

HOW AND WHY "LIVING ROCK" CACTI PULL DOWN IN THE SOIL



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INTRODUCTION

Plant roots can be highly specialized and have functions beyond basic anchorage and uptake of water and nutrients. Contractile roots, or roots that shorten longitudinally, are able to pull the shoot deeper into the substrate, where more moderate temperatures and greater soil moisture may occur (Pütz 2002). Features such as external transverse wrinkling and internal compression of vascular tissues can indicate the process of contraction. Although contractile roots have been identified in several plant families, the causes and consequences of root contraction for many arid-land species bear further investigation. "Living rock" cactus, *Ariocarpus fissuratus*, native to Mexico and southwestern United States, is known for the tendency of its shoot to be nearly level with the soil surface (Britton & Rose 1922). Preliminary research indicates that *A. fissuratus* has contractile roots; however, shoot contraction or shoot shrinkage could potentially contribute to its position within the substrate as well.

HYPOTHESES

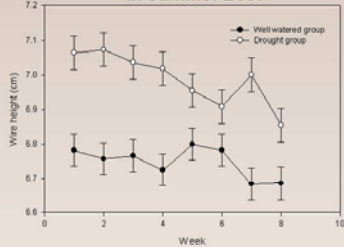
1. Above ground shoot height will decrease over time due to root contraction, shoot contraction and shoot shrinkage.
2. Root contraction plays the primary role in repositioning the shoot.
3. Shoot height will decrease more under water stress.
4. Below ground shoots will experience lower temperatures than shoots exposed to solar radiation.

GROWTH ANALYSIS

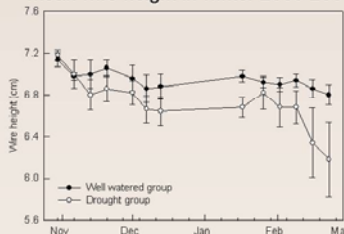
Plants of *A. fissuratus* were purchased from a nursery and grown in a glasshouse at Occidental College. Shoot position and growth data were analyzed using repeated measures two-factor ANOVA.

WIRE HEIGHT DATA

Mean wire height over 8 weeks in summer 2007



Mean wire height in winter 2006-2007



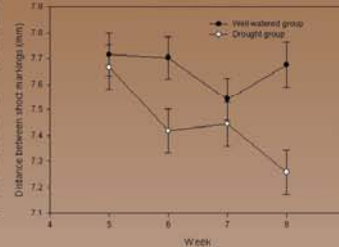
Wires were inserted in the shoot to track relative soil position every week. The well watered group (n = 11; watered weekly) showed no significant difference in wire height (P = 0.445) from the drought group (n = 11; watered every 3 weeks). However, both groups showed a significant decrease over time (P = 0.042). Shoot height decreased by a mean of 1.55 mm or 2.16%.

The well watered treatment (n = 5; watered bi-weekly) showed no significant difference (P = 0.119) from the drought treatment (n = 5; watered bi-monthly). Both groups showed a highly significant decrease over time (P < 0.001).

SHOOT CONTRACTION

Each shoot had two marks placed 4-11 mm apart. No significant difference was found in the distance between shoot markings for the two treatment groups (n = 11; P = 0.780); however, there was a significant decrease over time (P = 0.046). Shoots contracted by a mean of 0.22 mm or 2.35%.

Distance between shoot markings summer 2007



SHOOT SHRINKAGE

Projected surface area over 8 weeks in summer 2007

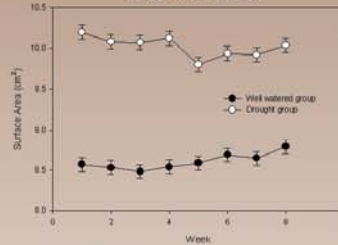
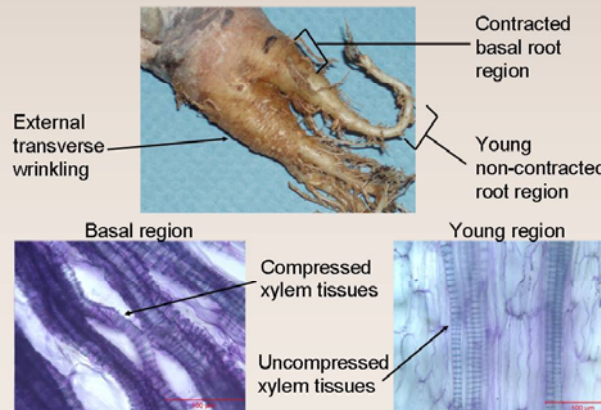


Image analysis of projected surface area and subsequent ANOVA testing showed no significant difference in regards to treatment (n = 11; P = 0.374) or over time (P = 0.283)



ANATOMY

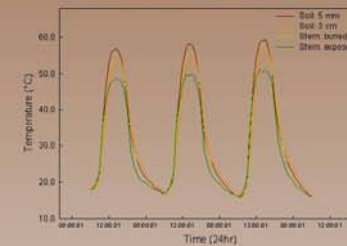
A Vibratome Series 1000 was used to make longitudinal sections of vascular tissue. Tissue was stained with 0.1% toluidine blue and observed with a light microscope at 100-400X. Observations of external transverse wrinkling and compressed xylem tissue indicate the presence of contractile roots in *A. fissuratus*. Every examined individual was observed to have these features.



TEMPERATURE DATA

iButton temperature sensors were inserted in the stem just beneath the photosynthetic tissue in two treatment groups (n = 5). One group was placed in pots with the stem surface level with the soil, while the other was positioned with 2-3 cm of its stem above the soil. Additionally, 3 iButtons were buried 3 cm in the soil and 3 more were placed just beneath the soil surface (~5mm). Temperature was recorded hourly over 8 days; data were analyzed using repeated measures ANOVA.

Soil and stem temperatures for *A. fissuratus* 7/24/07 - 7/26/07



Soil temperature was significantly lower at 3cm than 5 mm (P = 0.025). Buried stems experienced significantly higher temperatures than exposed stems (P = 0.005), but saw no significant difference due to soil treatment.



CONCLUSIONS

The decrease in above ground shoot height is likely due to both root and shoot contraction; however, shoot shrinkage was not found to aid in stem repositioning. Anatomical evidence indicates that roots contract, and shoot height declined significantly over time. Although the data is not definitive, root contraction may be the primary means of stem repositioning. In summer, wire height decreased by 1.55 mm, while shoots contracted by only 0.22 mm. It is likely that root contraction accounted for the remaining majority of stem movement. A quantitative means to analyze root contraction may warrant further investigation. Decreases in shoot height were not found to correlate to water stress. It is likely that the implemented watering regimen did not sufficiently stress these hardy desert succulents, and more drastic drought conditions are needed to induce significant differences. Exposed shoots actually experienced higher temperatures than buried shoots. This phenomenon is likely due to convective heat loss. Additionally, soil temperature data do suggest that lower stem position is advantageous in the form of more moderate temperatures. In future experiments, stem temperatures could be monitored at greater soil depths; in addition, measuring air, soil, and stem temperatures in winter would help elucidate the importance of root contraction.

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