Drought Tolerance and Palisade Cell Size

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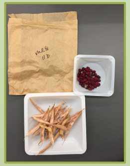
Introduction

A plant's ability to tolerate water stress and maintain yield is due to drought resistance mechanisms which help to minimize water loss. It has been shown that bean lines with varying levels of drought resistance have various sizes of palisade cells (Guha et al., 2010), suggesting a possible drought resistance mechanism that is functionally related to palisade cell size. Larger palisade cells effectively increase the resistance of the pathway water molecules must follow in order to transpire through the stomata but are also prone to deformation during water stress. Smaller palisade cells will be less sensitive to deformation by water loss, but not large enough to significantly affect resistance. **It is predicted that bean lines with mid-sized palisade cells will have the largest seed biomass under water-stressed conditions, and therefore be the most drought resistant, because they are able to maximize resistance to water loss while simultaneously minimizing likelihood of turgor loss**. Drought tolerance in bean plants can be evaluated by comparing palisade cell area to transpiration rates and seed biomass between plants grown in well-watered and water-stressed conditions.

Methods and Materials

Bean Lines: MR81, MR116, BH50, and BAT881 under well-watered and water-stressed conditions.
Palisade Cell Area: To measure palisade cell area, a thin slice of leaf for cross-section analysis was cut from the four bean lines with 3-4 replicates for each line and condition (well-watered and water-stressed) and viewed through a microscope under high magnification to be photographed for analysis. Three palisade cell areas were measured for each replicate using ImageJ and averaged out for analysis.
Transpiration Rate: Rates were collected using a potometer and 4-5 rates were collected for each bean line in ml/s/s.
Seed Biomass: Bean biomass was collected by weighing the beans produced from each plant. Bean biomass (g) was collected from 14-15 plants for each bean line.



Results and Figures

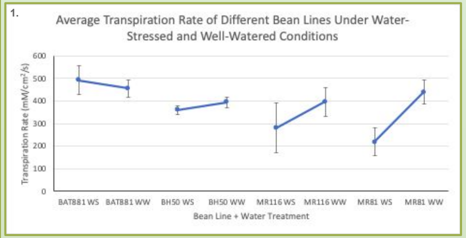
1.


Figure 1. This graph displays transpiration rate of bean lines BAT881, BH50, MR116, and MR81 in well-watered and water-stressed conditions. The blue lines span between each individual bean line, where each point represents the level of transpiration in the differing water treatments. Analysis for differences in average transpiration rate amongst individual bean lines, between both water treatments, resulted in p-values as follows: BAT881 WS & WW = 0.642, BH50 WS & WW = 0.321, MR116 WS & WW = 0.26556, MR81 WS & WW = 9.4E^-07. The error bars represent standard error.

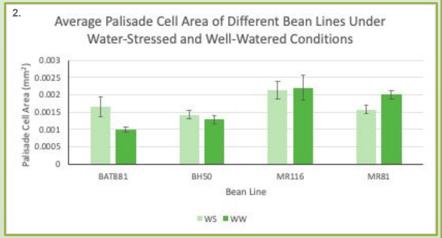
2.


Figure 2. This graph displays average palisade cell area for bean lines under both water treatments. Palisade cell area was averaged over three measurements for each replicate (3-4 replicates per plant per condition). Average palisade areas in mm^2 are as follows: BAT881 - WS = 0.00165, WW = 0.000993, BH50 - WS = 0.00143, WW = 0.00128, MR116 - WS = 0.00214, WW = 0.00221, MR81 - WS = 0.00158, WW = 0.00201. T-test p-values for each bean line between the water conditions: BAT881 WS & WW = 0.148, BH50 WS & WW = 0.367, MR116 WS & WW = 0.883, MR81 WS & WW = 0.0341. The error bars represent standard error.

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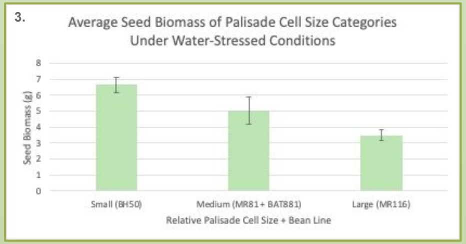

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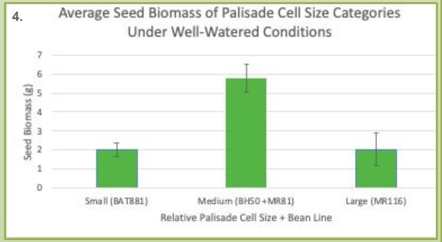

Figures 3 and 4. These graphs display the average seed biomass of the bean lines, as subdivided into categories based on relative palisade cell size. The lines were divided into "small", "medium" and "large" categories based on their relative palisade cell size for a given water condition. The two bean lines with the smallest difference in palisade cell size were placed into the same category for a given water condition. The seed biomass between "small", "medium" and "large" palisade cell bean lines under water-stress was not statistically significant (p = 0.063). However, the seed biomass between "small", "medium" and "large" palisade cell bean lines under well-watered conditions was determined to be statistically significant (p = 0.000921). The general trend for seed biomass under water-stressed conditions was that bean lines with smaller palisade sizes had the greater seed biomass.

Conclusion

Support for Hypothesis: It was originally thought that mid-sized palisade cells would be associated with the greatest amount of seed biomass when grown under water-stressed conditions. This association was only found in the well-watered treatment. The water-stressed mid-sized palisade cells were not associated with an increased biomass. There seemed to be a slight negative association between palisade cell size and seed biomass overall, yet the p-value shows no significance. Only MR81 had a significant difference in transpiration rates between well-watered and water-stressed conditions, meaning that for the majority of the bean lines, transpiration rate was not dependent on water treatment. Furthermore, transpiration rates were not significantly different between palisade cell size categories, and therefore the hypothesis that mid-sized palisade cells confer drought tolerance through decreased transpiration rates and increased seed biomass is not supported by our data.

Limitations: Results may have been skewed due to difficulties identifying the edges of the palisade cells due to varying visual quality of leaf cross-sections. The small sample size of four bean lines most likely contributed to challenges analysing the data regarding palisade cell size, particularly because a larger dataset for palisade cell area would provide a more accurate range of naturally-occurring values.

Future Directions: All four bean lines (BAT881, BH50, MR116, and MR81) in water-stressed conditions produced more seed biomass than in well-watered conditions, suggesting they may be beneficial for agriculture. This difference was statistically significant for MR81. Additional experiments testing other environmental factors which may affect seed growth such as humidity, heat exposure, or the addition of endophytes could also be performed. Sowing drought-resistant lines in the field may be able to provide more food by increasing bean yield while decreasing the amount of water which is required. As parts of the world continue to become warmer and dryer, the conservation of water is more critical than ever.

References

Guha, A., Sengupta, D., Rasineni, G. K., & Reddy, A. R. (2010). An integrated diagnostic approach to understand drought tolerance in mulberry (Morus indica L.). *Flora - Morphology, Distribution, Functional Ecology of Plants, 205*(2), 144-151. doi:10.1016/j.flora.2009.01.004a