The Art of Botany: The Effect of Drought on Plant Anatomy

Amanda Wong
University of Hawaiʻi at Mānoa

Follow this and additional works at: https://kahualike.manoa.hawaii.edu/horizons
Part of the Botany Commons

Recommended Citation
Available at: https://kahualike.manoa.hawaii.edu/horizons/vol3/iss1/19

This Article is brought to you for free and open access by Kahualike. It has been accepted for inclusion in Mānoa Horizons by an authorized editor of Kahualike. For more information, please contact sheila.yeh@hawaii.edu.
Plants are negatively affected by water deficiencies, and water stress is expected to increase due to more frequent and prolonged droughts from climate change. I investigated the effect of drought on the internal anatomy of the invasive Syzygium cumini plant. In the greenhouse, S. cumini plants were grown, such that half of the plants were watered daily, while the remaining number of plants did not receive any water for the entire experiment. After nine weeks, the base of the main stem was cut into thin disks, stained, and the center was viewed through a microscope for the pith cells that provide structural support, conduct water, and store starch. The regularly watered plants had circular shaped piths with expanded, rigid cells filled with water and starch, while the non-watered plants had pinched and elongated piths with shriveled cells filled with air, light staining, and a lack of starch. S. cumini demonstrated exceptional drought tolerance with no mortality and only slight wilting; however, the lack of water and the energy storage starch in the pith cells indicates that the plants were stressed. This experiment provides insight into the ability of the drought-tolerant S. cumini to become more invasive under climate change-induced drought in Hawai‘i.

Introduction

Earth is home to a diversity of plant species that exhibit remarkable variation in their internal and external structure. These structural differences within individuals of a species are not only attributed to genetic variation but are also influenced by interactions with herbivores, microbes, and their environments. Water deficiency due to drought is a major environmental stressor on plants and is expected to increase under climate change (Jaleel et al. 2009; Chadwick et al. 2016). In Hawai‘i, climate change-induced drought will increase in duration with less frequent rainfall and less rainfall overall (Chen and Chu 2014; Chu et al. 2010).

Drought stress negatively influences plant development that is apparent through a decrease in leaf size, plant height, and overall plant size. The visible reduction in plant development is driven by a decrease in turgor pressure, or fluid pressure, throughout the plant due to water stress at the cellular level that inhibits cell expansion and division (Jaleel et al. 2009; Chadwick et al. 2016).
2009). Pith cells are essential for maintaining turgor pressure, water balance, and structural support throughout the whole plant through water storage at the center of the plant's stem, water redistribution to water-stressed cells, and the presence of rigid lignin in the pith cell walls (Chabannes et al. 2001; Knipfer et al. 2017). Here, the cellular stem anatomy of the drought-tolerant *Syzygium cumini* (Myrtaceae), commonly known as java plum, is examined and exposed to regular watering or drought through a greenhouse experiment.

Species Description: *Syzygium cumini*

*S. cumini* is a large tree (approximately 60 feet tall) with pale bark, ovate, opposite aromatic leaves, red/pink/orange young leaves and petioles, small clustered white flowers, and small glossy, purple/dark purple/black oval berries with one seed per fruit (Motooka et al. 2003; ISSG 2018). It is native to South Asia, and records indicate that *S. cumini* were cultivated in Hawai‘i by 1871 (Motooka et al. 2003). *S. cumini* was introduced not only in Hawai‘i but across the Pacific for its ornamental features, timber, and fruit and has become invasive on many islands through the dispersal of the seeds by frugivorous birds and even pigs (ISSG 2018). In Hawai‘i, *S. cumini* invades mesic valleys along the stream edges and displaces native species by preventing their reestablishment (Motooka et al. 2003; ISSG 2018). *S. cumini* flourishes along the stream banks, but can also tolerate flooding and even drought (ISSG 2018). The Weed Risk Assessment score of 9 with a “High Risk” classification (PIER 2018) and the ability for *S. cumini* to tolerate not only flooding but also drought, makes *S. cumini* a species of interest for this experiment.

Methods

*S. cumini* fruits were collected from McBryde Garden, Kauai, and the seeds were sown in Dr. Barton’s Botany lab at the University of Hawai‘i at Mānoa (UHM) in November 2017. After the seedlings germinated and developed two true leaves, the seedlings were transplanted into 2-gallon pots with 4 kg of soil and slow-release Osmocote fertilizer in the Pope Greenhouse at UHM (Figure 1). The experimental watering treatments were initiated immediately following seedling transplant such that the “control” treatment plants were watered daily, while the “drought” treatment plants received no water at all for the duration of the experiment. At the conclusion of the nine-week treatment phase, the plant shoots (stems and leaves) were harvested at the soil interface where the shoot and root intersect.

In the lab, the base of the main stem closest to the cut was cut into thin, circular cross sections with a razor blade dipped in water. The cross sections were placed in one drop of Toluidine Blue O (TBO) on a microscope slide to stain the plant cells for identification (Figure 2). TBO stains pectin purple/pink and lignin blue/green to differentiated cells by the presence/absence of lignin in the cell secondary walls (O’Brien et al. 1964). The TBO stained stem cross sections were then rinsed with water and mounted on a microscope slide with a drop of water. A thin glass coverslip was then placed on the top of the stained cross section to protect the microscope lens and create an even image when viewed under the microscope. The stained stem cross sections were then observed and photographed for their internal structures.
through the compound microscope at a magnification of 10x and 40x.

Additional stem cross sections were cut from extra *S. cumini* that were not included in the experimental treatment groups but germinated from the same batch of seeds and were regularly watered. These cross sections were stained with one drop of potassium iodide solution (IKI or Lugol’s iodine) to identify the contents of the pith cells. IKI stains amylose starch blue and amylpectin starch red/purple in the starch storage compartments of the plant cells or amyloplasts (Whelan 1958; Zobel 1988). The IKI stained stem cross sections were mounted on a microscope slide with a drop of water and a coverslip. The IKI stained starch was viewed through the compound microscope and photographed at 10x and 40x magnification.

**Results**

*S. cumini* control plants that received water daily were visibly larger in leaf number, leaf size, plant height, stem thickness, and overall plant size, compared to the drought plants that did not receive any water for nine weeks. In terms of the cellular organization of the TBO stained piths, regularly watered *S. cumini* stem cross sections had circularly shaped piths with green and blue lignified pith cells (Figure 3), while the plants exposed to drought had piths that were elongated and pinched with pink and purple non-lignified pith cells (Figure 4). The TBO stained individual pith cells of the regularly watered plants were fully expanded with clearly defined cell walls and contained multiple amyloplasts with starch (Figure 5), while the pith cells of the plants exposed to the drought treatment were shriveled with indistinct cell walls, lightly stained, and lacking in starch (Figure 6). The IKI stain dyed the starch purple at the center of the stem in the pith with surrounding bands of starch and inside the multiple amyloplasts within each pith cell (Figure 7).

**Discussion**

Despite evidence that drought influenced the internal anatomy of the *S. cumini* plants, this species demonstrated amazing drought tolerance with no mortality, and only slight wilting, and maintained slower growth during a nine-week drought with no watering. Water stress induced by the drought treatment appeared to lead to a decrease in plant growth and turgor pressure or fluid pressure throughout the plant that was evident through the smaller and slightly wilted plants (Beauzamy et al. 2014). The effects of water stress through the decrease in turgor pressure were also apparent in the internal anatomy of the plants.

The plants exposed to drought and water stress exhibited elongated and pinched piths compared to the circular shaped piths of the regularly watered plants. Furthermore, the piths of the water stressed plants stained pink and purple with TBO that indicates a lack of lignin in the plant cell walls, while the regularly watered plants stained green and blue, which indicates the presence of lignin (O’brien et al. 1964). The low number of lignified pith cells that conduct water and structurally support the plant provides additional evidence of the decrease in turgor pressure in the water stressed plants (Chabannes et al. 2001). The elongated and pinched piths that were not lignified indicated a lower turgor pressure internally that translated to the wilted external stature of the water stressed plants.

Exposure to the drought treatment also caused individual pith cells to appear wrinkled with indistinct cell walls, lack
The light color intensity from the TBO stain may be attributed to pith cell autolysis or cell death by their enzymes that form air pockets within the pith cells (Knipfer et al. 2017). The pith cells filled with air instead of water do not allow the TBO stain to become effectively absorbed by the cell, resulting in a lack of color. The low abundance of amyloplasts containing starch indicates that the plants were allocating their energy towards maintaining plant function under drought conditions instead of storing energy in the form of starch (Zobel 1988). On the other hand, the purple color of the starch in the watered plants suggests that most of the starch was amylepectin versus amylose because amylepec-

Conclusion

Drought already negatively impacts plant growth through water stress, and is expected to increase in duration and frequency under climate change. This experiment investigated the effect of drought stress on cellular plant anatomy of S. cumini...
stem cross sections and found that the majority of plants exposed to drought had pinched, non-lignified piths, shriveled pith cells filled with air, faint stain absorbance, and low starch abundance. Although the drought tolerance of _S. cumini_ was favorable for this experiment, the results of this experiment could indicate the ability of _S. cumini_ to become more invasive even under climate change-induced drought. Even though _S. cumini_ exhibited high drought tolerance, its exceptional performance in drought is not indicative of the performance of other plant species under climate change-induced drought. Therefore, future work should experimentally investigate how other plant species respond to climate change-induced drought, and also incorporate how drought influences the interactions between other plants and herbivores, especially the interactions between native and invasive plant species. I propose a greenhouse experiment that investigates the competitive interactions between the native _Syzygium sandwicensis_ and the non-native _Syzygium cumini_ under climate change-induced drought.

**References**


