Proceedings of the 1st Joint Symposium on the Natural History and Geology of The Bahamas

June 12-16, 2015

Conference Organizer:
Thomas A. Rothfus

Content Editors:
Carol L. Landry
Dan S. Kjar

Production Editors:
Lee J. Florea
Carol L. Landry

Gerace Research Centre
San Salvador, Bahamas
2017

ISBN: 978-0-935909-40-1

Cover image - Patch reef near the wall off Grotto Beach (photo by Lee Florea).

The effects of stem height and insect damage on plant moisture stress on San Salvador Island, The Bahamas

Drew E. I. Barber, Todd P. Egan, and Lynn L. Gillie
Department of Biology, Elmira College, Elmira, NY

1. Abstract

There have been many ecological, reproductive, and systematic studies on the flora of San Salvador Island, the Bahamas, but little research has focused on the ecology or physiology of halophytic species. The present ecophysiological study builds on previous studies by incorporating plant moisture stress data into plant distribution studies. Plant moisture stress was determined via pressure chamber. Preliminary data were collected from several herbaceous and woody species at 3 locations on San Salvador Island. Data were collected for leaf, stem, and inflorescence samples, and for insect-damaged and intact plants. April 2015 was very dry, and as a result most plants growing along Reckley Hill Pond were too stressed to exude water even under high pressure. An exception was Bay Marigold with a value of 0.4 MPa, located 8 m from shore. Leaves or stems of tree species higher in the canopy demonstrated a greater tension compared to petioles or stems lower in the canopy. Higher tension can overcome the combined effects of gravity and friction through the xylem to move water to the top of the plant. Preliminary data from Graham's Harbour plants were highly variable, so more data are needed to determine an effect of insect predation or moisture stress between species. It is hypothesized that plant moisture stress will decrease with increasing distance from the Reckley Hill Pond shore. It is also hypothesized that the tension required to move water higher up a tree will increase with canopy height, and that insect damaged plants will be more moisture stressed than intact plants.

2. Introduction

Since the First Symposium on the Botany of the Bahamas in 1986 there have been many detailed studies on the reproductive biology (e.g. Rathcke et al. 1996; Shoffeitt and Wilson 1987), natural history (e.g. Landry et al. 2007; Smith 1993), and taxonomy and systematics (e.g. Cross and Cruz-Alvarez 2011; Hill and Smith 1987) of plants on San Salvador Island. There have also been several studies of the mangrove communities of San Salvador (Cross and Cruz-Alvarez 2011; Landry et al. 2007; Rathcke et al. 1996). In contrast, there has been only one study focused on non-mangrove halophyte (salt tolerant) species (Rivers 1986). In this study, Rivers identified the vegetation around several inland saline bodies of water, noting their salinity levels.

Edwards (1996) identified San Salvador's inland lakes as "islands" unto themselves, and outlined research opportunities in these unique habitats. Therefore, eco-physiological plant moisture studies of halophytic species such as *Batis maritima* L. (Batis), *Salicornia virginica* Forssk. (Salicornia), and *Borrichia arborescens* (L.) DC. (Bay Marigold) would be a meaningful addition to the research performed on San Salvador Island. It is also important to study the effects of water stress on non-halophyte species.

In pre-Columbian times, *Swietenia mahagoni* (L.) Jacq. (Mahogany) trees were once an important component of San Salvador's vegetation. However, in the early 1800's this valuable timber species was cut down by plantation owners for naval engineering. However, without this vegetative protection, much of the soil has eroded away leaving little soil for native plants or farming (White 1985). As a result of this erosion, San Salvador is now characterized as having a scrubland habitat. However, plant species are not homogeneously distributed around the island, but instead form a patchwork of different communities predicated upon different soil or substrate type and depths, proximity to fresh, saline, or hypersaline water, and protection from high winds (Smith 1993).

In addition to the halophytes above, the moisture stress of woody, non-halophyte species was tested. *Terminalia catappa* L. (Indian Almond) and Mahogany were tested because they are tree species capable of growing to approximately 24-25 meters tall (Correll and Correll 1996), and therefore have the potential to show the largest gradient in water tension due to plant height. As a remnant population, Mahogany is especially important to study. The shrubs *Gundlachia corymbosa* (Urb.) Britton ex Boldingh (Horse Bush) and *Tournefortia gnaphalodes* L. (Bay Lavender) often inhabit coastal rock communities that are buffeted by wind and salt spray, and *Croton linearis* Jacq. (Granny Bush) which will inhabit coastal rock and coastal coppice communities (Smith 1993). Halophyte distribution on San Salvador is similar to the distribution of halophytes in other parts of the world. Zia et al. (2007) found that salinity, temperature, and water availability are important factors in determining halophyte zonation. Dagar (1995) found that in many of the same species (or at least congeners) growing in India that are found on San Salvador, they have similar distribution patterns. Egan and Ungar (2000) state that physiological limitations can prevent seeds from germinating in areas that are too saline for a given species, but that competition from less salt tolerant species in lower saline areas may prevent more salt tolerant plants from moving into that area.

Our hypothesis is that plants in more water and salt stressed environments will require more tension to pull water through the stem. We further hypothesize that more tension is required to pull water further up a tree or shrub in any type of habitat. The results presented here serve as a pilot study for a more systematic investigation into plant water stress on San Salvador Island.

3. Methods

Three preliminary experiments to outline future studies took place from April to May of 2015. Experiments investigating water stress in multiple plant species were conducted at three locations on San Salvador. At Reckley Hill Pond, moisture stress in Batis, Salicornia, and Bay Marigold was measured at 1 m intervals over 8 m starting at the edge of the pond. Percent cover was estimated and soil samples were taken at this location to better understand the effects of salinity and osmotic stress on plant distribution and density.

On the Gerace Research Centre (GRC) campus, the tension required to pull water to the top and bottom of the canopy of Indian Almond inflorescence stems and Mahogany leaves was measured to determine the effects of plant height on water stress. The lowest Mahogany leaves on the tree were selected to be tested. Petioles on Indian Almond leaves were too large to fit into the compression gland of the pressure chamber, so the lowest inflorescence stems were collected instead. The highest samples were collected from as high up in the trees that Dr. Egan could safely maneuver through the canopy and cut samples, and plant heights were estimated. Data for the Indian Almond inflorescences are single measurements taken at 3.66 meters above the ground (at the top of the tree), and 1.22 meters above the ground (at the bottom of the tree). Mahogany values are an average of two pairs of measurements taken 5.5 m above the ground (at the top of the tree) and 1.83 m above the ground (at the bottom of the tree).

Along Graham's Harbour, moisture stress was measured in Horse Bush, Granny Bush, and Bay Lavender. Estimates of moisture stress were compared among species, plant organs, and intact vs. insect chewed stems. One to three samples were collected at chest height after close inspection for insect damage.

Samples were collected along the inland side of the Queen's Highway near the east fence opening at the GRC.

Xylem tension, an indicator of plant moisture stress, was determined using the pressure chamber technique (PMS Instrument Company, Model 1000) and air pressure was supplied via a SCUBA tank. The pressure at which stem sap moves backwards through the leaf or stem is equal to the tension required to pull water through the stem. Therefore, the more pressure it takes to push water through the stem, the more water stressed the plant is (Scholander et al. 1965; Scholander 1968).

4. Results

April 2015 was exceptionally dry, leaving Reckley Hill Pond with a high average salinity of 54 ppt which approaches twice that of seawater (Rivers 1986). As a result, the halophytes Batis and Salicornia yielded no data even at 2.7 MPa. Even though the pressure chamber we used was specifically constructed for halophyte work and therefore had a chamber rated in excess of 10 MPa, 2.5 MPa was the highest pressure we felt was safe to take because pressure needed to force water through Salicornia was so high that stem sections appeared to disarticulate making a loud popping noise (but remained attached) before water could be forced backward through the stem. In addition, Batis specimens shot out of the chamber at 2.7 MPa before sap would flow backwards through the stem. Bay Marigold had a moisture stress value of 0.4 MPa, 8 m from the shore but was immeasurable in specimens closer to the shore.

The trend in the data for both tree species was similar. It took more tension to pull water to the tops of the tree canopies compared to the bottom of the canopies. Tension values were 1.05 MPa (top) vs. 0.50 MPa (bottom) for Indian Almond, and 2.45 MPa (top) vs. 1.97 MPa (bottom) for Mahogany (Figure 1).

Moisture stress values for the shrub species Horse Bush and Bay Lavender did not show the same consistent trend. In Horse Bush, stem values (2.2 MPa) were higher than leaf values (1.38 MPa). However, in Bay Lavender, leaf values (0.8 MPa) were more than twice as high as stem values (0.3 MPa) (Table 1). In addition, no consistent differences were found between intact and insect damaged tissue, so data are not presented here.

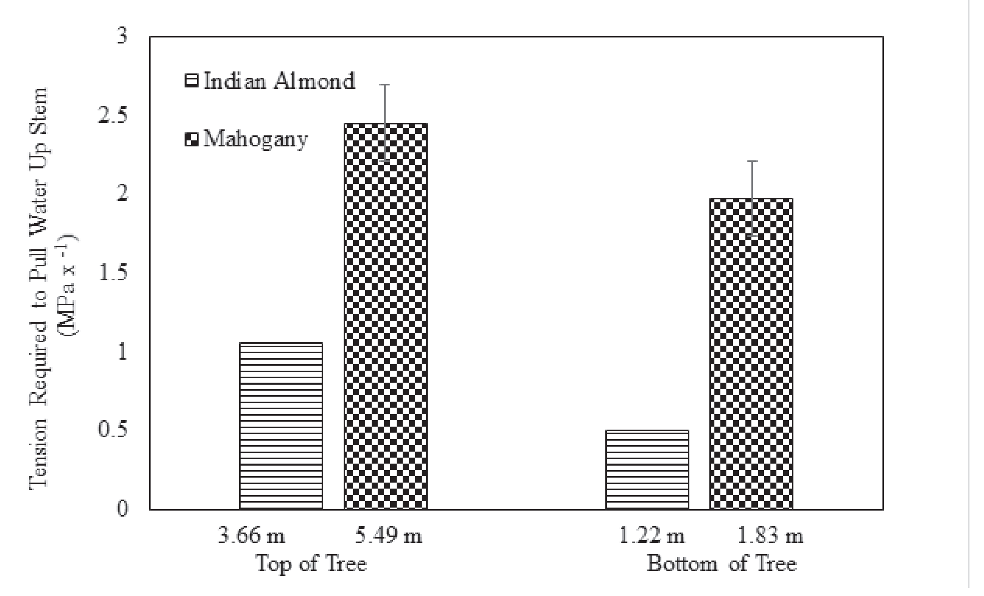

Figure 1. Differences in tension required to move water to different elevations of Indian Almond (*Terminalia catappa* L.) inflorescence stems and Mahogany (*Swietenia mahagoni* (L.) Jacq.) leaf stems along the length of the tree.

5. Discussion

As expected, increasing tension was required to pull water farther up Indian Almond and Mahogany stems because a greater tension is required to move water higher up a stem because additional stem height must be multiplied by the frictional resistance of the xylem as well as the gravitational pull on the column of water (Taiz and Zeiger 2010). Pressure values of the inflorescence stem of Indian Almond were more than twice as high for stems located approximately 3.7 m off the ground compared to the tension required to move water to the stems 1.2 m off the ground (Figure 1). A similar trend was found with Mahogany petioles where tension values for petioles 5.5 m above the ground were more than twice what was required to move water 1.8 m above the ground (Figure 1).

Moisture stress was measured in leaves and stems of Horse Bush, Bay Lavender, and Granny Bush growing between the beach and both sides of the Queen's Highway near Graham's Harbour. A trend we see is that for Horse Bush and Bay Lavender, higher values were observed from the leaf tissue compared to the stem tissue because leaves are further along the tension continuum compared to the stems (Taiz and Zeiger 2010). Moisture stress can be associated with insect predation (Cregg and Dix 2001), so a comparison was made between intact stems and insect-chewed stems of Horse Bush plants to determine if insect herbivory increased plant moisture stress. Preliminary data varied greatly between chewed and unchewed stems (data not shown) as well as among species and organs (Table 1). Therefore, much larger sample sizes are needed to elucidate meaningful biological trends.

Correll and Correll (1996) describe Bay Lavender as being somewhat succulent and Bay Marigold as being fleshy. It was observed that when sap was forced through the stems of these species via the pressure chamber, sap was exuded from succulent cortical tissue surrounding the xylem but not from the xylem tissue itself. This is a novel finding because sap flow through the stem xylem is usually what is reported (Cochard, et al. 2001).

The data presented in this study supports the hypothesis in only a moderate way. However, this study fulfilled its original purpose of providing direction and guidance for further studies.

6. Acknowledgements

The authors thank J. Forrest Meekins, Ph.D., for assistance with statistics and manuscript preparation, and students in the 2015 Elmira College Marine and Island Ecology students for assistance with preliminary studies. In addition we thank Tom and Erin Rothfus for logistical support on San Salvador Island. We also thank the Elmira College Summer Research Program for funding this research.

Table 1. Moisture stress values of stems and leaves of Horse Bush (*Gundlachia corymbosa* (Urb.) Britton ex Boldingh), Bay Lavender (*Tournefortia gnaphalodes* L.), and Granny Bush (*Croton linearis* Jacq.) at Graham's Harbour.

Species and Organ (Sample size)	Average MPa values
Horse Bush Leaf (3)	1.38
Horse Bush Stem (3)	2.2
Bay Lavender Leaf (1)	0.8
Bay Lavender Stem (2)	0.3
Granny Bush Stem (2)	0.18

7. References

COCHARD, H., S. FORESTIER, AND T. ARMEGLIO. 2001. A new validation of the Scholander pressure chamber technique based on stem diameter variations. *Journal of Experimental Botany* 52: 1361-1365.

CORRELL, D. S. AND H. B. CORRELL. 1996. Flora of the Bahama archipelago. A. R. G. Gantner Verlag K.-G., FL-9490 Vaduz, Devon, U.K.

CREGG, B. M. AND M. A. DIX. 2001. Tree moisture stress and insect damage in urban areas in relation to heat island effects. *Journal of Arboriculture* 27: 8-17.

CROSS, R. E. AND M. CRUZ-ALVAREZ. 2011. Identification of nuclear DNA microsatellites from red mangrove (*Rhizophora mangle*) populations on San Salvador. *In* J. E. Baxter and E. S. Cole [eds.], Proceedings of the 13th Symposium on the Natural History of The Bahamas, 2011, 74-76. Gerace Research Centre, San Salvador Island, Bahamas.

DAGAR, J. C. 1995. Characteristics of halophytic vegetation in India. *In* M. A. Khan and I. A. Ungar [eds.], Biology of Salt Tolerant Plants, 1995, 255-276. Department of Botany, University of Karachi, Karachi, Pakistan.

EDWARDS, D. C. 1996. The inland saline waters of the Bahamas as distinctive scientific resources. *In* N. B. Elliott, D. C. Edwards, P. J. Godfrey [eds.], Proceedings of the 6th Symposium on the Natural History of The Bahamas, 1996, 152-163. Gerace Research Centre, San Salvador Island, Bahamas.

EGAN, T. P. AND I. A. UNGAR. 2000. Similarity between seed banks and above-ground vegetation along a salinity gradient. *Journal of Vegetation Science* 11: 189-194.

HILL, J. AND R. R. SMITH. 1987. A taxonomic and ecological study of the genus *Coccoloba* (Polygonaceae) on San Salvador Island. *In* R. R. Smith [ed.], Proceedings of the 2nd Symposium on the Botany of The Bahamas, 1987, 18-30. Gerace Research Centre, San Salvador Island, Bahamas.

LANDRY, C. L., B. J. RATHCKE, AND L. B. KASS. 2007. The natural history of white mangrove, *Langunculare a racemosa* (Combretaceae): the forgotten mangrove. *In* B. J. Rathcke and W. Hayes [eds.], Proceedings of the 11th Symposium on the Natural History of The Bahamas, 2007, 43-53. Gerace Research Centre, San Salvador Island, Bahamas.

PMS INSTRUMENT COMPANY. 2014. http://www.pmsinstrument.com/products/model-1000-pressure-chamber-instrument. Accessed May 2015.

RATHCKE, B., L. B. KASS, AND R. E. HUNT. 1996. Preliminary observations on the reproductive biology of a San Salvador mangrove community. *In* N. B. Elliott, D. C. Edwards, P. J. Godfrey [eds.], Proceedings of the 6th Symposium on the Natural History of The Bahamas, 1996, 87-96. Gerace Research Centre, San Salvador Island, Bahamas.

RIVERS, W. G. 1986. Halophytes of the hypersaline lakes of San Salvador, Bahamas. *In* R. R. Smith [eds], Proceedings of the 1st Symposium on the Botany of The Bahamas, 1986, 87-100. Gerace Research Centre, San Salvador Island, Bahamas.

SCHOLANDER, P. F. 1968. How mangroves desalinate seawater. *Physiologia Plantarum* 21: 251-261.

SCHOLANDER, P. F., E. D. BRADSTREET, H. T. HAMMEL, AND E. A. HEMMINGSEN. 1965. Sap concentration in halophytes and some other plants. *Plant Physiology* 41: 529-532.

SHOFFEITT, D. H. AND T. K. WILSON. 1987. The floral morphology and pollination biology of three species of Bahamian Malpighiaceae. *In* R. R. Smith [ed.], Proceedings of the 2nd Symposium on the Botany of The Bahamas, 1987, 37-44. Gerace Research Centre, San Salvador Island, Bahamas.

SMITH, R. R. 1993. Field guide to the vegetation of San Salvador Island, The Bahamas, 2nd ed. Bahamian Field Station, San Salvador Island, Bahamas.

TAIZ, L. AND E. ZEIGER. 2010. Plant physiology, 5th ed. Sinauer Associates, Inc., Sunderland, Massachusetts, USA.

WHITE, V. 1985. The outermost island, an oral history of San Salvador. The Bahamas, CCFL Bahamian Field Station, 270 Southwest 34th St., Ft. Lauderdale, FL. USA.

ZIA, S., T. P. EGAN, AND M. A. KHAN. 2007. Population studies of *Limonium stocksii* (Plumbaginaceae) from a salt desert near the Arabian Sea coast. *Soil Science and Plant Analysis* 38: 1975-1990.