysis Laboratory.

Third year survival and growth measurements on the plants in the soil amelioration plots were made as before by Elaine Harris.

Results and Discussion

Groundwater depth and chemistry varied considerably at the study site, both spatially and temporarily (Table 1). For example depth to the groundwater varied from 56 to 93 cm, while Na^+ and Cl^- levels varied from 67 to over 902 mg L^{-1} and 73 to over 2400 mg L^{-1}, respectively. In comparison, typical seawater has about 10,556 mg L^{-1} Na^+ and 18,980 mg L^{-1} Cl^{-1}. EC values ranged from 0.99 to 6.99 mS/cm, well below that of typical seawater at 50 mS/cm. So, the groundwater at the Moody Garden site, while salt affected, is currently far less salty than seawater.

Table 1. Means of groundwater parameters for the Moody Gardens study area, over the duration of the study. Water parameters are pH, electrical conductivity (EC), Na^+, Cl^- and depth to water table (DTWT).

Piezometer	Mean pH	Mean EC (mS/cm)	Mean Na^+ (mg L-1)	Mean Cl^- *(mg L-1)	Mean DTWT (cm)
1	7.93	2.77	269.7	843.4	64.5
2	8.03	1.52	188.7	289.9	68.8
3	7.78	0.78	67.5	73.5	93.6
4	7.85	5.41	789.7	1975.2	59.5
5	8.10	2.57	342.7	634.7	74.3
6	7.94	0.99	96.4	133.4	91.6
7	7.85	5.98	876.6	2051.2	56.6
8	7.76	6.99	902.7	2436.8	79.5
9	8.05	1.45	237.9	175.19	81.9

Foliage samples on the soil amelioration plots showed no significant differences in Na+ concentrations among the treatments. However considerable variation in foliage Na+ concentrations existed on nearby plots where different *Taxodium* genotypes were planted, ranging from just over 6400 mg kg^{-1} to over 11000 mg kg^{-1}. The highest concentrations were found in the T406 and T405 genotypes, which are known to have the highest Na+ tolerance.

Table 7. Select elemental concentrations, for the *Taxodium* genotypes within the Moody Gardens study site.

Genotype	Na (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg-1)	S (mg kg-1)
T. *distichum*	6412.64	9269.92	12295.47	2957.54	1881.92
T. 'Oaxaca child"	7236.63	16743.72	7702.69	3022.98	1813.83
T407	9373.53	9860.28	12256.20	3690.60	1820.91
T406	11059.84	12278.70	8790.98	3401.17	1990.16
T405	10579.38	10852.37	9453.77	3209.54	1853.30
T27	8700.53	11664.61	9092.05	3057.79	1948.55
T502	9062.56	9569.70	8765.69	3169.62	1753.47
T406-North Plots	8662.15	10939.84	10637.03	3382.27	1360.97

Plant survival and growth on the soil amelioration plots remained largely unchanged from the previous two years of measurement, with no significant treatment effects.

Table 1. Concentrations of nutrients in *Taxodium* genotypes, listed in ppm.

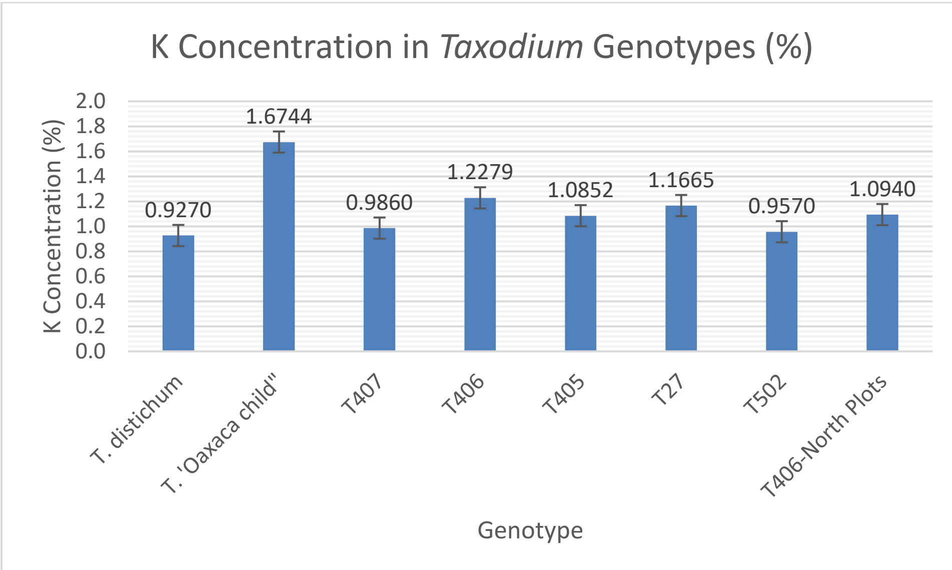
Genotype	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	Na (ppm)
T. distichum	9269.92	12295.47	2957.54	1881.92	6412.64
T. 'Oaxaca child"	16743.72	7702.69	3022.98	1813.83	7236.63
T407	9860.28	12256.20	3690.60	1820.91	9373.53
T406	12278.70	8790.98	3401.17	1990.16	11059.84
T405	10852.37	9453.77	3209.54	1853.30	10579.38
T27	11664.61	9092.05	3057.79	1948.55	8700.53
T502	9569.70	8765.69	3169.62	1753.47	9062.56
T406-North Plots	10939.84	10637.03	3382.27	1360.97	8662.15

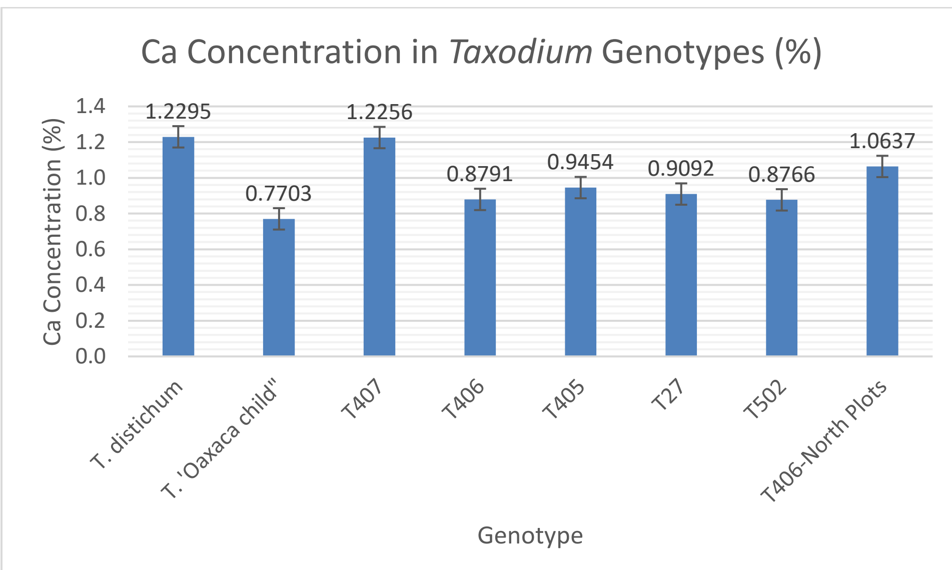
Table 2. Concentrations of nutrients in *Taxodium* genotypes, listed in percentages.

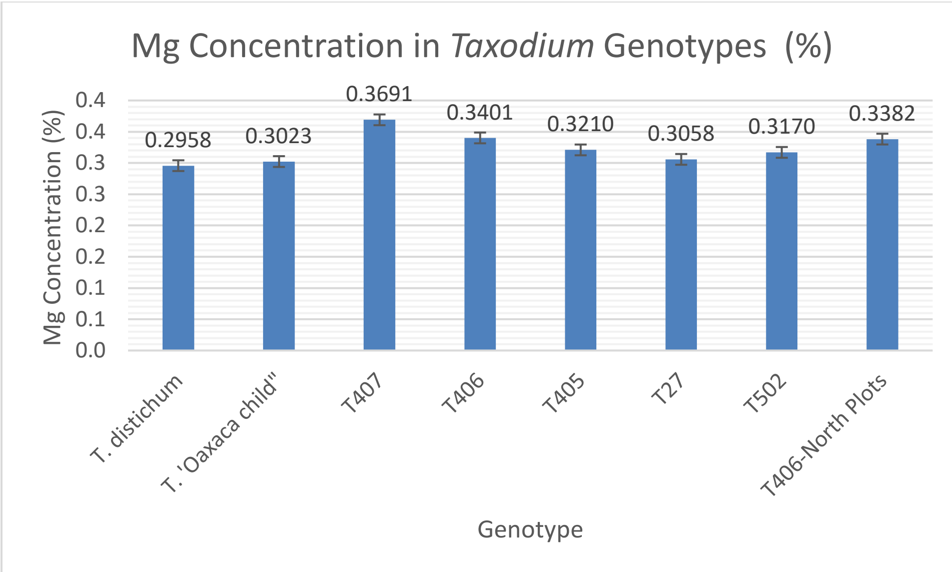
Genotype	K (%)	Ca (%)	Mg (%)	S (%)	Na (%)
T. distichum	0.9270	1.2295	0.2958	0.1882	0.6413
T. 'Oaxaca child"	1.6744	0.7703	0.3023	0.1814	0.7237
T407	0.9860	1.2256	0.3691	0.1821	0.9374
T406	1.2279	0.8791	0.3401	0.1990	1.1060
T405	1.0852	0.9454	0.3210	0.1853	1.0579
T27	1.1665	0.9092	0.3058	0.1949	0.8701
T502	0.9570	0.8766	0.3170	0.1753	0.9063

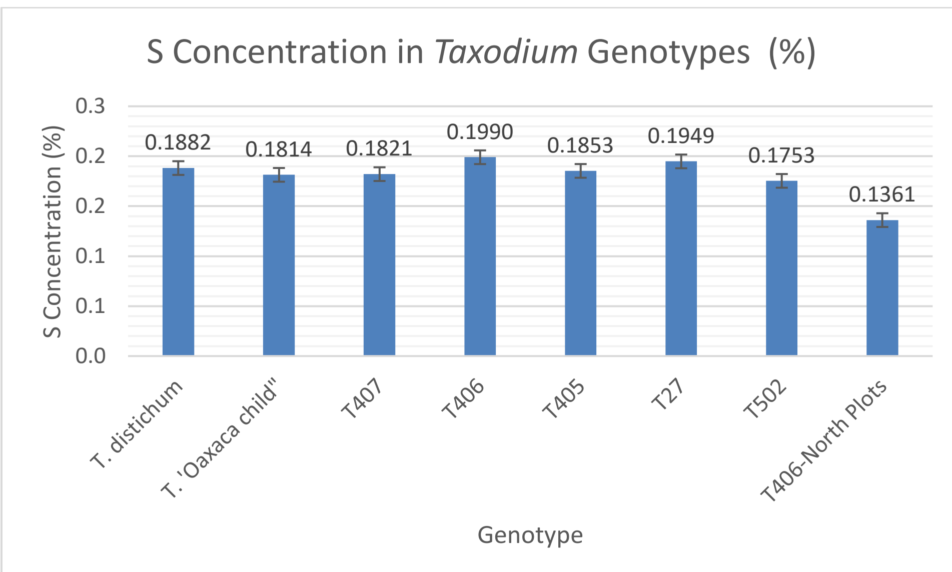
T406-North Plots	1.0940	1.0637	0.3382	0.1361	0.8662

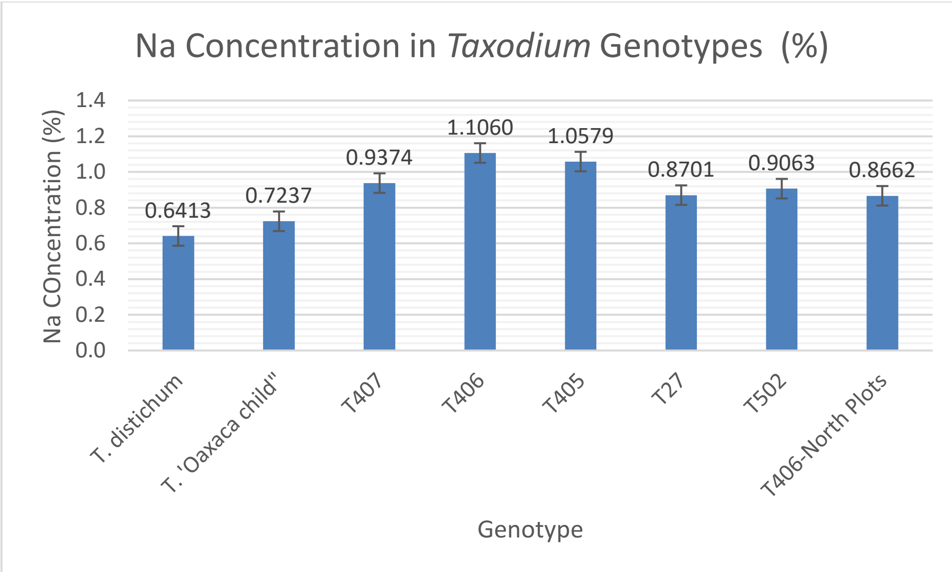
Figures:






Mg Concentration in Taxodium Genotypes (%)
Mg Concentration (%)
0.0
0.1
0.1
0.2
0.2
0.3
0.3
0.4
0.4
0.2958
0.3023
0.3691
0.3401
0.3210
0.3058
0.3170
0.3382
T. distichum
T. 'Oaxaca child"
T407
T406
T405
T27
T502
T406-North Plots
Genotype


S Concentration in Taxodium Genotypes (%)
S Concentration (%)
0.0
0.1
0.1
0.2
0.2
0.3
0.1882
0.1814
0.1821
0.1990
0.1853
0.1949
0.1753
0.1361
T. distichum
T. 'Oaxaca child"
T407
T406
T405
T27
T502
T406-North Plots
Genotype


Na Concentration in Taxodium Genotypes (%)
Na COncentration (%)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.6413
0.7237
0.9374
1.1060
1.0579
0.8701
0.9063
0.8662
T. distichum
T. 'Oaxaca child"
T407
T406
T405
T27
T502
T406-North Plots
Genotype

Drs. Stephen Wagner and Josephine Taylor

Project Overview

Even though microorganisms compose less than 1% of a given soil's mass, they play an intricate role in the growth, health, and success of plants growing in that soil. Beneficial organisms, such as mycorrhizal fungi and nitrogen-fixing microbes not only promote plant growth and health, but also help reduce the need for nitrogen and phosphorus fertilization. We have investigated the role that these microbes have on the growth of plant species being studied at the Moody Gardens research site.

Project Objectives

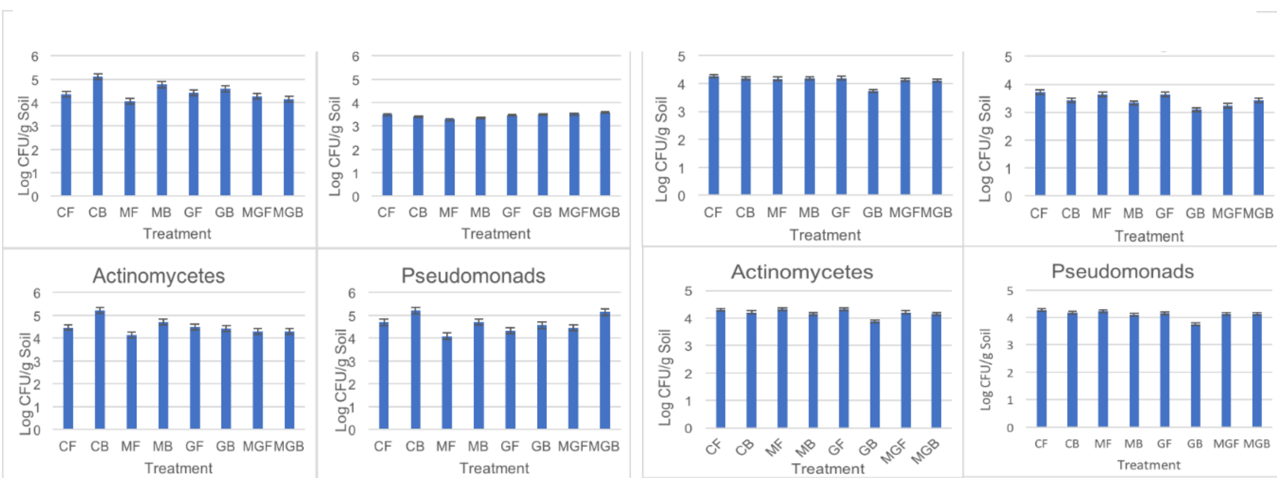
We have focused on three specific objectives:

1. Assess the effects of soil amelioration approaches on microbial populations and activities at the Moody Gardens Research Site.
2. Determine native mycorrhizae populations at the Moody Gardens study area.
3. Test the efficacy of mycorrhizae inoculants on plant species being evaluated at the Moody Gardens site,

Soil Microbial Population/Activity Study. Because microbial species play an intricate role in the success of the *Hibiscus hamabo*, *Quercus virginiana* and *Taxodium distichum* plants growing in the soil amelioration study at the Moody Gardens site, research included assessing indigenous microbial populations and activity. This work was the subject of a Master of Science thesis project conducted by Elaine Fowler (Environmental Science) and was directed by Stephen Wagner. Soil samples were collected in July and October 2016 and January 2017 to estimate total bacteria and fungi populations. These were determined by serial dilution plating on selective media using a spiral plating system. Soil respiration rates were determined using a Model EGM-4 Environmental Gas Monitor for CO_2 evolution. Bacteria populations ranged from 4.07 to 5.12 and 3.73 to 4.26 log CFU g^{-1} in soils collected in July and October, respectively. Fungi ranged from 3.27 to 3.58 and 3.09 to 3.71 log CFU g^{-1}. Fungal populations were not significantly different between treatments. Bacteria populations were significantly higher only in control bedded and mulch flat treatments. Likewise soil respiration rates ranged from 0.873 to 3.07 g CO_2 m^{-2} hr^{-2} but showed little response to soil amendments. These results indicate that there are relatively large and active soil microbial communities inhabiting soils at the field site. However, soil amendments had little effect on microbial populations and activities. Elaine successfully completed and defended her thesis and graduated in May, 2017. Additionally, these results were reported in a poster presentation given at the Soil Science Society of America Annual meeting held in Tampa, FL in October 2017.

Environmental Science Graduate Students Elaine Fowler and Elaine Harris Conducting Studies

Effect of Soil Amendments on Microbial Populations at Moody Gardens Study Site



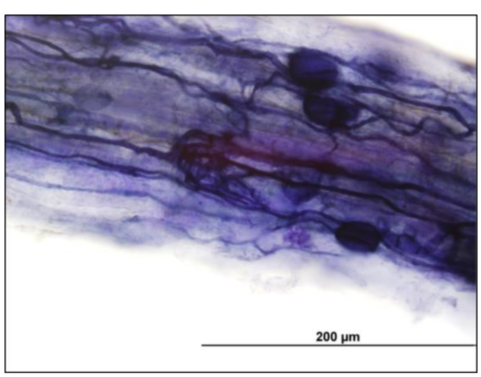
Effect of Soil Amendments on Soil Respiration Rates at Moody Gardens Study Site

Treatment	Respiration	SNK
Mulch Bedded	3.07	A
Mulch Flat	2.56	A, B
Gypsum Flat	2.56	A, B
Control Flat	2.25	A, B
Mulch Gypsum Flat	2.13	A, B
Gypsum Bedded	1.84	A, B
Control Bedded	1.63	A, B
Mulch Gypsum Bedded	0.87	B

Soil samples were also collected from each treatment in this study to determine the effect of the treatments on endomycorrhizae populations. A most probable number technique, whereby soil samples were grown on tall fescue plants in a greenhouse was set up and conducted by several undergraduate students to determine these populations. The greenhouse work was accomplished during the 2018-2019 academic year and will be analyzed this fall.

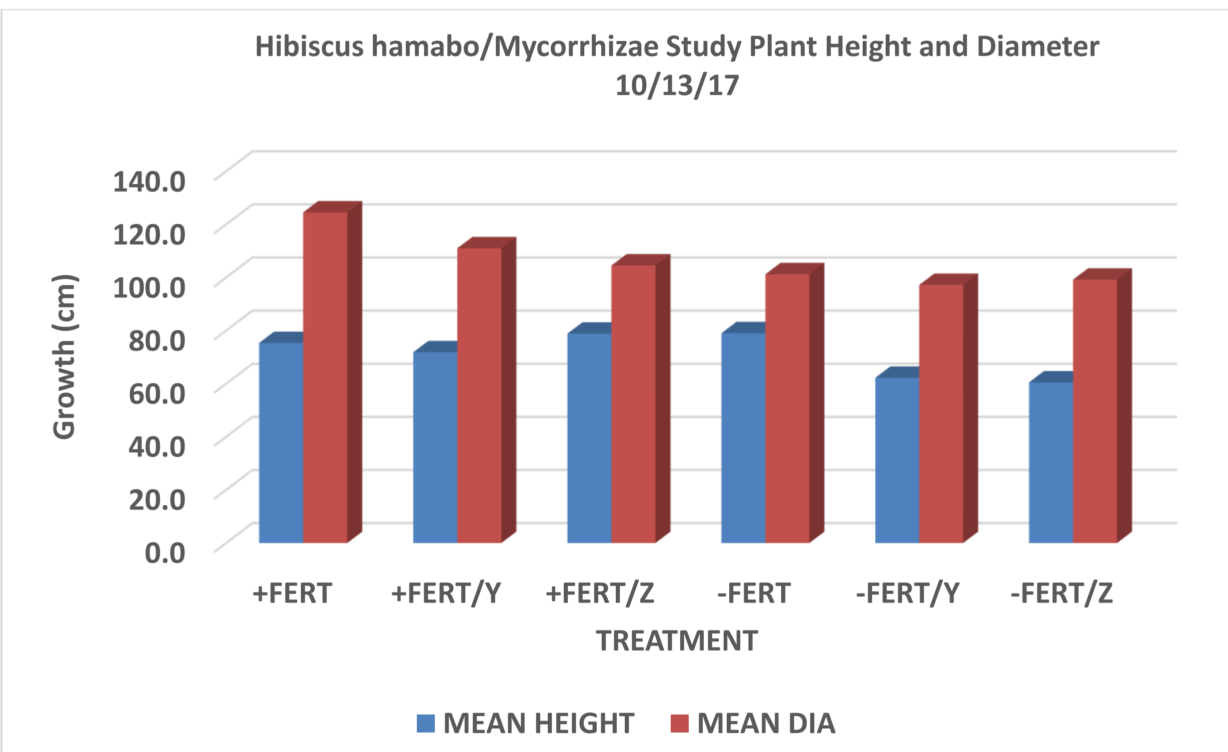
Native Mycorrhizal Fungi Studies. We have characterized the colonization of these fungi on the roots of several native grass and wildflower species as well as determine most probable numbers (MPN) of endomycorrhizae at the field research site. Dr. Josephine Taylor led an investigation by undergraduate students to ascertain arbuscular mycorrhizae colonization of herbaceous roots of 3 native species *Gomphrena serrata* (Amaranthaceae), *Gaillardia pulchella* (Asteraceae), and *Digitaria* spp. (Poaceae) collected from the research site. Through microscopic examination it was determined that all three native plant species exhibited AM associations, as evidenced by the presence of fungal hyphae, vesicles and arbuscules within their root tissues. The abundance of arbuscules, as well as their morphology, varied between the plant hosts, indicating that a number of different fungal species may be involved.

Mycorrhizae in Stained Roots of a Native Species at Moody Gardens



In the MPN analysis, presence or absence of AM colonization in each soil dilution was assessed in order to estimate natural population levels of these fungi. Results revealed a range of 2.9 x 10^4 to more than 1.1 x 10^8 AM propagules per gram of soil (Table 1). Taken together, these data indicate that plants on Galveston Island are associated with an active AM community. Graduate student Angela Rittenberry (Secondary Education) presented a poster at the Texas Academy of Science Meeting in March 2017 at Mary Hardin Baylor University and at the SFASU Graduate Research Conference on April 20, 2017.

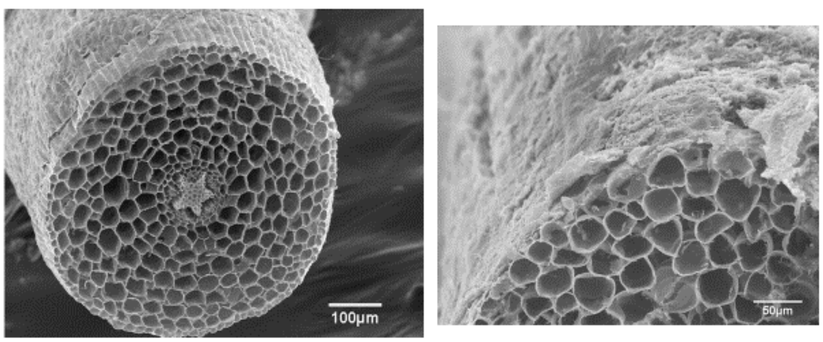
Effect of Mycorrhizal Fungi Inoculation on Growth of Candidate Hibiscus Species. We have also begun studying the utilization of plant growth-promoting microorganisms such as mycorrhizal fungi, on the growth of candidate plant species. An initial greenhouse and subsequent field study (transplanted in February, 2017) is assessing the effect of two different endomycorrhizae commercial inoculants on the growth of *Hibiscus hamabo.* Initial growth measurements (plant height and diameter) showed that the inoculants did not improve plant growth. However, research indicates that there are long-term effects of inoculants. Consequently, we are continuing to collect data on the growth and development of these plants.



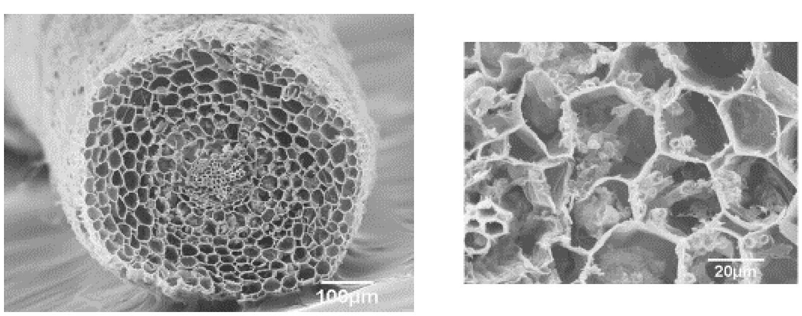
***Hibiscus hamabo* Study at Moody Gardens Field Site**

Undergraduate students directed by Dr. Taylor prepared samples from the *Hibiscus hamabo* greenhouse study for scanning electron microscopy and generated images of control and mycorrhizal inoculated roots.

SEM micrographs of *Hibiscus hamabo* control roots – no mycorrhizal inoculation



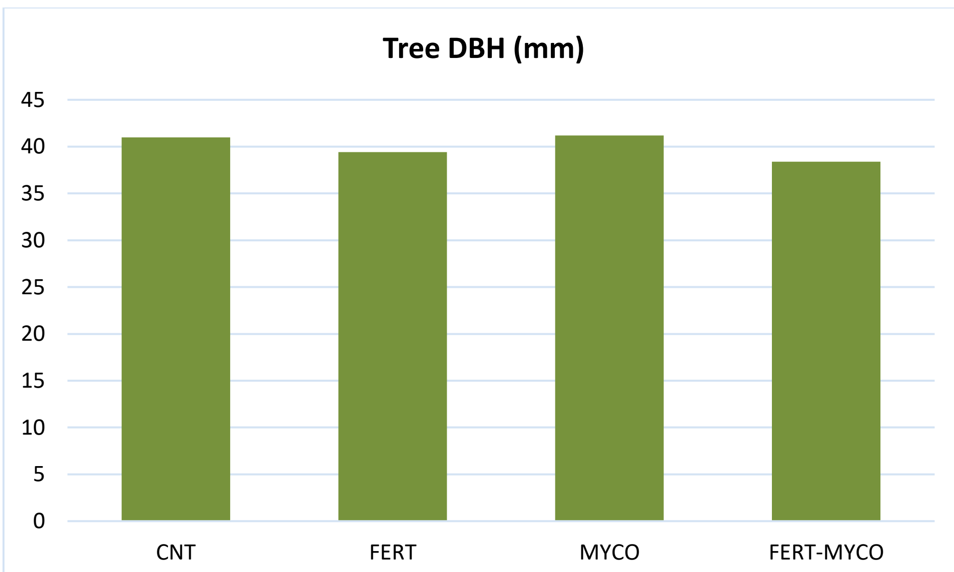
SEM micrographs of *Hibiscus hamabo* roots inoculated with mycorrhizal preparation Z



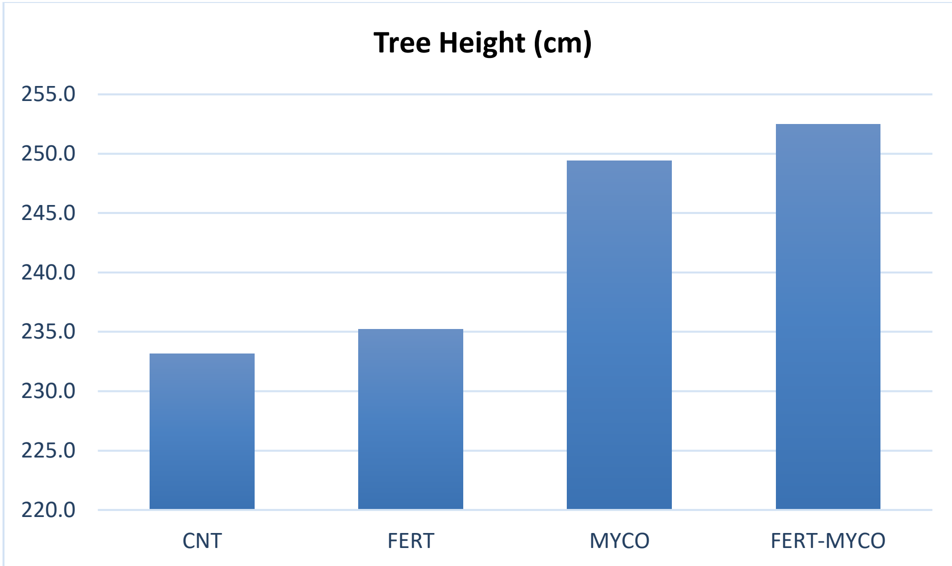
Effect of Endo/Ecto-Mycorrhizae Inoculation of *Taxodium* Candidate Genotypes. A study was initiated in 2018 to determine the effect of inoculation of three candidate genotypes of cypress trees with a commercial endomycorrhizae/ ectomycorrhizae consortium on the plants' growth and development. These genotypes (A, B and C) were 3 different selections of crosses made between *Taxodium distichum* var *distichum* and *T. distichum* var *mexicanum*. Saplings of each genotype were treated with the following amendments: 1) no additives of fertilizer or mycorrhizae (CNT); 2) fertilizer alone (FERT); 3) mycorrhizae alone (MYC); 4) both fertilizer and mycorrhizae inoculant (FERT-MYC). After the first season, mean tree heights for the CNT, FERT, MYC and FERT-MYC treatments, respectively, were 264, 254, 257 and 269 cm for genotype A, 233, 235, 249 and 252 cm for genotype B, and 273, 250, 293 and 320 cm for genotype C. Mean diameter at breast heights (DBH) for the CNT, FERT, MYC and FERT-MYC treatments respectively were 36, 38, 39 and 40 mm for genotype A, 41, 39, 41 and 38 mm for genotype B, and 41, 37, 37 and 46 mm for genotype C. Although there was no difference between treatments for genotype A, inoculation with mycorrhizae seemed to improve mean tree height for both genotypes B and C. Data for the second season will be collected and reported to determine if these trends continue and/or are genotype-dependent.

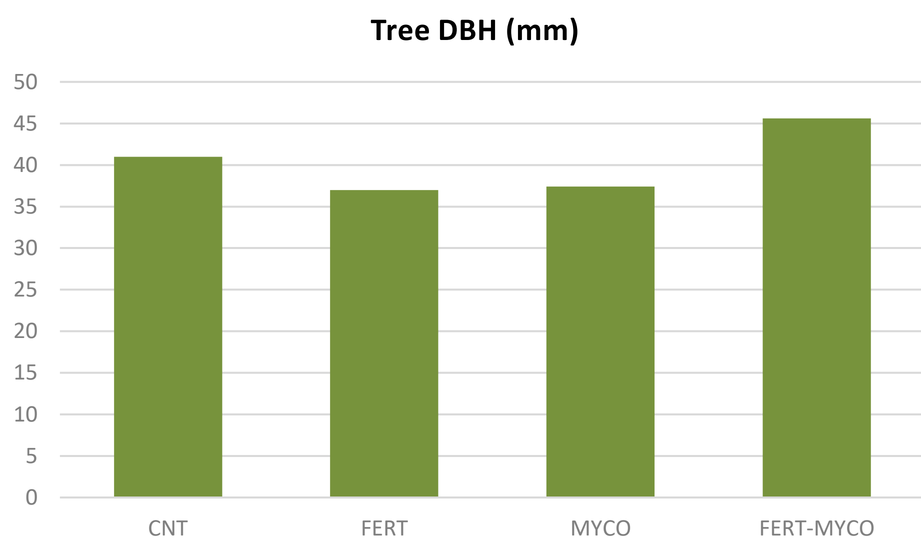
Taxodium/Mycorrhizae Inoculation Study at Moody Gardens Field Site

Effect of Mycorrhizae Inoculants on Taxodium Genotype A

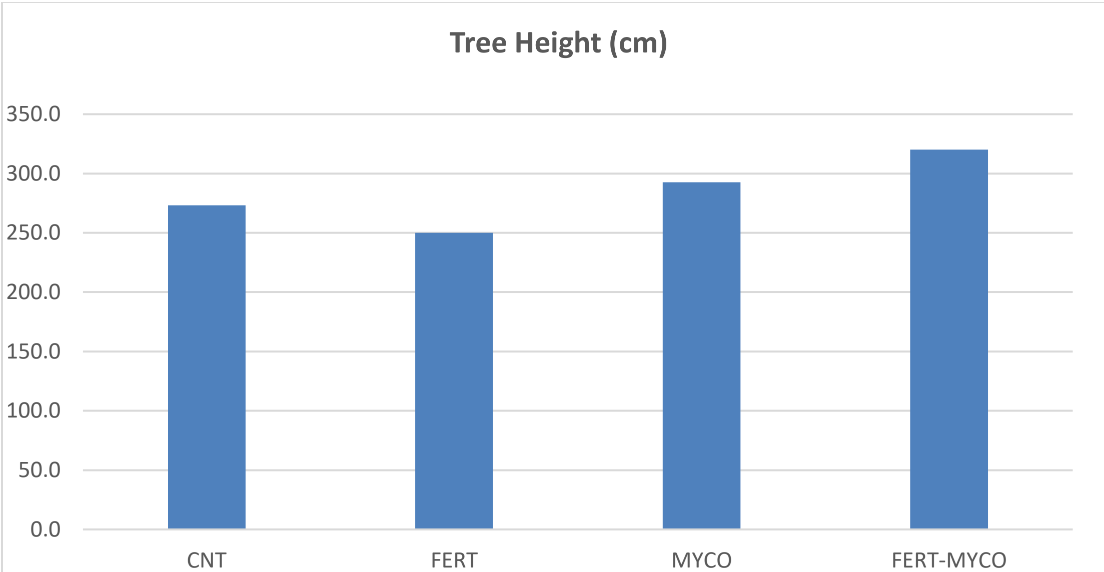


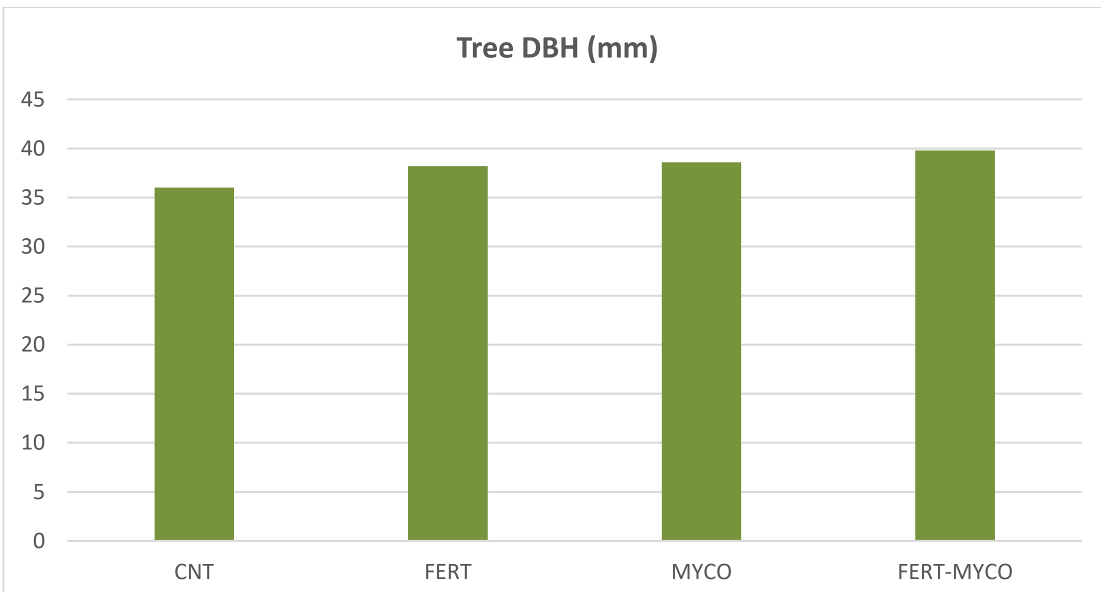
Effect of Mycorrhizae Inoculants on Taxodium Genotype B





Effect of Mycorrhizae Inoculants on Taxodium Genotype C





Effect of Mycorrhizae Amendment on Three Cypress Genotypes Grown in Hurricane Impacted Soils

Stephen Wagner, Josephine Taylor, and David Creech

Hurricanes and tropical storms, such as Hurricanes Ike and Harvey in Texas, continue to devastate US coastal plant communities. Consequently, a project has been initiated at a field site on Galveston Island to evaluate, introduce and promote a wide range of salt- and hurricane- tolerant plants. Because most land plants depend upon mycorrhizal fungi for proper growth and development, an important element of this project is to test the efficacy of mycorrhizae on plants being evaluated. A study was initiated in 2018 to determine the effect of inoculation of three candidate genotypes of cypress trees with a commercial endomycorrhizae/ ectomycorrhizae consortium on the plants' growth and development. These genotypes (A, B and C) were 3 different selections of crosses made between *Taxodium distichum* var *distichum* and *T. distichum* var *mexicanum*. Saplings of each genotype were treated with the following amendments: 1) no additives of fertilizer or mycorrhizae (CNT); 2) fertilizer alone (FERT); 3) mycorrhizae alone (MYC); 4) both fertilizer and mycorrhizae inoculant (FERT-MYC). After the first season, mean tree heights for the CNT, FERT, MYC and FERT-MYC treatments respectively were 264, 254, 257 and 269 cm for genotype A, 233, 235, 249 and 252 cm for genotype B and 273, 250, 293 and 320 cm for genotype C. Mean diameter at breast heights (DBH) for the CNT, FERT, MYC and FERT-MYC treatments respectively were 36, 38, 39 and 40 mm for genotype A, 41, 39, 41 and 38 mm for genotype B, and 41, 37, 37 and 46 mm for genotype C. Although there was no difference between treatments for genotype A, inoculation with mycorrhizae seemed to improve mean tree height for both genotypes B and C. Data for the second season will be collected and reported to determine if these trends continue and/or are genotype-dependent.

Hibiscus Plots and "Taxiway"

Taxodium 502	101	102	103	104	201	202	203	204	301	302	303	304	401	402	403	404	501	502	503	504
Genotype A																				
Taxodium 407	101	102	103	104	201	202	203	204	301	302	303	304	401	402	403	404	501	502	503	504
Genotype B																				
Taxodium 405	101	102	103	104	201	202	203	204	301	302	303	304	401	402	403	404	501	502	503	504
Genotype C																				

Farish Plots and Bayou

Taxodium 502 Treatment Assignment					
Treatment	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**	**Rep 5**
Control	103	202	301	403	501
Fertilizer Only	102	201	303	401	502
Mycorrhizae Only	101	204	302	402	503
Myrorrhizae and Fertlizer	104	203	304	404	504

Taxodium 407 Treatment Assignment					
Treatment	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**	**Rep 5**
Control	101	201	301	404	502
Fertilizer Only	103	203	302	403	504
Mycorrhizae Only	102	204	304	401	503
Myrorrhizae and Fertlize	104	202	303	402	501

Taxodium 405 Treatment Assignment					
Treatment	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**	**Rep 5**
Control	102	202	303	404	504
Fertilizer Only	103	204	304	403	503
Mycorrhizae Only	101	201	302	402	501
Myrorrhizae and Fertlizer	104	203	301	401	502

2018 ANNUAL REPORT

Stephen F. Austin State University
The Moody Foundation Project Update
Mar 2018

SUMMARY

1. Since the last Project Update (Oct 1, 2017) we continue to make progress. The cold snap in early January 2018 brought a very light freeze to the research plots but only minor damage to some of the more sensitive species. A little over ¾ of the plot is occupied by a wide range of interesting plant materials. The open rows have been kept clean of weeds, and the nutgrass is almost eliminated by the use of Image. The open rows on the west end will be filled by plants we have accumulated and organized at the SFA Gardens nursery. We had intended to plant them at the first of the year but decided to wait until February/March. Currently, our two growing seasons reveal plenty of standouts and a few failures. The failures (whether performing poorly because of aerial salt or soil conditions) will be removed and replaced with more promising candidates. We remain pleased with the study by Dr. Hua to test the impact of using a Hibiscus hamabo rootstock (very salt tolerant) grafted to *Hibiscus syriacus* (Rose of Sharon) to determine if this will allow growth of this popular ornamental. Finally, by March 2018, the entire plot area will be occupied. At the end of <u>this</u> growing season, we recommend digging the standouts and moving them to locations in the Moody Gardens landscape or to appropriate civic projects on the island. We have a backlog of plants destined for the research plot. One example shown is a very salt tolerant rare endemic from Florida, *Salix floridana*, which makes a small tree.
2.

An experiment to test the performance of Hibiscus syriacus on their own roots or grafted on to Hibiscus hamabo. Hamabo is very salt tolerant.

3. Dr. Ken Farrish, Environmental Science. Elaine Harris, Graduate Research Assistant, is in the process of writing her MS thesis. Her project involves 288 trees close to Offat's Bayou planted to evaluate the effectiveness of soil management treatments on the growth and survival of three species, *Quercus virginiana*, *Hibiscus hamabo* and *Taxodium distichum*. The eight treatments were the Control Flat, Control Bedded, Mulch Flat, Mulch Bedded, Gypsum Flat, Gypsum Bedded, Mulch Gypsum Flat and Mulch Gypsum Bedded. The trees were measured during and at the end of the growing season for the past two years determining the groundline stem diameter and height of each plant. Using this data, the average cumulative growth for each parameter can be used to evaluate the effectiveness of each treatment. Daniel Morgan (a GRA provided by Dr. Farrish) will be inheriting this project to determine treatment impacts on growth. In addition, Daniel has undertaken a new project. He has installed nine groundwater sampling piezometers ranging 1.0 to 1.5 meters in depth which have been built and installed on the site. These piezometers are used to collect bimonthly water samples, as well as to record the depth to the water table throughout the site. The samples collected on the site have been sent to the Stephen F Austin Soil, Plant & Water Analysis Laboratory to be tested for pH, electrical conductivity, sodium, calcium and other metals. In addition to the testing of extracted samples, three Solinst Leveloggers are installed in piezometers onsite where they collect water level, temperature and electrical

conductivity on a thirty minute interval. With these instruments, data can be continuously collected to form a more complete understanding of the factors that affect the site.

4. **Soil Microbial Population/Activity Study.** Dr. Steve Wagner and Josephine Taylor, Biology, have a number of projects that focus on mycorrhiza in this salty environment. Because microbial species play an intricate role in the success of the *Hibiscus hamabo*, *Quercus virginiana* and *Taxodium distichum* plants growing at the Moody Gardens study site, research included assessing indigenous microbial populations and activity. This work was the subject of a Master's of Science thesis project conducted by Elaine Fowler (Environmental Science) and was directed by Stephen Wagner. Soil samples were collected in July and October 2016 and January 2017 to estimate total bacteria and fungi populations. These were determined by serial dilution plating on selective media using a spiral plating system. Soil respiration rates were determined using a Model EGM-4 Environmental Gas Monitor for CO_2 evolution. Bacteria populations ranged from 4.07 to 5.12 and 3.73 to 4.26 log CFU g^{-1} in soils collected in July and October respectively. Fungi ranged from 3.27 to 3.58 and 3.09 to 3.71 log CFU g^{-1}. Fungal populations were not significantly different between treatments. Bacteria populations were significantly higher only in control bedded and mulch flat treatments. Likewise soil respiration rates ranged from 0.873 to 3.07 g CO_2 m^{-2} hr^{-2} but showed little response to soil amendments. These results indicate that there are relatively large and active soil microbial communities inhabiting soils at the field site. However, soil amendments had little effect on microbial populations and activities. Elaine successfully completed and defended her thesis and graduated in May, 2017. Additionally, these results were reported in a poster presentation given at the Soil Science Society of America Annual meeting held in Tampa, FL in October 2017.

   Drs. Steve Wagner and Josephine Taylor initiated a second study at the Moody Gardens site in June, 2017 whereby another species of Hibiscus was inoculated with a commercial endomycorrhizae or an endomycorrhizae/ectomycorrhizae inoculant under two fertilization levels. Initial growth measurements were collected in November, 2017 and are currently being analyzed. We will continue to manage and measure this study during the 2018 growing season.

   A third study is being designed now to test the impact of a commercial mycorrhizal inoculant on three selections of bald cypress planted on the West side with a total of 60 trees in the project.

5. In the next two months, Malcolm Turner, our SFA Gardens Technician and I will be collecting growth and visual ranking data on the species and varieties in the plant evaluation project. We will also be collecting leaf tissue to analyze for Na levels to document if there are significant differences that explain plant performance. Malcolm will be staking and repositioning plants. We will be planting new plants and think our strategy to plant five of each is appropriate. We will also be applying a layer of mulch down the rows and will be bringing the SFA Gardens tractor/front end loader to accomplish this task.

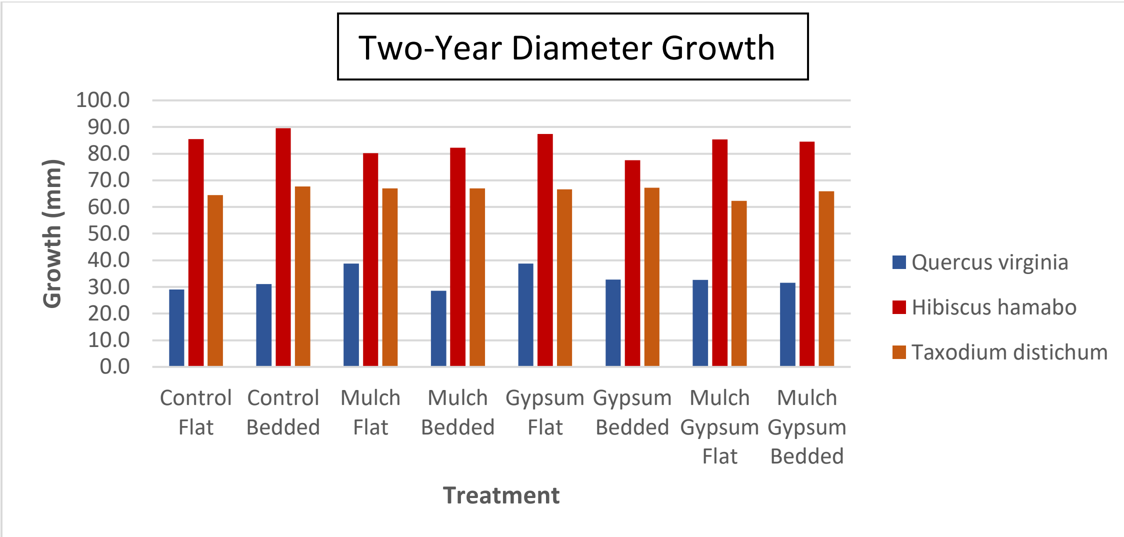
Dr. Ken Farrish, Environmental Science

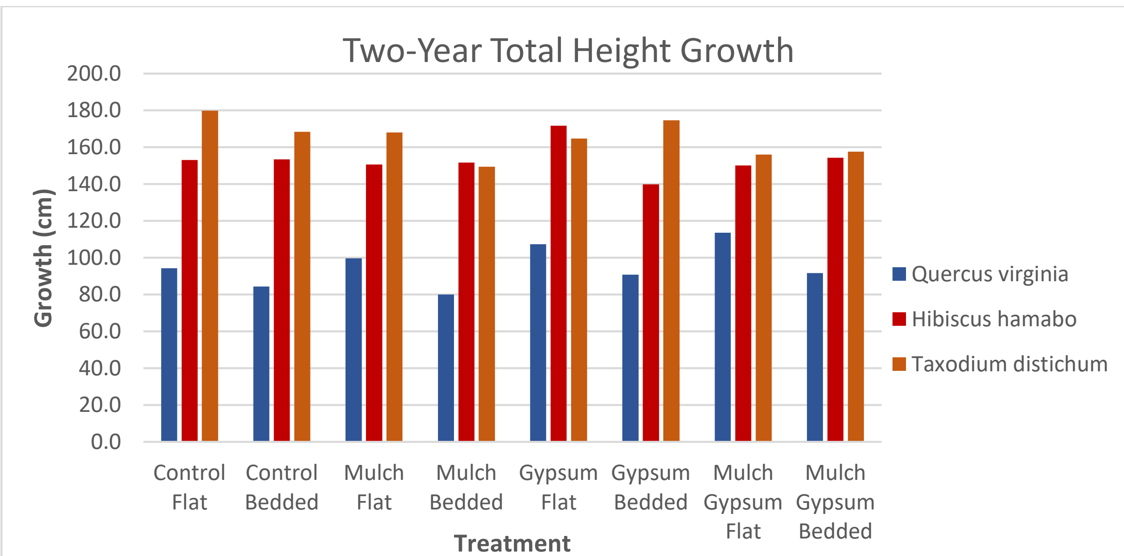
Summary: Dr. Ken Farrish provided the following update for this report. He provided the Graduate Research Assistantship (GRA) for the MS thesis project of Elaine Harris. Elaine is currently finishing the writing part of her MS thesis. Dr. Farrish is now providing the GRA for Daniel Morgan who will be continuing the data collection for that project – and is continuing to measure wet fall/dry fall in an aerial salinity monitoring project we have at Moody Gardens. In addition, Daniel Morgan is undertaking a very interesting project to sample ground water beneath the research plots using an instrument called a peizometer.

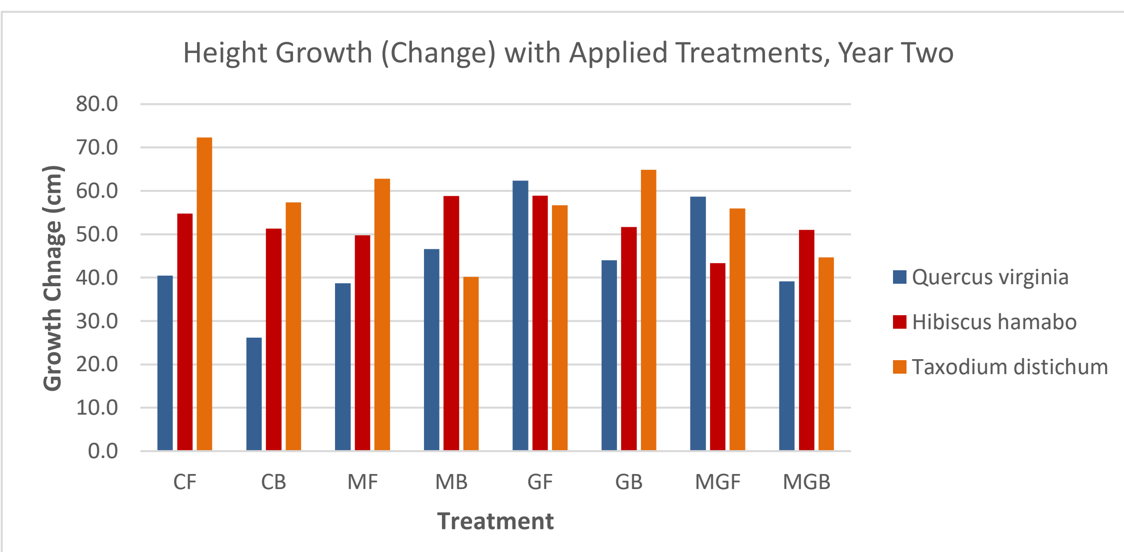
1. In 2016, 288 trees were planted on the Moody Gardens property close to Offat's Bayou to evaluate the effectiveness of soil management treatments on the growth and survival of three species, *Quercus virginiana*, *Hibiscus hamabo* and *Taxodium distichum*. The eight treatments were the

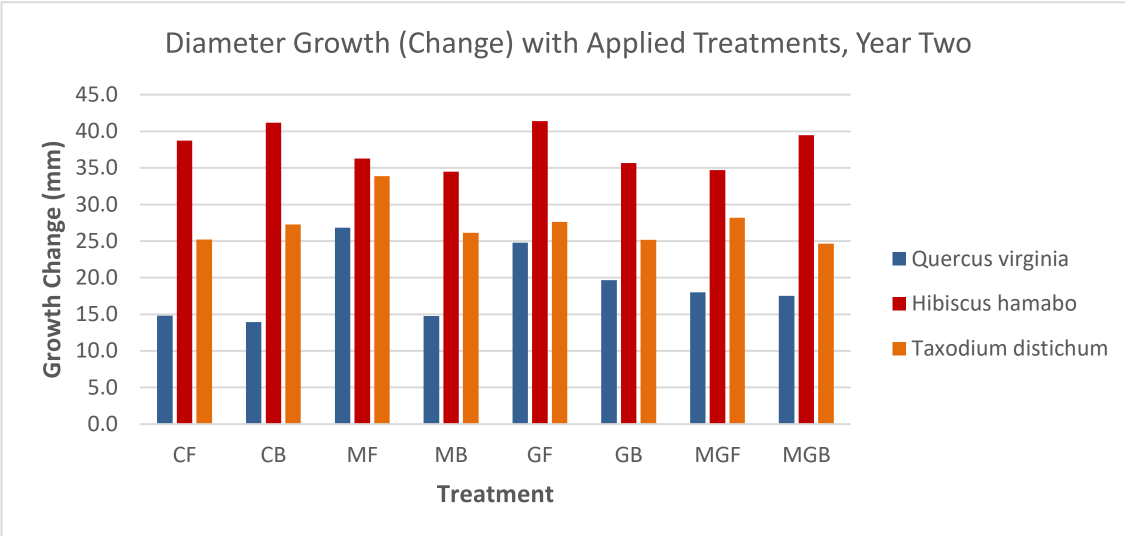
Control Flat, Control Bedded, Mulch Flat, Mulch Bedded, Gypsum Flat, Gypsum Bedded, Mulch Gypsum Flat and Mulch Gypsum Bedded. The trees were measured during and at the end of the growing season for a two-year period in order to determine the groundline stem diameter and height of each plant. Using this data, the average cumulative growth for each parameter can be used to evaluate the effectiveness of each treatment.

		Year One Growth		Year Two Growth		Cumulative Growth to Date	
Treatment	Species	Ground-level Diameter (mm)	Height/Crown Diameter (cm)	Ground-level Diameter (mm)	Height/Crown Diameter (cm)	Ground-level Diameter (mm)	Height/Crown Diameter (cm)
Control Flat	*Quercus virginia*	14.22	53.82	14.82	40.50	29.04	94.32
	Hibiscus hamabo	46.71	98.29	38.72	54.75	85.43	153.04
	Taxodium distichum	39.27	107.58	25.21	72.33	64.48	179.91
Control Bedded	*Quercus virginia*	17.17	58.18	13.95	26.18	31.12	84.36
	Hibiscus hamabo	48.37	102.15	41.17	51.29	89.54	153.44
	Taxodium distichum	40.38	111.06	27.27	57.33	67.65	168.39
Mulch Flat	*Quercus virginia*	11.93	61.08	26.85	38.67	38.78	99.75
	Hibiscus hamabo	43.87	100.82	36.29	49.79	80.16	150.61
	Taxodium distichum	33.11	105.22	33.87	62.83	66.98	168.05
Mulch Bedded	*Quercus virginia*	13.81	33.43	14.76	46.58	28.57	80.01
	Hibiscus hamabo	47.81	92.77	34.46	58.83	82.27	151.60
	Taxodium distichum	40.86	109.18	26.15	40.17	67.01	149.35
Gypsum Flat	*Quercus virginia*	14.01	45.04	24.79	62.33	38.80	107.37
	Hibiscus hamabo	46.03	112.82	41.37	58.92	87.40	171.74
	Taxodium distichum	39.07	108.04	27.61	56.67	66.68	164.71
Gypsum Bedded	*Quercus virginia*	13.10	46.83	19.66	44.00	32.76	90.83
	Hibiscus hamabo	41.94	88.16	35.67	51.67	77.61	139.83
	Taxodium distichum	42.08	109.82	25.17	64.83	67.25	174.65
Mulch Gypsum Flat	*Quercus virginia*	14.65	54.99	18.02	58.67	32.67	113.66
	Hibiscus hamabo	50.65	106.74	34.71	43.38	85.36	150.12
	Taxodium distichum	34.11	100.03	28.20	55.98	62.31	156.01
Mulch Gypsum Bedded	*Quercus virginia*	14.00	52.46	17.52	39.17	31.52	91.63
	Hibiscus hamabo	45.04	103.21	39.45	51.00	84.49	154.21
	Taxodium distichum	41.22	112.89	24.65	44.67	65.87	157.56


Two-Year Diameter Growth
Growth (mm)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Control Flat
Control Bedded
Mulch Flat
Mulch Bedded
Gypsum Flat
Gypsum Bedded
Mulch Gypsum Flat
Mulch Gypsum Bedded
Treatment
Quercus virginia
Hibiscus hamabo
Taxodium distichum

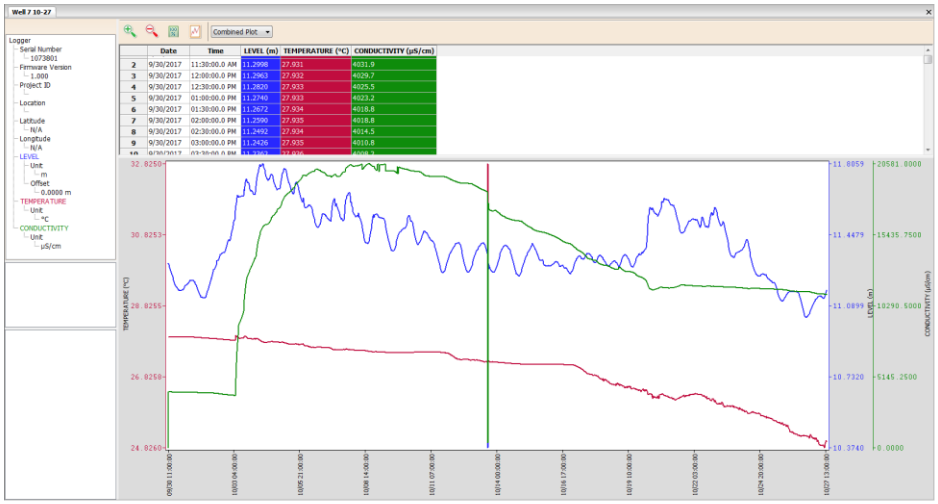

Two-Year Total Height Growth
Growth (cm)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Control Flat
Control Bedded
Mulch Flat
Mulch Bedded
Gypsum Flat
Gypsum Bedded
Mulch Gypsum Flat
Mulch Gypsum Bedded
Treatment
Quercus virginia
Hibiscus hamabo
Taxodium distichum

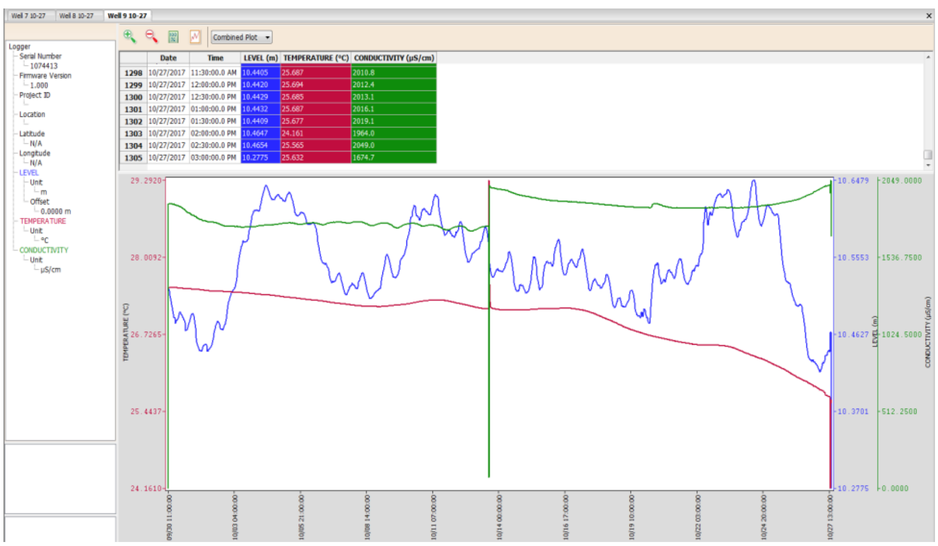

Height Growth (Change) with Applied Treatments, Year Two
Growth Chnage (cm)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
CF
CB
MF
MB
GF
GB
MGF
MGB
Treatment
Quercus virginia
Hibiscus hamabo
Taxodium distichum

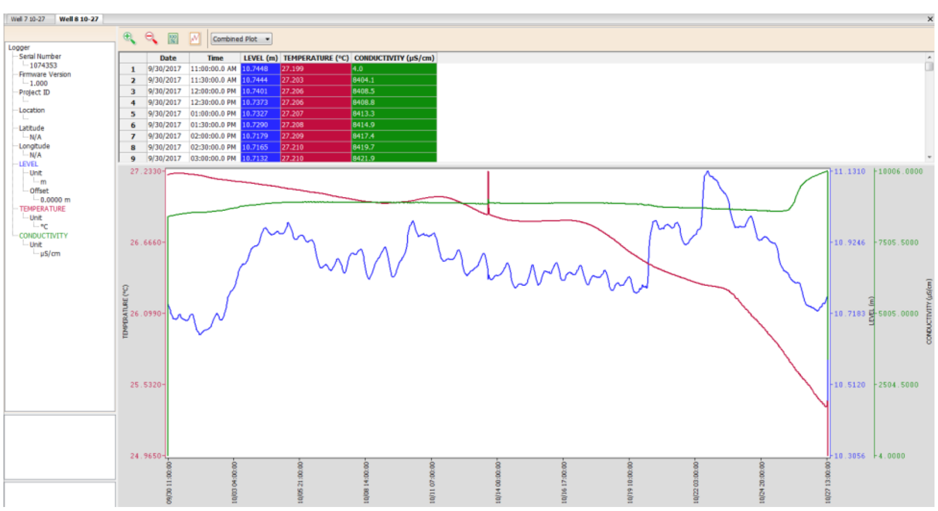

Diameter Growth (Change) with Applied Treatments, Year Two
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Growth Change (mm)
CF
CB
MF
MB
GF
GB
MGF
MGB
Treatment
Quercus virginia
Hibiscus hamabo
Taxodium distichum

Dr. Ken Farrish and GRA Daniel Morgan installed nine groundwater sampling piezometers ranging 1.0 to 1.5 meters in depth. These piezometers are used to collect bimonthly water samples, as well as to record the depth to the water table throughout the site. The samples collected on the site have been sent to the Stephen F Austin Soil, Plant & Water Analysis Laboratory to be tested for pH, electrical conductivity, sodium, calcium and other metals. In addition to the testing of extracted samples, three Solinst Leveloggers are installed in piezometers onsite, where they collect water level, temperature and electrical conductivity on a thirty minute interval. With these instruments, data can be continuously collected to form a more complete understanding of the factors that affect the site.

Peziometer data reveals ground water levels and variation over time.



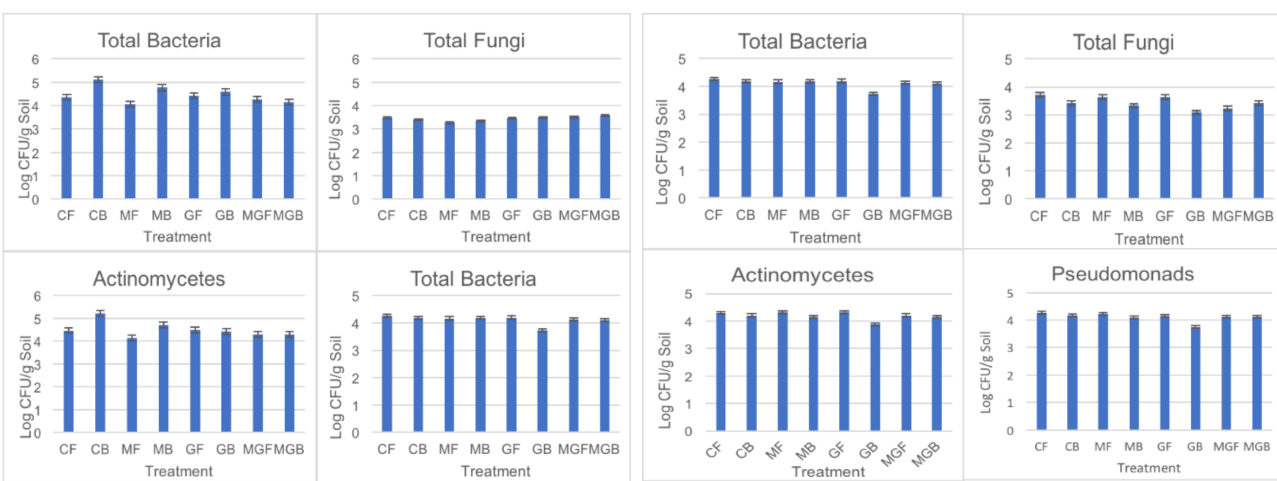




Moody Gardens Project Microbiology Studies
Directed by Stephen Wagner and Josephine Taylor

Soil Microbial Population/Activity Study. Because microbial species play an intricate role in the success of the *Hibiscus hamabo*, *Quercus virginiana* and *Taxodium distichum* plants growing at the Moody Gardens study site, research included assessing indigenous microbial populations and activity. This work was the subject of a Masters of Science thesis project conducted by Elaine Fowler (Environmental Science) and was directed by Stephen Wagner. Soil samples were collected in July and October 2016 and January 2017 to estimate total bacteria and fungi populations. These were determined by serial dilution plating on selective media using a spiral plating system. Soil respiration rates were determined using a Model EGM-4 Environmental Gas Monitor for CO_2 evolution. Bacteria populations ranged from 4.07 to 5.12 and 3.73 to 4.26 log CFU g^{-1} in soils collected in July and October respectively. Fungi ranged from 3.27 to 3.58 and 3.09 to 3.71 log CFU g^{-1}. Fungal populations were not significantly different between treatments. Bacteria populations were significantly higher only in control bedded and mulch flat treatments. Likewise soil respiration rates ranged from 0.873 to 3.07 g CO_2 m^{-2} hr^{-2} but showed little response to soil amendments. These results indicate that there are relatively large and active soil microbial communities inhabiting soils at the field site. However, soil amendments had little effect on microbial populations and activities. Elaine successfully completed and defended her thesis and graduated in May, 2017. Additionally, these results were reported in a poster presentation given at the Soil Science Society of America Annual meeting held in Tampa, FL in October 2017.

Effect of Soil Amendments on Microbial Populations at Moody Gardens Study Site



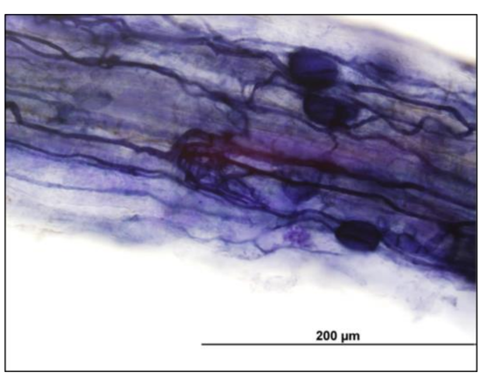
Effect of Soil Amendments on Soil Respiration Rates at Moody Gardens Study Site

Treatment	Respirati	SNK
Mulch Bedded	3.07	A
Mulch Flat	2.56	A, B
[illegible]	2.55	A, B
Control Flat	2.25	A, B
Mulch Gypsum Flat	2.13	A, B
Gypsum Bedded	1.84	A, B
Control Bedded	1.63	A, B
Mulch Gypsum Bedded	0.87	B

Environmental Science Graduate Students Elaine Fowler and Elaine Harris Conducting Studies

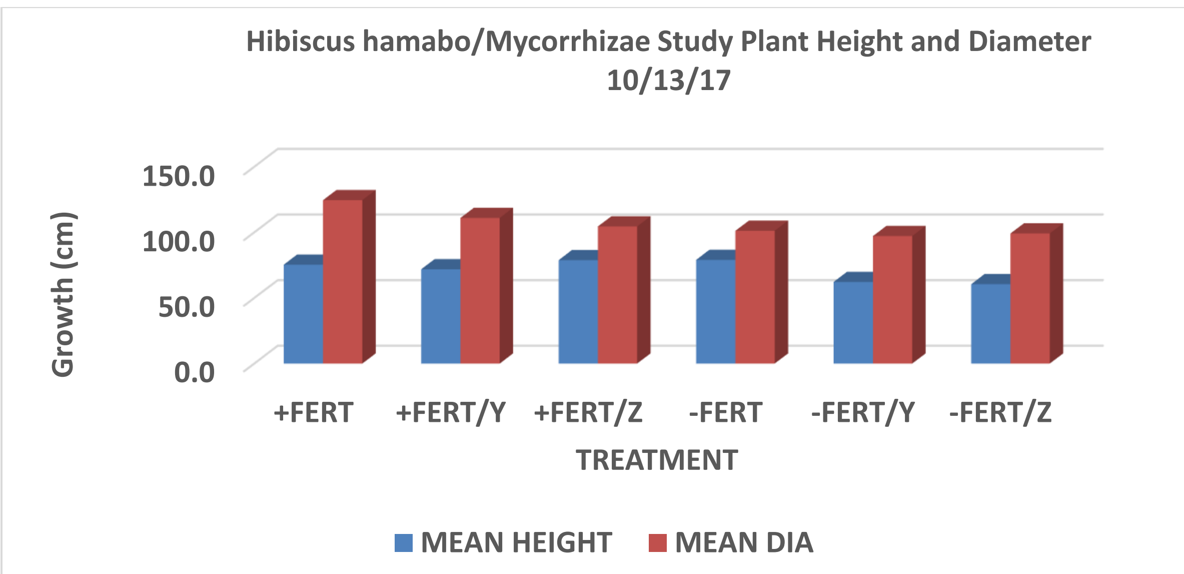
Mycorrhizal Fungi Studies. We have characterized the colonization of these fungi on the roots of several native grass and wildflower species as well as determined most probable numbers (MPN) of endomycorrhizae at the field research site. Dr. Josephine Taylor led an investigation by undergraduate students to ascertain arbuscular mycorrhizae colonization of herbaceous roots of 3 native species *Gomphrena serrata* (Amaranthaceae), *Gaillardia pulchella* (Asteraceae) and *Digitaria* spp. (Poaceae) collected from the research site. Through microscopic examination it was determined that all three native plant species exhibited AM associations, as evidenced by the presence of fungal hyphae, vesicles and arbuscules within their root tissues. The abundance of arbuscules, as well as their morphology, varied between the plant hosts indicating that a number of different fungal species may be involved.

Mycorrhizae in Stained Roots of a Native Species at Moody Gardens



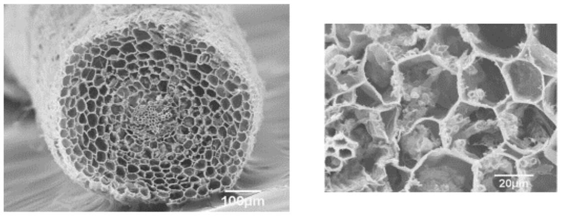
In the MPN analysis, presence or absence of AM colonization in each soil dilution was assessed in order to estimate natural population levels of these fungi. Results revealed a range of 2.9 x 10^4 to more than 1.1 x 10^8 AM propagules per gram of soil (Table 1). Taken together these data indicate that plants on Galveston Island are associated with an active AM community. Graduate student Angela Rittenberry (Secondary Education) presented the attached poster at the Texas Academy of Science Meeting in March 2017 at Mary Hardin Baylor University and at the SFASU Graduate Research Conference on April 20, 2017.

We have also begun studying the utilization of plant growth-promoting microorganisms, such as mycorrhizal fungi, on the growth of candidate plant species. An initial greenhouse and subsequent field study (transplanted in February, 2017) is assessing the effect of two different endomycorrhizae commercial inoculants on the growth of *Hibiscus hamabo.* Initial growth measurements (plant height and diameter) showed that the inoculants did not improve plant growth. However, research indicate that there are long-term effects of inoculants. Consequently, growth parameters will be continued to be measured during the second season of growth in the field.

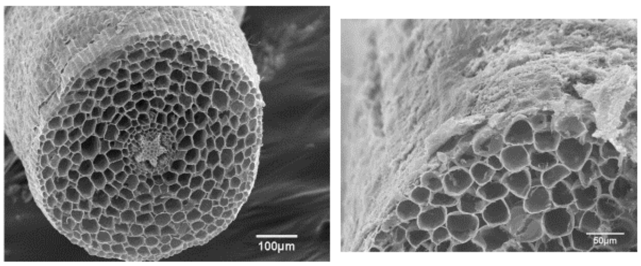


Undergraduate students Jessica Bronstad and Taylor Williams prepared samples from the Hibiscus hamabo greenhouse study for scanning electron microscopy and generated images of control and mycorrhizal inoculated roots.

SEM micrographs of *Hibiscus hamabo* roots inoculated with mycorrhizal preparation Z



SEM micrographs of *Hibiscus hamabo* control roots – no mycorrhizal inoculation



We also initiated a new study at the Moody Gardens site in June, 2017 whereby another species of Hibiscus was inoculated with a commercial endomycorrhizae or a endomycorrhizae/ectomycorrhizae inoculant under two fertilization levels. Initial growth measurements were collected in November, 2017 and are currently being analyzed.

We will continue to manage and measure this study during the 2018 growing season.

Hibiscus sp. Endomycorrhizae/Ectomycorrhizae Inoculant Study

Future Work. Studies will continue to address understanding the microbial community that inhabits the field research area, focusing on the role that these organisms play in the growth and development of plant species being tested. We will conduct the following studies in the next year:

1. Determine mycorrhizae most probable numbers in soils collected from the soil amendment study.
2. Continue second season of field study of the two Hibiscus species.
3. Initiate mycorrhizae inoculant study on Taxodium trees planted at the Moody Gardens site.

4. Prepare publications for submission to peer-reviewed journals.

CONSTRAINTS ENCOUNTERED AND OVERCOME

Only one surprise occurred in the last year. Recently, the airport is putting up a fence and that will take out two rows next to the tarmac. We cheerfully moved plants in those rows to some on the west side and watered them in. Back in business. While that pressures us with space for plants now, we can find new space to the WEST.

2017 ANNUAL REPORT

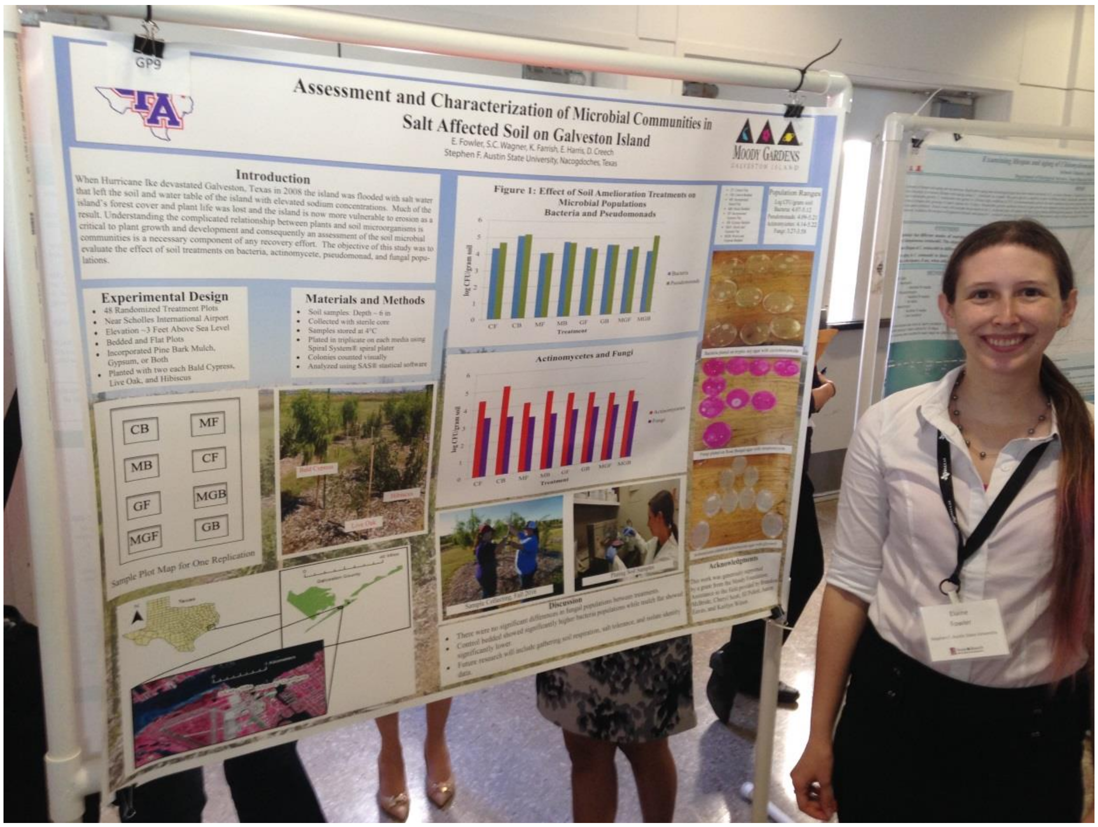
Stephen F. Austin State University
The Moody Foundation Project Update
May 2017

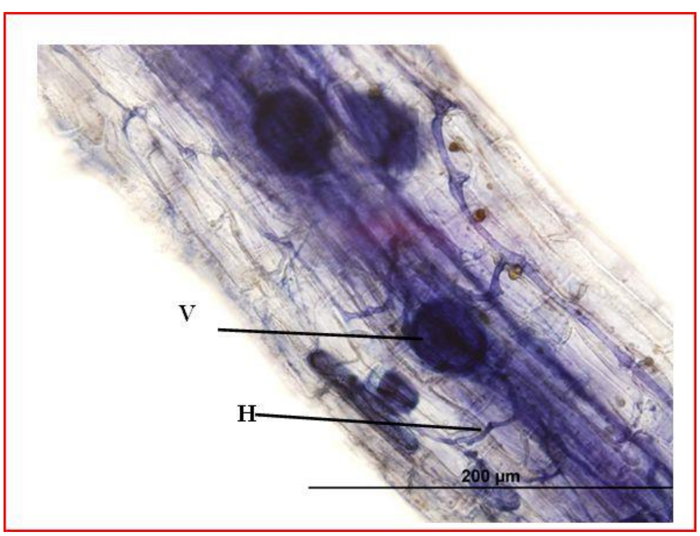
1. Plant materials under Evaluation. At this writing the research plot beds are in place. A little over half of the plots have been planted. The research plot is divided into two blocks. The East side block is now planted and the first plantings are now in place on the west side block.

In general, the plantings have fared well. An excel spread sheet map of the area is attached. Image is of Grevillea robusta, a silk oak.

Dave Creech, Kenneth Farrish, and Elaine Harris. 2017. Woody Ornamental Plant Establishment Studies on a Salt-Affected Soil, Galveston Island, Texas. Presentation to 2017 Annual Conference of the Southern Region American Society for Horticultural Science, Mobile, Alabama, Feb 3-6, 2017.

2. Elaine Fowler's MS thesis project has been completed and is attached. This interesting project was under the direction of Dr. Steve Wagner in Biology, SFA. Elaine's research focused on mycorrhizal populations at the Moody Gardens Research plot. Her paper presentation: November 11, 2016. E. Fowler, S.C. Wagner, K. Farrish, E.Harris, D. Creech. 2016. Assessment and Characterization of Microbial Communities in Salt Affected Soil on Galveston Island. Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas. A presentation to the Texas Branch Fall Meeting of the American Society for Microbiology, UT-Dallas, TX

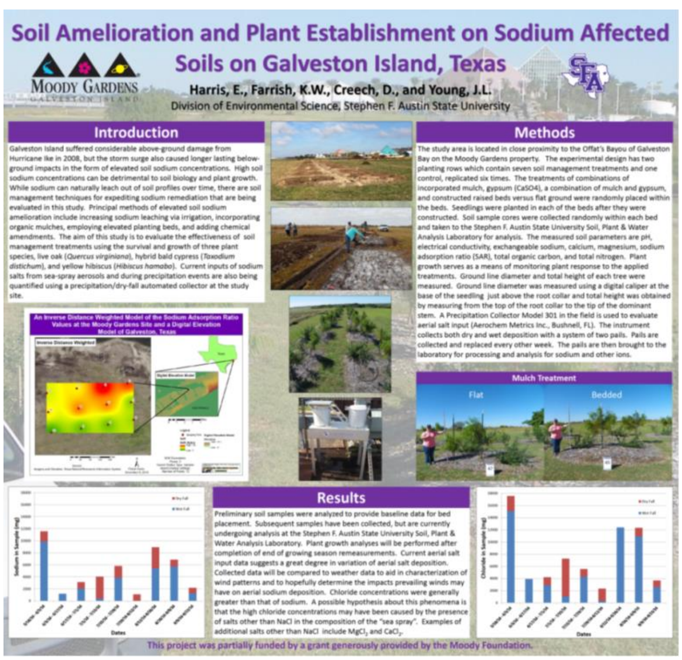




SFA Biology Professor Steve Wagner directed Elaine's thesis research and funded her assistantship. Moody funding supported her lab costs and travel, primarily. Elaine's thank you letter is attached.

3. Elaine Harris's MS thesis project is nearly completed, and she graduates this summer. Her study investigated the impact of raised beds, gypsum applications and compost on growth of three salt-tolerant plants: Bald cypress, Live oak and a beach Hibiscus, Hibiscus hamabo. All plants in all treatments performed well, no doubt due to adequate water via the irrigation system. This is a three year project just into the second year and growth will be followed this season and next. Daniel Morgan, a new Graduate research assistant under Dr. Farrish will carry the project forward. Daniel's graduate assistantship was provided by the Environmental Science program at SFA. The Moody Endowment Foundation fund will be utilized to assist Daniel with travel, supplies and soil/plant analyses.

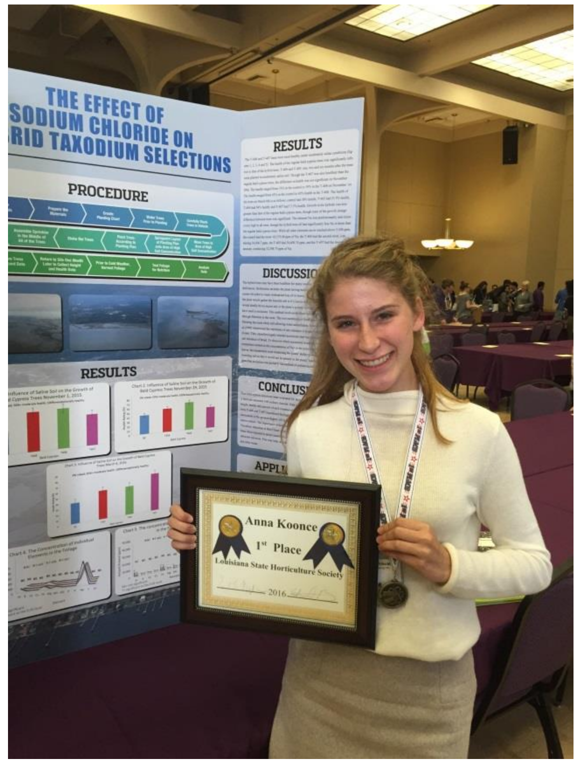
E. Harris, K.W. Farrish, D. Creech and J.L. Young. 2016. Soil Amelioration and Plant Establishment on Sodium Affected Soils on Galveston Island, Texas. Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas. A presentation to the Society for Ecological Restoration Texas Chapter, Livingston, TX, November 11, 2016.



Hibiscus hamabo has been a strong performer in this windy and salt burdened environment and is currently putting on an excellent show of flowers. The Taxodium are doing well, but wind is affecting the shape of the plant material.

4. Professor Hua Jianfeng is a new visiting scientist (Fall 2016). He is an associate professor from Nanjing Botanical Garden, Nanjing, CN, and will be with us for one year. His focus is salt tolerance in a wide range of ornamentals. Dr. Hua and I instigated an experiment to test the efficacy of using *Hibiscus hamabo* as a rootstock for *H. syriacus*, Rose of Sharon. The latter is a very popular woody ornamental with summer blooms but does poorly in most Galveston soils because of salinity. We have a trial that tests two varieties of *Hibiscus syriacus* on their own roots and on *H. hamabo*.

5. ANNA KOONCE TAKES SECOND PLACE POSTER PAPER. I have just heard that Anna Koonce, a young high schooler from Louisiana, has won second in the world in the ISEF Fair 2017, Los Angeles, CA, May 18, 2017 with a paper titled, "The Effect of Sodium Chloride on Hybrid Taxodium Selections. Anna had previously won the state competition in Louisiana. We collaborated with Anna and Dr. Ed Bush, LSU, to bring this project to completion. Results indicated the Taxodium hybrids were more salt tolerant than native bald cypress.



2016 ANNUAL REPORT

UPDATE ON SFA'S SALINITY PROJECT AT MOODY GARDENS

June 1, 2016

Acquiring, Evaluating and Promoting Salt- and Hurricane-Tolerant

Plant Materials for Galveston Island, Texas

From the original proposal: This three year project will evaluate, introduce and promote a wide range of landscape trees, shrubs, groundcovers and herbaceous perennials for Galveston Island. The location for this project is a two-acre plot on the northern edge of Moody Gardens adjacent to Offatts Bayou.

This project will 1) characterize the soil, topography and drainage patterns of Moody Gardens utilizing the resources of the Arthur Temple College of Forestry and Agriculture's Geographic Information Systems (GIS) laboratory at Stephen F. Austin State University (SFASU), 2) establish a long term platform for acquiring, evaluating and propagating plant materials that show promise under the soil, water and climate conditions of Moody Gardens, 3) establish research projects with root zone treatments that mitigate soil conditions to allow for better growth and performance of test plant materials, 4) establish an outreach program to educate the public about the results of this research project, and 5) propagate and grow the most successful plant materials for further testing at Moody Gardens and other locations on Galveston Island.

This project is a first for Galveston Island in that it establishes a long term platform for plant materials testing. While designated as a three year project, the investigators emphasize that plant materials testing -- particularly for trees and shrubs -- requires a much longer time frame for final assessment of adaptability and environmental fit. It is our goal that this project be evaluated at the end of the third year, assessed for its contributions, continued if it shows promise and discontinued if it does not.

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ACCOMPLISHMENTS TO DATE

1. We have collected soil cores to 150 cms (0-60") across the research project area. These cores have been analyzed in the Soil and Plant Tissue Testing Laboratory, SFASU for a wide range of plant nutrients, conductivity and sodium values. A portion of that data is presented later in this document.
2. We have installed the research plot for Elaine Harris, the MSc Thesis project to test the impact of raised beds, incorporated organic matter and Calcium sulfate on *Quercus virginiana*, Taxodium 406 and *Hibiscus hamabo*. Elaine's Graduate Research Assistantship is funded through Environmental Science at SFA.
3. We have initiated a MSc thesis project for Elaine Fowler (advisor Dr. Steve Wagner, Biology). Elaine will be studying mycorrhizal associations and looking at the impact of these fungal associations on salt tolerance. Elaine Fowler's Graduate Research Assistantship is funded through the Biology Department, SFA.
4. We are just now initiating the MSc thesis project for Rebecca Burnett (advisor Michael Maurer, Horticulture). Rebecca will be studying the impact of salt water inundation on a range of containerized trees, and the project will occur here at SFA. Rebecca's Graduate Research Assistantship is funded partially through the Moody grant and partially through the Houston Livestock Show and Rodeo.

5. A small portion of the Moody Foundation grant has been utilized to partially fund a genomic study of Taxodium genotypes. Dr. Yuhong Zheng ("Jade") is a Professor and visiting scientist from Nanjing Botanical Garden. That work was presented at the Southern Region meeting of the American Society for Horticultural Science held in February 2016 in San Antonio, Texas.
6. We have also established ten raised bed rows, each 450' long and 15' apart and have begun planting those rows – the planting plan is presented later in this update.
7. We have connected with a range of nurserymen and academicians across the South and are accumulating plant material at SFA Gardens that will be planted at the Moody Plots.

Field progress.

The mainline and submain system is in place. Sabino Bilon (Moody Gardens Irrigation) and I are connected on irrigation details. Getting to know Sabino and Jose Flores, now connected by text and phone, has been of great value. It's useful that I speak a little Spanish and have the Ag vernacular down. Danny Carson continues to be lead contact and has been very helpful. I met with Paul Corona, M and E, and we will take care of details associated with finding a small storage area for our garden tools, equipment and supplies. I've connected with Alfredo Cedlillo. We have the number for Moody Security for those times when the gate is closed.

General conclusions:

Heavy rains characterize this spring with boggy field conditions. However, we are making progress. Our immediate goal is to prepare 4800' of raised beds and to plant them to a range of trees, shrubs and herbaceous perennials as conditions allow.

Our Technician, Brock Vinson, has moved to another job, and we will be hiring Josh Donnelly to take his place. He will be coming on board in mid-May. Half of his salary will come from the Moody grant and the other half will be funded from another source.

We are fortunate to have garnered additional graduate students on external funding. This augments the Moody grant. There is great interest here for a number of additional projects in the future.

Off-island bank sand to create modest raised beds. A long term investment for an in-ground Moody Gardens nursery.

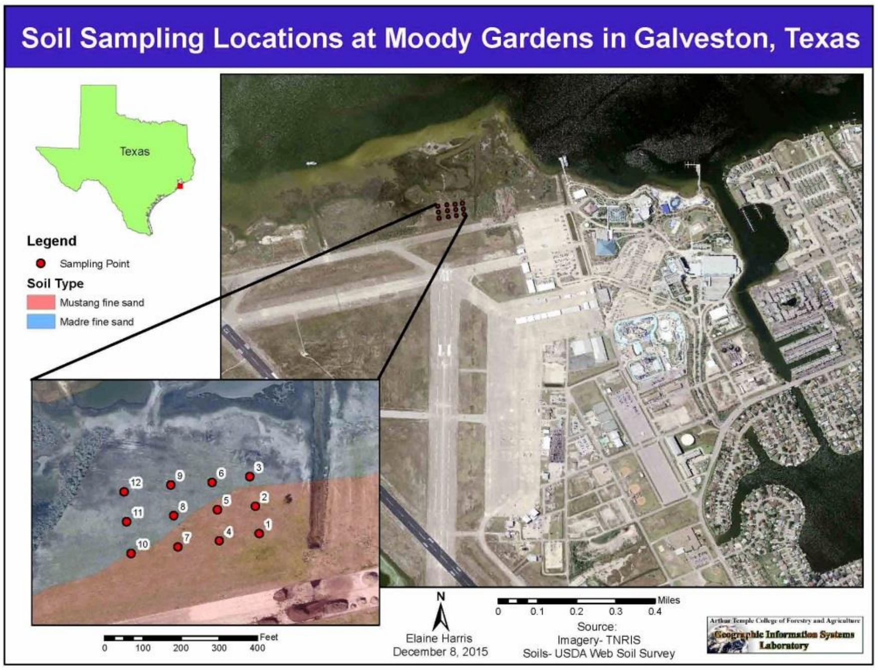
It's been great connecting with Sabino Bilon, Moody Gardens Irrigation Manager and Jose Flores, his assistant. Sabino is seen holding the first ever Galveston Island planting of Taxodium 'Oaxaca Child' – cutting grown from the big one in Oaxaca, Mexico.

Drip irrigation using Netafim ½ gph emitters at the plant.

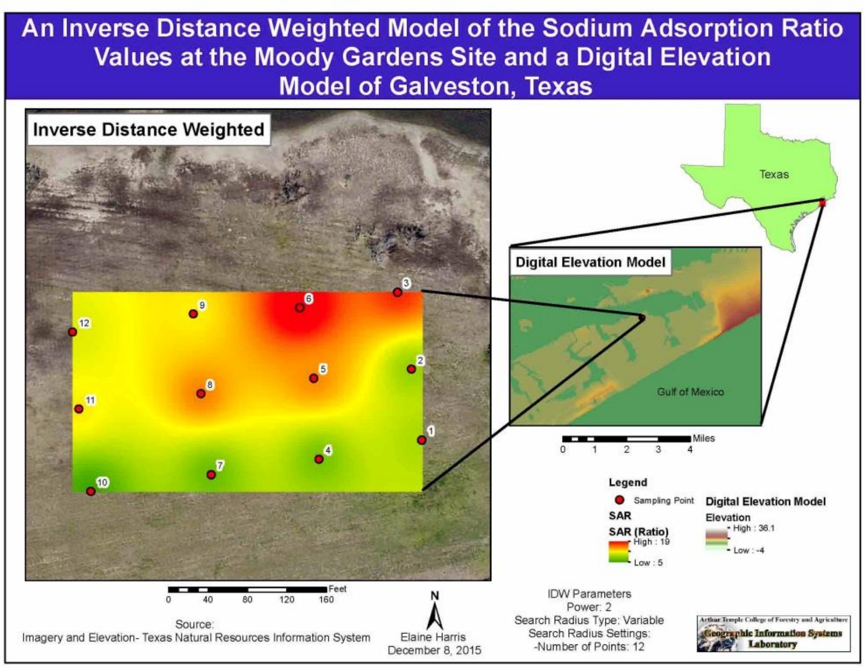
Wind issues at the site affecting sprinkler irrigation. Studying trellis or staking needs.

SOIL CHARACTERIZATION OF THE RESEARCH PLOTS AT MOODY GARDENS,

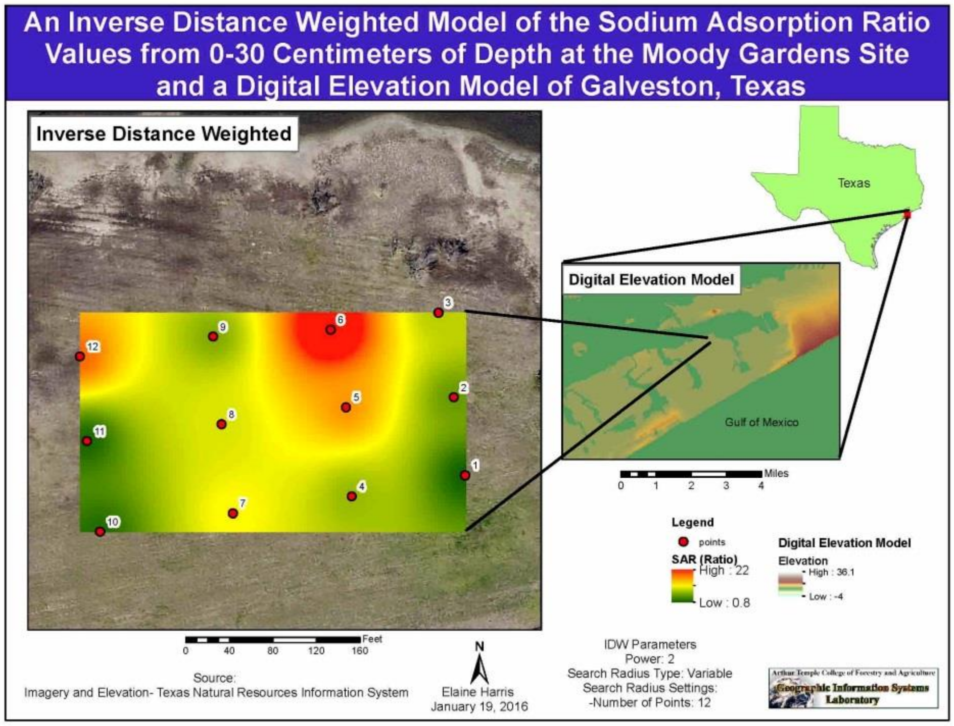
The spot selected for the nursery research plots has been cored and soil samples analyzed. The plots vary from four to five feet above sea level on the inland side and run to just above the bay. SFA ran soil samples of the plots at varying depths, and we have GIS-generated the first generalized salinity maps. In general, the images point out that with closeness to bay and depth, salinity increases. Maps were generated by Elaine Harris, MSc thesis project in Environmental Science, Ken Farrish, advisor.



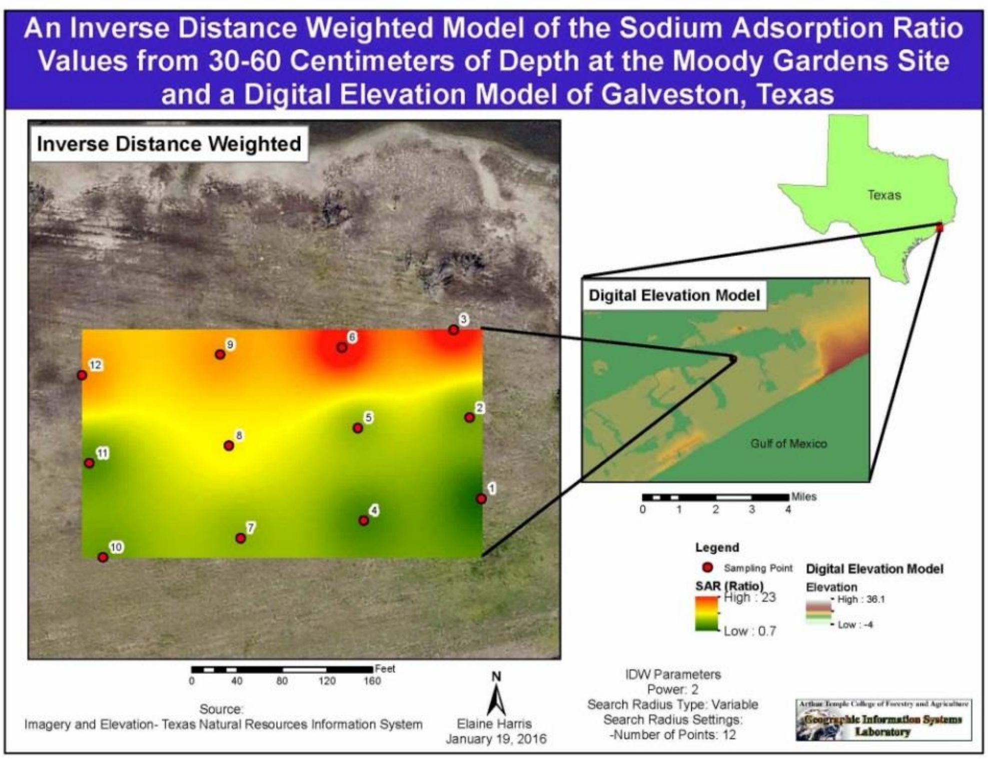
SAR averaged over all depths, 0-120 cms



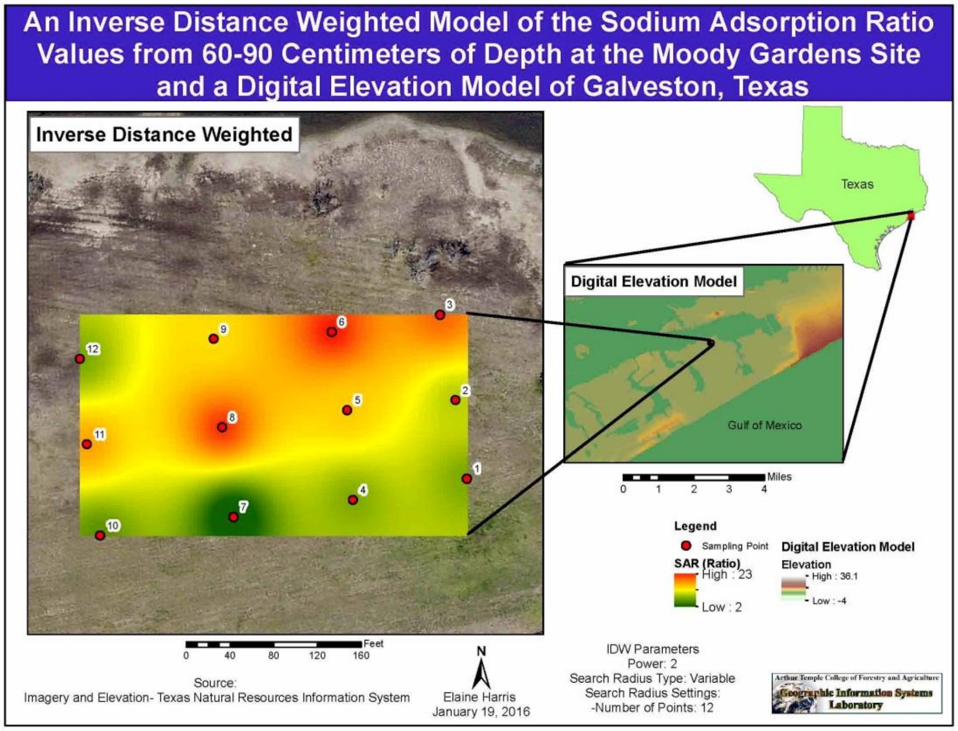
SAR at 0-30 cms



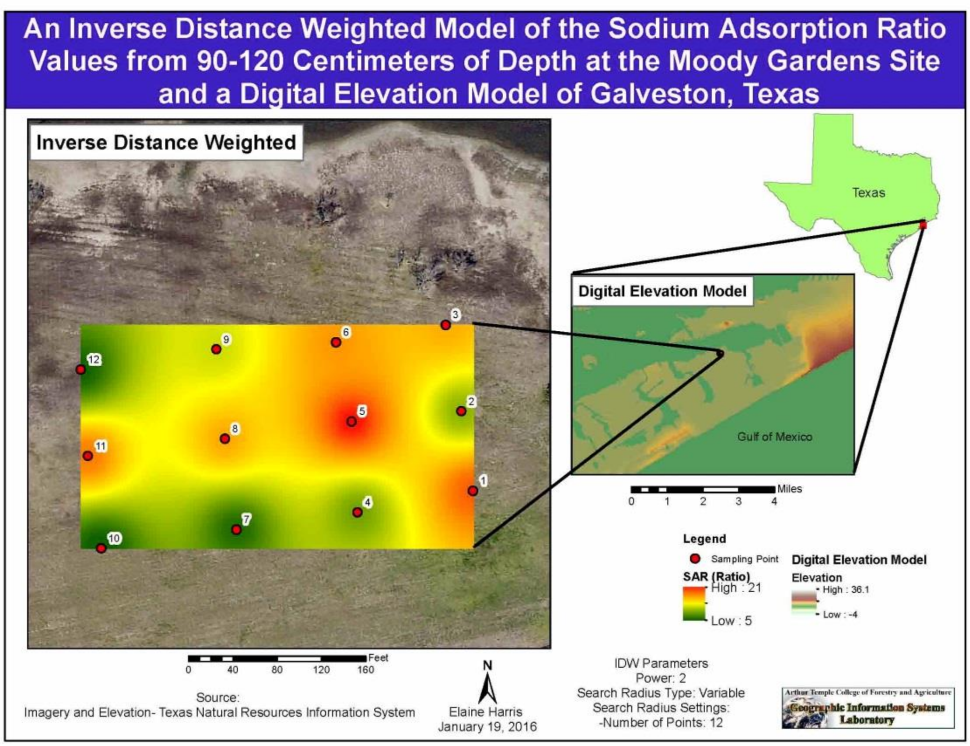
SAR at 30–60 CMS



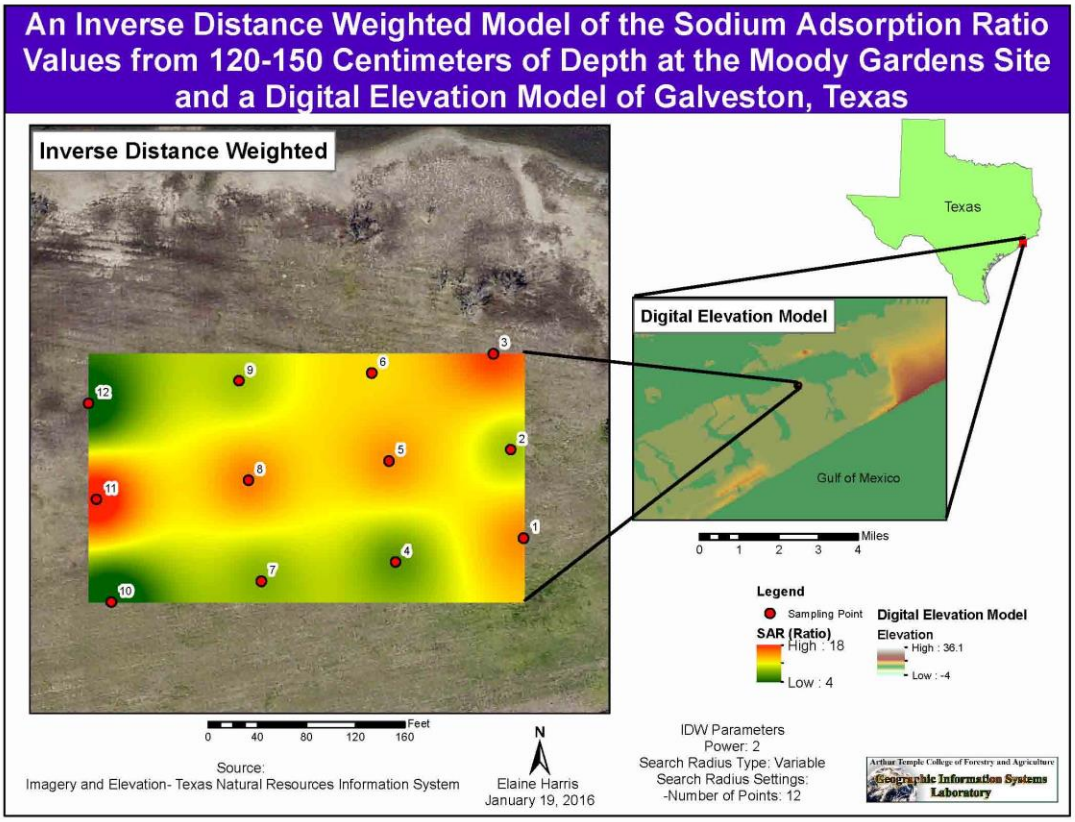
SAR at 60-90 cms



SAR at 90-120 cms



SAR at 120-150 cms



CLIMATE FACTS

There's no doubt 2015 was wetter than normal for Galveston. Average rainfall for the thirty year period 1981-2010 is 50.7 inches and 2015 blessed Galveston with 61.5 inches. Most telling is the Aug – Dec period which saw over 36 inches fall on the island. Tropical depression Bill, June 17-18, 2015 saw over five inches and severe beach and estuary erosion. 2015 Temperatures can be categorized as close to the norm.

GALVESTON 2015

2015	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain Totals (in)	5.44	0.7	7.69	5.3	3.05	2.75	0.23	6.4	11.1	9.8	5.55	3.49	61.53
Mean Temp (°F)	51.1	54.5	62.5	72.4	78.2	83.1	86.6	86.1	81.9	76.1	66.6	61.2	71.2
Avg High (°F)	57.7	60.9	67.8	77.1	83	87.7	91.6	91.9	86.9	82	72.2	67	77.2
Avg Low (°F)	44.5	48.1	57.1	67.7	73.3	78.5	81.6	80.3	76.9	70.2	61	55.3	66.2

GALVESTON 30 YEAR AVERAGE (1981-2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain Totals (in)	4.20	2.57	3.16	3.05	4.32	5.69	3.80	4.39	6.03	5.52	4.51	3.52	50.76
Mean Temp (°F)	55.2	57.6	63.4	70.1	77.6	82.9	84.5	85.0	81.6	74.3	65.1	57.3	71.2
Avg High (°F)	61.8	64.3	70.2	75.9	83.0	88.2	89.6	90.3	87.4	80.6	71.6	63.9	77.2
Avg Low (°F)	48.6	50.9	56.6	64.4	72.3	77.5	79.4	79.7	75.9	68.1	58.6	50.7	65.2

Record High Temperature:	104 set on September 5, 2000
Record Low Temperature:	8 set on February 12, 1899
Greatest one day rainfall:	13.93 inches set on October 8, 1901

http://www.srh.noaa.gov/hgx/?n=climate_gls_normals_summary

NEW OR TIED RECORDS IN 2015

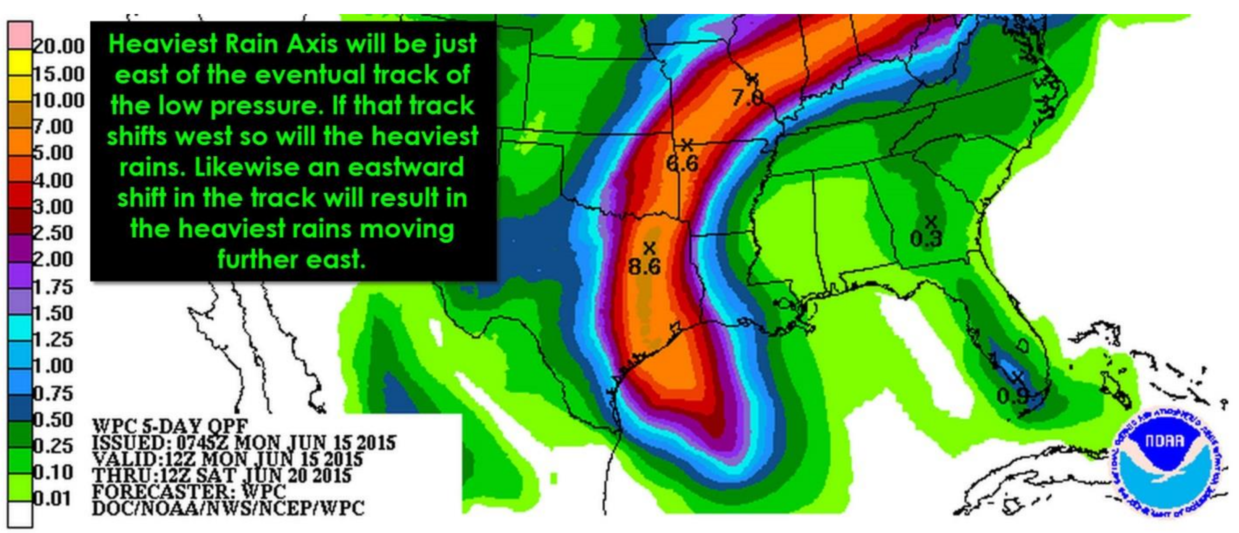
Of four official weather stations in the region, there were 100 records broken in 2015. It's interesting to note no daily low minimum temperature records set in 2015.

SITE	RAIN	LOW MAX T	HIGH MAX T	LOW MIN T	HIGH MIN T
GALVESTON	2	0	14	0	6
COLLEGE STATION	8	2	1	0	6
HOBBY AIRPORT	11	3	8	0	13
CITY OF HOUSTON	5	0	5	0	9
TOTALS	26	5	28	0	41

https://nwschat.weather.gov/p.php?pid=201601190336-KHGX-NOUS44-PNSHGX

TIDES, HURRICANES, AND TROPICAL DEPRESSIONS

Tropical Depression Bill was perhaps the most significant rainfall and tidal event in 2015. The storm released over five inches on the island with heavy winds and considerable beach and estuary erosion. Climate and extreme weather events remain significant issues for the success of this project. As noted in the original proposal, the project is one major hurricane away from disaster.



http://springhappenings.com/2015/06/dangerous-flooding-expected-on-tuesday-wednesday/

MOODY IRRIGATION WATER

This analysis was provided by Moody Gardens. Conclusion: good water. We will be periodically taking water samples during the course of this project.

Secondary and Other Not Regulated Constituents

(No associated adverse health effects)

Year (Range)	Constituent	Average Level	Minimum Level	Maximum Level	Limit	Unit of Measure	Source of Constituent
2012	Bicarbonate	128	128	128	NA	ppm	Corrosion of carbonate rocks such as limestone.
2007	Calcium	38.9	38.9	38.9	NA	ppm	Abundant naturally occurring element.
2012	Chloride	62	62	62	300	ppm	Abundant naturally occurring element; used in water purification; byproduct of oil field activity
2009	Copper	0.029	0.029	0.029	1	ppm	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives.
2007	Magnesium	8.7	8.7	8.7	NA	ppm	Abundant naturally occurring element.
2007	Nickel	0.002	0.002	0.002	NA	ppm	Erosion of natural deposits.
2012	pH	7.1	7.1	7.1	>7.0	units	Measure of corrosivity of water.
2012	Sodium	48.4	48.4	48.4	NA	ppm	Erosion of natural deposits; byproduct of oil field activity.
2012	Sulfate	44	44	44	300	ppm	Naturally occurring; common industrial byproduct; byproduct of oil field activity.
2012	Total Alkalinity as CaCO3	106	106	106	NA	ppm	Naturally occurring soluble mineral salts.
2012	Total Dissolved Solids	271	271	271	1000	ppm	Total dissolved mineral constituents in water.
2007	Total Hardness as CaCO3	133	133	133	NA	ppm	Naturally occurring calcium.
2007	Zinc	0.165	0.165	0.165	5	Ppm	Moderately abundant naturally occurring element; used in the metal industry.

TAXODIUM AND THE GENETICS OF SALT TOLERANCE

The following abstract is a continuation of work at Stephen F Austin State University that was undertaken by a visiting scientist, Dr. Yuhon Zheng from the Institute of Botany, Jiangsu Province & Chinese Academy of Sciences, Nanjing, China 210014. "Jade" spend a year at SFASU and her work overlapped the beginning of the Moody Project. While mostly externally funded, a small portion of Moody Foundation grant was utilized in this work. The work provides a foundation for our work with bald cypress at Moody.

Yuhong Zheng[3], Bea Clack2, Yin Yunlong3, David Creech1. 2016. Genetic Diversity of a Range of Taxodium distichum Genotypes and Cultivars Based on ISSR Markers. [1]Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches TX 75962; [2]Department of Biology, Stephen F. Austin State University, Nacogdoches, TX 75962; [3]Institute of Botany, Jiangsu Province & Chinese Academy of Sciences, Nanjing, China 210014.
Hortscience 51(9): S24

Taxodium is in the cypress family, Cupressaceae, one of several ancient genera in the family commonly known as cypresses. Once three separate species under the genus, we are accepting Taxodium as one species with three botanical varieties: 1) Baldcypress, BC; *Taxodium distichum* (L.) Rich.var. *distichu*, 2) Pondcypress, PC*; T. distichum* var. *imbricarium* (Nutt.) Croom, and 3) Montezuma cypress, MC; *T. distichum* var. *mexicana* Gordon. In recent years, *Taxodium* has found favor in coastal windbreak forest, tidal land, and bottomland restoration projects, as well as being a modestly popular deciduous shade tree. The species is appreciated for tolerance to flood, salinity, alkalinity and hurricanes. In this research project, the genetic diversity of the three botanical varieties (BC, PC and MC), the purported hybrids from China, and 'Dongfangshan', a clone promoted as a hybrid of *Taxodium* and *Cryptomeria* in China, was analyzed. Samples were evaluated by Inter-Simple Sequence Repeat (ISSR) markers. A total of 135 individuals produced 108 bands when amplified by using nine ISSR primers. The Nei's gene diversity (h), the Shannon's Information index (I) and the Percentage of Polymorphic Loci (PPL) between different genotypes of BC were 0.2581, 0.3931 and 87.96%, respectively. For PC, the values were 0.2278, 0.3445 and 72.22%, respectively. For MC, the values were 0.2068, 0.3120 and 61.11%, respectively. Gene differentiation analysis showed that the gene flow (Nm) and coefficients of gene differentiation (Gst) of the three taxa were 0.7189 and 0.1955 for BC, 0.2696 and 0.2942 for PC, and 0.9861 and 0.0071 for MC. This study reports rich genetic diversity between the genotypes of Taxodium, but less noticeable diversity within. There was less gene exchange between genotypes in Taxodium that will lead to population differentiation. Data confirms that the parents of the purported hybrids were MC and BC. Finally, our data indicates 'Dongfangshan' does not appear to be a BC X *Cryptomeria* hybrid.

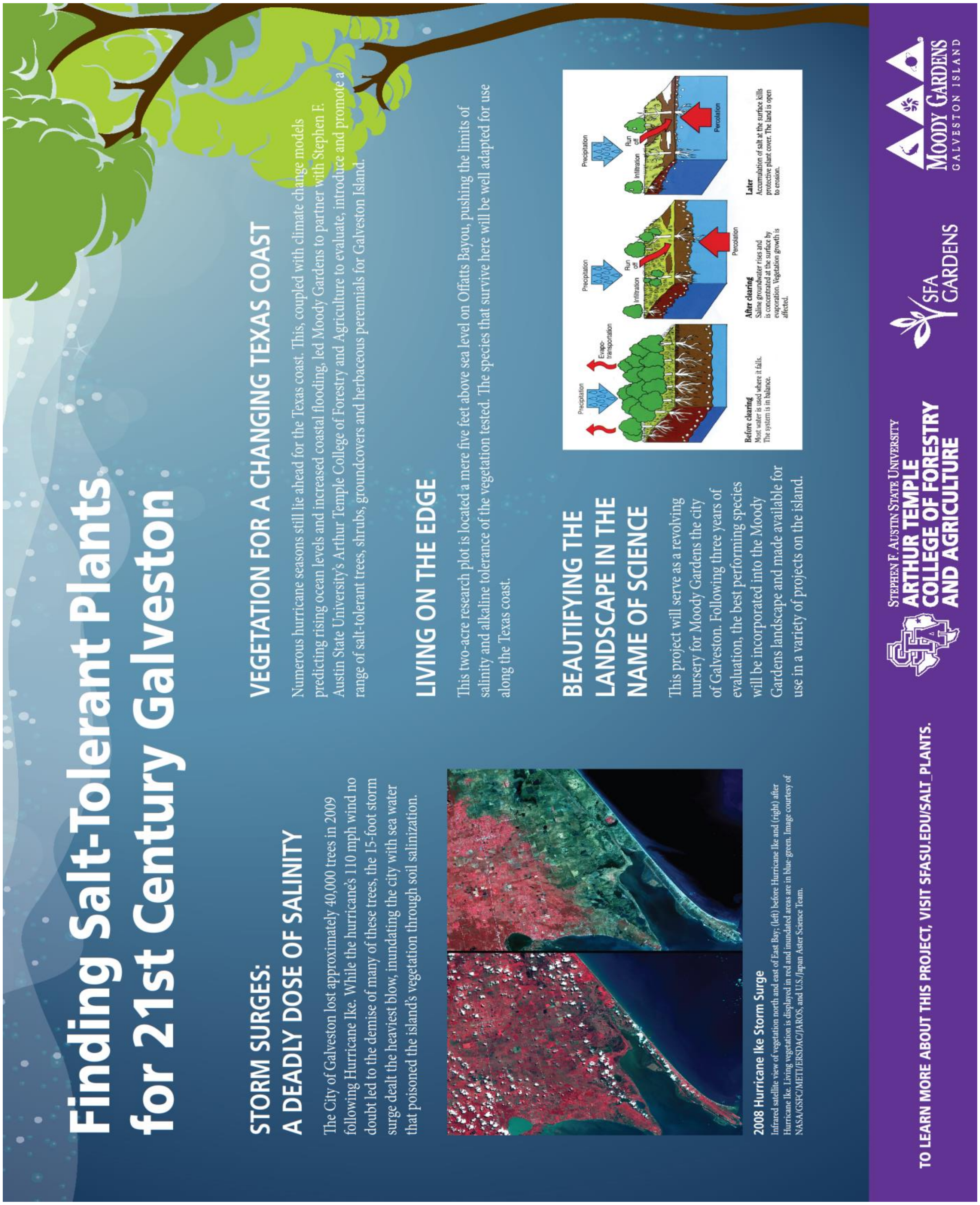
A FEW UNUSUAL ORNAMENTAL PLANTS DESTINED FOR MOODY GARDEN EVALUATION

Afrocarpus falcatus
Agathis robusta
Allocasuarina littoralis
Araucaria cunninghamii
Bursera species (especially the Florida native, Gumbo limbo)
Casuarina species (many to try – not all are beasts)
Juniperus barbadensis
J. bermudiana (endemic to Bermuda – so must tolerate hurricanes)
Leitneria floridana – native to areas that get inundated – small ornamental
Nageia nagi (hurricane proof!)
Persea borbonia or *P. palustris* (we have some laurel wilt tolerant P. borbonia you could try)
Pinus clausa (grows near shore in panhandle of Florida)
Pinus elliottii var. *densa* (south Florida slash pine is very salt tolerant – will try to get seeds from the Keys)
Populus alba var. *subintegerrima* (a small, suckering poplar from Spain that grows great in Florida, tolerates frost, and would stabilize sandy coastal sites – it does sucker though) - known to be very salt tolerant
Populus nigra 'Chile' - a semi-evergreen clone of the "Lombardy poplar" - it tolerates wind very well and indicates so far that it is much more disease resistant than the more commonly encountered straight species. Salt tolerance unknown.
Sapindus species (native soapberry is very salt tolerant and grows on old shell middens at Cedar Key)
Palms/desert lilies – working with Danny Carson, Grant Stephenson and some cooperating nurseries/botanical gardens to build a wide range collection of palms, from commodities to rare, purchased as three to five gallon plants. LSU's Ed Bush is providing the project with six selections of Paspalum. Also, developing a collection of Hesperaloe, Dasylirion, Agave, Yucca, Nolinas.

Salt Tolerant Palm and Allies list

High			
	Zone		**Zone**
Allagoptera arenaria	9	Pseudophoenix sargentii	
Coccothrinax argentata		Sabal palmetto	8
Cocos nucifera		Sabal Mexicana	8
Phoenix dactylifera	9	Serenoa repens	9
Pritchardia pacifica		Thrinax radiata	
Pritchardia thurstonii		Zombia antillarum	
Moderate			
Acoelorrhaphe wrightii	9B		
Acrocomia aculeata	9B	Licuala ramsayi	
Adonidia merrillii		Licuala spinosa	9
Areca vestiaria		Livistona australis	
Bismarckia nobilis	9B	Livistona chinensis	9
Borassus flabellifer		Livistona decipiens	9B
Brahea armata	9	Livistona mariae	9B
Brahea edulis		Livistona saribus	8
Chamaerops humilis	8	Nannorrhops ritchiana	7B
Coccothrinax barbadensis		Phoenix canariensis	9B
Coccothrinax crinita		Phoenix loureiri	9B
Coccothrinax miraguama		Phoenix reclinata	9B
Copernicia hospita		Phoenix rupicola	9
Copernicia macroglossa		Phoenix sylvestris	8
Copernicia prunifera	9B	Ravenea rivularis	
Dictyosperma album		Rhapidophyllum hystrix	7B
Dypsis lutescens		Roystonea regia	9B
Elaeis guineensis		Sabal causiarum	9
Hyophorbe lagenicaulis		Sabal minor	7B
Hyophorbe verschaffeltii		Syagrus romanzoffiana	9B
Hyphaene thebaica	9B	Syagrus schizophylla	
Latania loddigesii	9B	Veitchia arecina	
Latania lontaroides		Veitchia joannis	
		Veitchia winin	8
		Washington filifera	8B
		Washington robusta	

As part of the project we proposed design and installation of a small interpretive sign at the research plots. This is a first DRAFT version.



CONCLUSIONS – This project is well underway. The infrastructure is in place. The location is challenging. Based on wind and salt pressures, this place gets an A+. This is a great opportunity to expand the plant palette for Galveston island and discover horticultural strategies to manage plant materials in a salt challenged environment. Both are worthy goals.

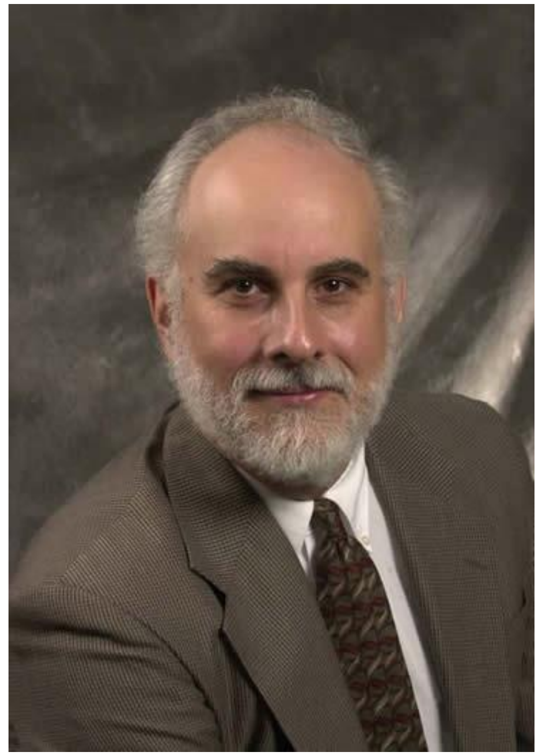
Image of a group of Texas A & M University student volunteers smoothing out raised beds and mulch in early April, 2016.

Key Staff for Moody Foundation Project and Qualifications:

Dr. David Creech
Professor Emeritus and Director, SFA Gardens
Stephen F. Austin State University
936-679-3460 and dcreech@sfasu.edu
Ph.D. -- Texas A & M University
M.S. -- Colorado State University
B.S. -- Texas A & M University
Dr. Creech is the lead Principal Investigator on this project. He has been at Stephen F. Austin State University since 1978 and currently directs SFA Gardens, a 128 acre garden that has long been associated with the testing and introduction of new plant materials. Dr. Creech is a Regent's Professor and Professor Emeritus. He has a long list of scholarly and trade publications. He's a past-President of the Native Plant Society of Texas and the Southern Region of the American Society of Horticultural Science. He has held numerous positions in other organizations. His primary interest is introduction of plant materials, environmental education and spreading the gospel of adventuresome horticulture.

Malcolm L. Turner, SFA Gardens Technician started in March 2017 as the SFA Gardens Garden Technician. His responsibilities include taking care of the blueberry, fig, muscadine and kiwifruit plantings. In addition, half of his time is dedicated to the Moody Gardens Research project. Malcolm was born in Houston, Texas but soon moved to Clinton, Iowa where he was raised near fields of corn along the Mississippi River. He was part of an avid gardening family, and he and his younger brothers sold produce at the end of their drive, just like his grandfather did in New London, Texas. In 2014, Malcolm moved to a small farm in San Augustine County, Texas.

Dr. Kenneth Farrish
Director, Division of Environmental Science
Stephen F. Austin State University
phone: 936-468-2475 | kfarrish@sfasu.edu
Education: Ph.D. -- University of Minnesota; M.S.-
Michigan Technological University; B.S. -
Michigan Technological University



Dr. Farrish came to SFA in 1996 as Associate Professor from Louisiana Tech University. In 2001 he was named Director of the Division of Environmental Science. His research interests include forest soil ecology, forest soil productivity maintenance and enhancement, root system dynamics, remediation and reclamation of disturbed lands and alternative right-of-way vegetation management. He has overseen major modifications of curricula for the BS and MS degrees in Environmental Science and played a major role in a proposal to establish a Ph.D. program in Environmental Science. In 2003, he was named the Arnold Distinguished Professor of Forest soils and Environmental Science.

Dr. Josephine Taylor
Professor, Department of Biology
Stephen F. Austin State University
Phone: 936.468.2268 E-mail: jtaylor@sfasu.edu
Education: Ph.D. -- University of Georgia
B.S. – Stephen F. Austin State University

Dr. Taylor joined the biology faculty in 1992 following a two year postdoctoral research associate appointment at Texas A&M University. She teaches courses in introductory biology, mycology, plant pathology and electron microscopy. Dr. Taylor's research interests include fungal identification, plant-fungal interactions and mechanisms of plant disease resistance. She is a member of the Texas Academy of Science, the American Phytopathological Society and the Mycological Society of America. Dr. Taylor will be involved in examining the role of mycorrhizal fungi in salt tolerance.

Dr. Stephen Wagner
Professor, Department of Biology
Stephen F. Austin State University
phone: 936-468-2135 | swagner@sfasu.edu
Education:
Ph.D. -- Agronomy (Soil Microbiology), Clemson University
M.S. – Microbiology, North Carolina State University
B.S. – Environmental Biology, Heidelberg University

Dr. Wagner came to Stephen F. Austin in 1996 after serving as a Postdoctoral Research Associate with the USDA-ARS Southern Weed Science Laboratory. He teaches general biology, microbiology, cell biology, and applied and environmental biology courses. His research has focused upon microbial ecology and incorporated several different projects, including the impact of oil/brine spills on microbial and plant communities, the effect of cropping systems on herbicide biodegradation and plant/microbe interactions involving mycorrhizal fungi and nitrogen-fixing bacteria. Additionally, he served as the principal investigator of several projects involved in professional development programs that train pre- and in-service teachers in innovative, inquiry-based approaches to teaching science. Dr. Wagner has an extensive publication record of research articles and reviews in several journals, conference proceedings and online textbooks. His work has been supported by the American Society for Microbiology, Baker Hughes, Inc., the National Science Foundation, NASA, the U.S. Department of Education, the Texas Higher Education Coordinating Board, USDA-ARS and the Waksman Foundation.

GRADUATE STUDENTS

THREE MSC THESIS PROJECTS

Elaine Harris. MS thesis: Soil Amelioration and Plant Establishment on Salt Affected Soils - Graduate Research Assistantship funded through SFA Environmental Science

High soil sodium concentrations can be detrimental to soil physical and chemical properties that affect plant establishment and growth. Sodium can naturally leach out of the soil profile over time, but there are soil management techniques for expediting soil sodium remediation that are employed in this study. Principal methods of amelioration of elevated soil sodium concentrations utilized in this study include increasing sodium leaching though organic mulch incorporation, elevated planting beds and chemical amendments. The mulch that will be utilized is pine bark mulch, the elevated beds will be constructed with soil originating from an off - island source, and the applied chemical amendment will be calcium sulfate (gypsum). The study will also evaluate the suitability of three plant species, (live oak (*Quercus virginiana*), bald cypress (*Taxodium distichum*) and Yellow Hibiscus (*Hibiscus hamabo*) for growth in the sodium affected soils. Various combinations of the soil amelioration practices and the vegetative species will be implemented in order to ensure meaningful results for determination of the most effective practice or combination of practices for lowering soil sodium concentrations and establishing suitable vegetative species. Natural inputs of sodium salts from sea-spray aerosols and during precipitation events will also be quantified using a precipitationl/dry-fall automated collector at the study site. Elaine will defend her thesis in the Fall, 2019.

Elaine Fowler. MS Thesis: Microbial Assessment of Soil Organisms Colonizing High Salt Challenged Plants on Galveston Island, Texas –GRA funded externally through the Department of Biology, SFASU.

When Hurricane Ike swept the island of Galveston, Texas in 2008 it was flooded with salt water that left the soil and water table of the island with elevated sodium concentrations. Much of the island's forest cover and plant life was lost, and the island is more vulnerable to erosion as a result. As a part of a long term study that aims to restore plant life to the salt affected soils of the island, various salt tolerant plants and soil amelioration techniques will be tested. Understanding the complicated relationship between plants and soil microorganisms is critical to plant growth and development. Consequently an assessment of the soil microbial communities is a necessary component of any recovery effort. The rhizosphere soil and non-rhizosphere soil from the plots of the plants being evaluated will be assessed for bacteria and fungal populations and enzyme activity. Additionally salt-tolerant bacteria will be isolated and characterized for possible utilization in futures studies for plant growth promoting abilities. Overall soil viability will be evaluated using microbial diversity and soil enzyme activity as a measure of soil health. This project will, 1) Evaluate the effect of gypsum and pine bark amendments as well as raised planting beds on plant rhizosphere and non-rhizosphere soil bacteria, actinomycete, pseudomonad and fungal populations, 2) Evaluate the effects of each treatment on soil esterase enzyme activity, 3) Isolate and characterize salt tolerant bacteria, 4) Use data gathered (total microbial populations, enzyme activity and salt tolerance of iso-lates) to evaluate overall soil viability using microbial diversity as an indicator for soil health.

Daniel Morgan. MS Thesis: Evaluation of Groundwater Sodium and Sodium Uptake in Taxodium in Galveston, Texas

Daniel Morgan is Dr. Kenneth Farrish's GRA funded via Environmental Science. He will receive his MS in Environmental Science in Dec 2019. Daniel is from Nacogdoches, Texas and holds a Bachelor of Science degree in Biology with a minor in Philosophy from Henderson State University. During his undergraduate studies, Daniel served as a Microbiology Lab Assistant where he conducted screening of isolates capable of antibiotic inhibition and purification of successful isolates for further study. In his graduate research, he studied the groundwater characteristics and sodium uptake in plants in Galveston, Texas. Daniel will defend his thesis in the Fall 2019.

TWO VISITING SCIENTISTS

Dr. Yuhong Zheng, Associate Professor, Department of Ornamental Plants, Institute of Botany, Jiangsu Province and Chinese Academy of Sciences (Nanjing Botanical Garden, Mem. Sun Yat-Sen)

Phone: +86 025 84347131
E-mail: friend266@163.com
Education:
Ph.D. -- Nanjing Agricultural University
M.S. -- Institute of Botany, Jiangsu Province & Chinese Academy of Sciences
B.S. --Zhoukou Normal University

Dr. Zheng joined the Institute of Botany, Jiangsu Province and Chinese Academy of Sciences (Nanjing Botanical Garden Mem. Sun Yat-Sen) in 2006. Her research mainly focuses on the improvement and application of ornamental plant germplasm resources.

Dr. Jianfeng Hua was a visiting scientist from the Institute of Botany, Jiangsu Province and Chinese Academy of Sciences (Nanjing Botanical Garden) and initiated a number of projects at the Moody Garden Research Plots.

Professor, Department of Plant Ecology and Environment
Institute of Botany, Jiangsu Province and Chinese Academy of Sciences (Nanjing Botanical Garden)
Phone: +86 025 84347096
E-mail: jfhua2009@gmail.com
Education:
Ph.D. -- Institute of Soil Science, Chinese Academy of Sciences
M.S. -- Institute of Applied Ecology, Chinese Academy of Sciences
B.S. --Nanjing Agricultural University

Dr. Hua joined the Institute of Botany, Jiangsu Province and Chinese Academy of Sciences (Nanjing Botanical Garden) in 2009. In 2014 he was named Vice Director of the Department of Plant Ecology and Environment. His research mainly focuses on the plant resources, stress resistance and soil ecology.

PUBLICATIONS AND PRESENTATIONS CONNECTED TO THIS PROJECT

Creech, David. October 26, 2016. Woody Ornamentals for a 21st Century Landscape – A Perspective from Texas. Presentation at the Southern Region International Plant Propagators Society conference, Virginia Beach, VA (Oct 22-26, 2016).

Creech, David. Aug 30-Sept 2, 2016. Woody Ornamentals for the Gulf South. Presentation at the Southern Plant Conference, Southern Nurserymen's Association, Athens, Georgia.

Yuhong Zheng3, Bea Clack2, Yin Yunlong3, David Creech1. 2016. Genetic Diversity of a Range of Taxodium distichum Genotypes and Cultivars Based on ISSR Markers. [1]Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches TX 75962; [2]Department of Biology, Stephen F. Austin State University, Nacogdoches, TX 75962; [3]Institute of Botany, Jiangsu Province & Chinese Academy of Sciences, Nanjing, China 210014. **Hortscience** 51(9): S24

November 11, 2016. E. Fowler, S.C. Wagner, K. Farrish, E.Harris, D. Creech. 2016. Assessment and Characterization of Microbial Communities in Salt Affected Soil on Galveston Island. Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas. A presentation to the Texas Branch Fall Meeting of the American Society for Microbiology, UT-Dallas, TX.

E. Harris, K.W. Farrish, D. Creech, and J.L. Young. 2016. Soil Amelioration and Plant Establishment on Sodium Affected Soils on Galveston Island, Texas. Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas. A Poster Paper presentation to the Society for Ecological Restoration Texas Chapter, Livingston, TX, November 11, 2016.

Dave Creech, Kenneth Farrish, and Elaine Harris. 2017. Woody Ornamental Plant Establishment Studies on a Salt-Affected Soil, Galveston Island, Texas. Presentation to 2017 Annual Conference of the Southern Region American Society for Horticultural Science, Mobile, Alabama, Feb 3-6, 2017.

Stephen Wagner1, Elaine Fowler2, Kenneth W. Farrish2 and David Creech3,
Oct 23, 2017. Assessment and Characterization of Microbial Communities in Salt Affected Soils on Galveston Island. (1) Dept. of Biology, Stephen F. Austin State University, Nacogdoches, TX. (2)Environmental Science, Stephen F. Austin State University, Nacogdoches, TX, (3)SFA Gardens, Stephen F. Austin State University, Nacogdoches, TX. A poster presentation at the Soil Science Society of America's Annual Conference, Tampa, Florida.

Creech, David. 2017. Feb 22-24, 2017. SFA Gardens update. Presentation at the annual conference of the Texas Association of Botanical Gardens and Arboreta, Grapevine, Texas. 65 attendees.

Creech, David. 2017. July 27, 2017. Oral Presentation "Finding climate change friendly ornamentals for Galveston Island, Texas and the Strategies Needed to Deal with a Salt Challenged Environment." International Botanical Conference, Shenzhen, China, July 27, 2017.

D. Creech*, K. Farrish, E. Harris, S. Wagner, and E.Fowler. Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, TX. Also, I moderated the T6-14 session on "Botanical Gardens and the Exploration of Salt Tolerant Crops." 65 in attendance and a lively debate. August 2017.

Qin Shi, Yunlong Yin, Zhiquan Wang, David Creech & Jianfeng Hua. Influence of soil properties on the performance of the Taxodium hybrid 'Zhongshanshan 407' in a short-term pot experiment. 2017. Soil Science and Plant Nutrition Vol. 63 , Iss. 2, 2017

August 2, 2017. Dave Creech, a presentation in Jingjiang, China. "Taxodium research and use in USA." Second annual conference on Taxodiums at the Jingjiang Taxodium Research and Germplasm Base.

Creech, David. Sept 22, 2018. Woody Ornamentals for a 21st Century Gulf South.
Mobile Botanical Gardens, the first Marion Drummond Lecture.

Creech, David. Oct 17, 2018. Climate change friendly plants for a 21st century Galveston Island. Texas Forestry Association annual meeting, preconference presentation (with SFA Professors Steve Wagner, Jo Taylor, and Ken Farrish), Galveston, Texas.

Creech, David. 2018. Climate Change Friendly Woody Ornamentals for a 21st Century Texas. Two presentations at the annual conference of the Texas Master Gardeners,
College Station, Texas. April 4-6, 2018

David Creech[1]*, Malcolm Turner[1], Steve Wagner[2], Josephine Taylor[2], and Kenneth Farrish[3]. **A Synopsis of Three Years of Tree Research at Moody Gardens, Galveston Island, Texas.**
[1] Department of Agriculture, Stephen F. Austin State University, Nacogdoches, TX 75962, [2]Biology Department, Stephen F Austin State University, Nacogdoches, TX 75962, [3]Division of Environmental Science, Stephen F. Austin State University, Nacogdoches, TX 75962. Oral presentation at the American Society for Horticultural Science Southern Region, Birmingham, Alabama, Feb 2, 2019.

Creech, David. August 9, 2019. New Plants for the Gulf South. Presentation at the Texas Nursery and Landscape Association annual conference and convention, San Antionio, Texas. Included a summary of Moody Gardens woody work. 50 participants.

Stephen Wagner, Josephine Taylor, and David Creech. 2019. Effect of Mycorrhizae Amendment on Three Cypress Genotypes Grown in Hurricane Impacted Soils. Stephen F. Austin State University, Nacogdoches, Texas. Paper accepted for presentation at the 2019 ASA-CSSA-SSSA International Annual Meeting, Nov. 10-13, 2019, San Antonio, Texas.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

APPENDIX A

Planting plan Moody Research plots (11-01-2019)

Rows run N to S, Plants run W to E in the row

NORTH EDGE RESEARCH BLOCK (KEN FARRISH/DANIEL MORGAN)

Quercus virginiana	Treetown
Hibiscus hamabo	SFA
Taxodium T406	SFA

EAST SIDE BLOCK (PLANTS W TO E)

Row		
1	Populus X 'Purpureus'	Jason Smith
1	Ilex decidua 'Parson's Pride'	SFA
1	Ehretia longiflora	Adam Black
1	Chilopsis linearis 'Bubba'	SFA
1	Hibiscus syriacus ''Lavender Chiffon' graft	SFA
1	Hibiscus syriacus ''Lavender Chiffon' graft	SFA
1	Hibiscus syriacus ''Lavender Chiffon' graft	SFA
1	Hibiscus syriacus ''Lavender Chiffon' graft	SFA
1	Podocarpus foresttii	UFL
1	Grevillea robusta	UFL
1	Grevillea robusta	UFL
1	Taxodium X 'T140'	SFA
1	Philadelphus ernestii	
1	Pinus glabra	UFL
1	Hibiscus syriacus 'Ball French Cabaret Blush'/H. hamabo	SFA
1	Hibiscus syriacus 'Ball French Cabaret Blush'/H. hamabo	SFA
1	Hibiscus syriacus 'Ball French Cabaret Blush'/H. hamabo	SFA
1	Hibiscus syriacus 'Ball French Cabaret Blush'/H. hamabo	SFA
1	Hibiscus syriacus 'Ball French Cabaret Blush'/H. hamabo	SFA
1	Hibiscus syriacus 'Ball French Cabaret Blush'/H. hamabo	SFA
1	Podocarpus macrophylla 'Yew So Fine'	SFA
1	Podocarpus macrophylla 'Sunshine'	SFA
1	Podocarpus macrophylla 'Edgefield'	SFA
1	Populus tomentosa	SFA
1	Ficus virens	SFA
1	Ehretia longiflora	Jason Smith

1	Ficus gasparinina	Adam Black
1	H. hamabo (Adam Black Form) talipiriti	Adam Black
1	Aruaucaria angustifolia	Heritage
1	Populus X canadensis	Jason Snith
1	Populus yunnanensis	Jason Smith
1	Populus nigra 'Chile'	Jason Smith
1	Taxodium distichum - South LA genotype	Ed Bush
1	Taxodium distichum - South LA genotype	Ed Bush
1	Taxodium distichum - South LA genotype	Ed Bush
1	Taxodium distichum - South LA genotype	Ed Bush
1	Taxodium distichum - South LA genotype	Ed Bush
Row		
2	Grevillea robusta	SFA
2	Eucalyptus LLC1	Mark Crawford
2	Myrcianthes fragrans	UFL
2	Myrcianthes fragrans	UFL
2	Myrcianthes fragrans	UFL
2	Myrcianthes fragrans	UFL
2	Myrcianthes fragrans	UFL
2	Amelanchier denticulata	Mexico form
2	Amelanchier denticulata	Mexico form
2	Amelanchier denticulata	Mexico form
2	Amelanchier denticulata	Mexico form
2	Amelanchier denticulata	Mexico form
2	Euschapis japonica	seedlings
2	Euschapis japonica	seedlings
2	Grevillia robusta	SFA
2	Euschapis japonica	seedlings
2	Euschapis japonica	seedlings
2	Taxodium 'Oaxaca Child'	cutting grown
2	Taxodium 'Oaxaca Child'	cutting grown
2	Taxodium 'Oaxaca Child'	cutting grown
2	Taxodium 'Oaxaca Child'	cutting grown
2	Taxodium 'Oaxaca Child'	cutting grown
2	Taxodium 407	cutting grown
2	Taxodium 407	cutting grown
2	Taxodium 407	cutting grown
2	Taxodium 407	cutting grown
2	Taxodium 407	cutting grown
2	Taxodium 406	cutting grown
2	Taxodium 406	cutting grown
2	Taxodium 406	cutting grown

2	Taxodium 406	cutting grown
2	Taxodium 406	cutting grown
2	Taxodium 405	cutting grown
2	Taxodium 405	cutting grown
2	Taxodium 405	cutting grown
2	Taxodium 405	cutting grown
2	Taxodium 405	cutting grown
2	Taxodium 27	cutting grown
2	Taxodium 27	cutting grown
2	Taxodium 27	cutting grown
2	Taxodium 27	cutting grown
2	Taxodium 27	cutting grown
2	Taxodium 502	cutting grown
2	Taxodium 502	cutting grown
2	Taxodium 502	cutting grown
2	Taxodium 502	cutting grown
2	Taxodium 502	cutting grown
Row		
3	Prunus X 'Purple Pride'	
3	Prunus X 'Purple Pride'	
3	Prunus X 'Purple Pride'	
3	Prunus X 'Purple Pride'	
3	Acacia anisophylla	
3	Acacia anisophylla	
3	Acacia anisophylla	
3	Acacia anisophylla	
3	Acacia anisophylla	
3	Eucalyptus LLC1 V66	Mark Crawford
3	Eucalyptus LLC1 V66	Mark Crawford
3	Eucalyptus LLC1 V66	Mark Crawford
3	Eucalyptus LLC1 V66	Mark Crawford
3	Eucalyptus LLC1 V66	Mark Crawford
3	Sophora affinis	
3	Sophora affinis	
3	Sophora affinis	
3	Sophora affinis	
3	Sophora affinis	
3	Quercus spp.	Mexico
3	Quercus spp.	Mexico
3	Chilopsis linearis 'Bubba'	SFA
3	Chilopsis linearis 'Bubba'	SFA
3	Quercus canbyi	

3	Quercus canbyi	
3	Quercus canbyi	
3	Quercus canbyi	
3	Quercus canbyi	
3	Quercus rysophylla	
3	Quercus rysophylla	
3	Quercus rysophylla	
3	Quercus rysophylla	
3	Quercus rysophylla	
3	Sabal mexicana	
3	Sabal mexicana	
3	Sabal mexicana	
3	Sabal mexicana	
3	Sabal mexicana	
3	Yucca recurvifolia	
3	Yucca recurvifolia	
3	Yucca recurvifolia	
3	Yucca recurvifolia	
3	Grevillea robusta	UFL
3	Sabal X -	Brazoria palm
3	Sabal X -	Brazoria palm
3	Sabal X -	Brazoria palm
3	Sabal X -	Brazoria palm
3	Sabal X -	Brazoria palm
4	Sabal uresana	Adam Black
4	Chamaerops humilis 'Volcano'	Adam Black
4	Livistonia chinensis	Michael Richard
4	Nannrrhops ritchiana	Michael Richard
4	Serenoa repens Blue	Michael Richard
4	Salix nigra HSC weeping	Michael Richard
4	Sophora secundiflora	seedling of white
4	Sophora secundiflora	seedling of white
4	Sophora secundiflora	seedling of white
4	Sophora secundiflora	seedling of white
4	Sophora secundiflora	seedling of white
4	Sophora secundiflora	seedling of white
4	Sophora secundiflora	seedling of

		white
4	Punica granatum	Purple Heart
4	Punica granatum	'Red Silk'
4	Punica granatum	Double Flower
4	Purnic granatum	Desertnyi?
4	Salix humboldtiana	
4	Salix chinensis	fastigata
4	Populus nigra	Chile
4	Parrotia persica	Biltmore
4	Parrotia persica	Biltmore
4	Parrotia persica	Biltmore
4	Parrotia persica	Biltmore
4	Parrotia persica	Biltmore
4	Callicarpa rubella	NA81624
4	Callicarpa rubella	NA81624
4	Callicarpa rubella	NA81624
4	Callicarpa rubella	NA81624
4	Callicarpa rubella	NA81624
4	Leucophyllum langmaniae	Lynn's Legacy'
4	Leucophyllum langmaniae	Lynn's Legacy'
4	Leucophyllum langmaniae	Lynn's Legacy'
4	Leucophyllum langmaniae	Lynn's Legacy'
4	Leucophyllum langmaniae	Lynn's Legacy'
4	Hibiscus dasycalyx	
4	Ilex vomitoria	Kathy Ann
4	Ilex vomitoria	Kathy Ann
4	Ilex vomitoria	Kathy Ann
4	Ilex vomitoria	Kathy Ann
4	Ilex vomitoria	Kathy Ann
4	Ilex vomitoria	Kathy Ann
5	Trachycarpus wagnerianus ?	SFA
2	Sabal from Tamaulipas	SFA
5	Pinus taiwaniensis	UFL
5	Chamadorea radicalis	Michael Richard
5	Rhapis excelsa	Michael Richard
5	Rhapis excelsa	Michael Richard
5	Rhapis excelsa	Michael Richard
5	Rhapis excelsa	Michael Richard
5	Rhapis excelsa	Michael Richard
5	Washintonia robusta	Michael Richard
5	Washintonia robusta	Michael Richard
5	Washintonia robusta	Michael Richard
5	Washintonia robusta	Michael Richard

5	Washintonia robusta	Michael Richard
5	Seranoa repens green	Michael Richard
5	Seranoa repens blue	Michael Richard
5	Seranoa repens blue	Michael Richard
5	Seranoa repens blue	Michael Richard
5	Seranoa repens blue	Michael Richard
5	Seranoa repens blue	Michael Richard
5	Allagoptera arenaria	Michael Richard
5	Allagoptera arenaria	Michael Richard
5	Allagoptera arenaria	Michael Richard
5	Allagoptera arenaria	Michael Richard
5	Allagoptera arenaria	Michael Richard
5	Butia capitata (female) X Syagrus romanzoffyana (male)	Michael Richard
5	Butia capitata (female) X Syagrus romanzoffyana (male)	Michael Richard
5	Butia capitata (female) X Syagrus romanzoffyana (male)	Michael Richard
5	Butia capitata (female) X Syagrus romanzoffyana (male)	Michael Richard
5	Butia capitata (female) X Syagrus romanzoffyana (male)	Michael Richard
5	Taxodium 'Sentido #1'	SFA
6	Sabal Tamaulipas	
6	Chamaerops humilis green	Michael Richard
6	Chamaerops humilis green	Michael Richard
6	Chamaerops humilis green	Michael Richard
6	Chamaerops humilis green	Michael Richard
6	Phoenix canariensis	Michael Richard
6	Phoenix canariensis	Michael Richard
6	Phoenix canariensis	Michael Richard
6	Phoenix canariensis	Michael Richard
6	Phoenix canariensis	Michael Richard
6	Podocarpus 'Michael Richard clone'	Michael Richard
6	Butia capitata	Michael Richard
6	Butia capitata	Michael Richard
6	Butia capitata	Michael Richard
6	Butia capitata	Michael Richard
6	Butia capitata	Michael Richard
6	Chamaerops humilis green	Michael Richard
6	Chamerops humilis blue	Michael Richard
6	Chamerops humilis blue	Michael Richard
6	Chamerops humilis blue	Michael Richard
6	Chamerops humilis blue	Michael Richard
6	Chamerops humilis blue	Michael Richard
6	Trachycarpus fortunei	Michael Richard
6	Trachycarpus fortunei	Michael Richard

6	Trachycarpus fortunei	Michael Richard
6	Trachycarpus fortunei	Michael Richard
6	Phoeniz sylvestris	Michael Richard
6	Phoeniz sylvestris	Michael Richard
6	Phoeniz sylvestris	Michael Richard
6	Phoeniz sylvestris	Michael Richard
6	Phoeniz sylvestris	Michael Richard
6	Pinus remoto	Adam Black

Row		
7	Sabal minor (division)	Michael Richard
7	Sabal minor (division)	Michael Richard
7	Sabal minor (division)	Michael Richard
7	Sabal minor (division)	Michael Richard
7	Sabal minor (division)	Michael Richard
	Dr. Hua experiment	SFA
Row		
8	Dr. Hua experiment (OLD PLANTING MOVED)	SFA
Row		
9	Steve Wagner/Elaine Fowler study	SFA

WEST SIDE BLOCK (PLANTS W TO E)

Row		
1	Taxodium 405 (20 trees)	
	Medjool Date Plam	
	Sylvester Date Palm	
	Pittosporum heterophyllum 'variegata'	SFA
	Pittosporum tobira 'McMillan variegated'	SFA
	Hibiscus hamabo (Adam Black Form)	PECKERWOOD
Row		
2	Taxodium 407 (20 trees)	
	Trachycarpus wagnerianus	SFA
	Ehretia longiflora	PECKERWOOD
	Kostletzyka virginica 'Peter Loos'	SFA
	Hibscus hamabo (Black Form)	PECKERWOOD
Row		
3	Taxodium 502 (20 trees)	

Ficus virens PECKERWOOD

Row 4 Hibiscus hamabo/H. syriacus study, see new map (Final Report to Moody Foundation) which describes the experimental design of Dr. Hua's experiment