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Abstract

The dominant vegetation types in southern California's coastal foothills are chaparral and costal sage scrub. Chaparral shrubs have mechanically strong evergreen leaves whereas coastal sage scrubs bear mechanical weak, facultative deciduous leaves. What about the ferns that live in the understory of these vegetation types, especially considering their adaptations to a summer dry, Mediterranean-type climate? We tested the hypothesis that some fern leaves are stronger than others and mechanically strong leaves are associated with greater dehydration tolerance. Twelve fern species were examined. Tissue water relations were assessed via pressure volume curves using Scholander-Hammel pressure chambers. We estimated osmotic potential at saturation ($\Psi_{s,sat}$) and at the turgor loss point ($\Psi_{s,tlp}$). We examined pinna strength using an Instron Mechanical Testing Device to measure Young's Modulus (YM) and tensile stress at break (TSB). We also measured vein density to determine if it was associated with mechanical strength.

We found significant differences among our 12 fern species. Young's Modulus was positively correlated with dehydration tolerance of leaf tissues, increasing with osmotic potentials at saturation ($r^2 = 0.514$) and osmotic potentials at the turgor loss point ($r^2 = 0.536$). Consistent with our initial hypothesis, we also found vein density to increase with mechanical strength and Young's Modulus to increase with increasing tensile stress at break. We conclude that similar to species of chaparral shrubs and coastal sage scrubs in California the mechanical strength that increasing mechanical strength of leaves may be associated with increasing dehydration tolerance of their cellular tissues.

Introduction

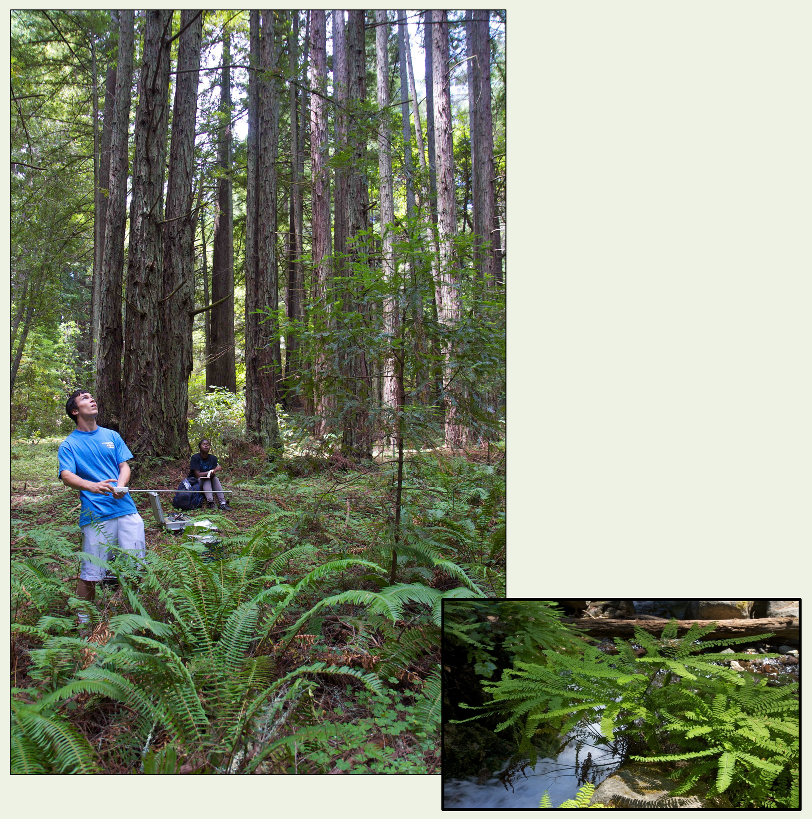
Ferns are an often overlooked group of plants—little data can be found in the literature regarding either water relations or pinna mechanical strength. Because they produce neither lumber nor fruit, industries find little value in these primitive plants. However, evolutionarily and ecologically ferns comprise significant understories in California's plant communities, from redwood forests to evergreen chaparral shrubs (see photos below).

Despite the lack of attention, study of the progenitors of gymnosperms and angiosperms, may provide insight to evolutionary adaptations in a broad context. Not only are ferns a good model, they can also be a natural warning system in changes in the environment. As temperatures increase due to global warming, less water will be available for plants and those that rely more heavily on rainfall are at risk of disappearing.

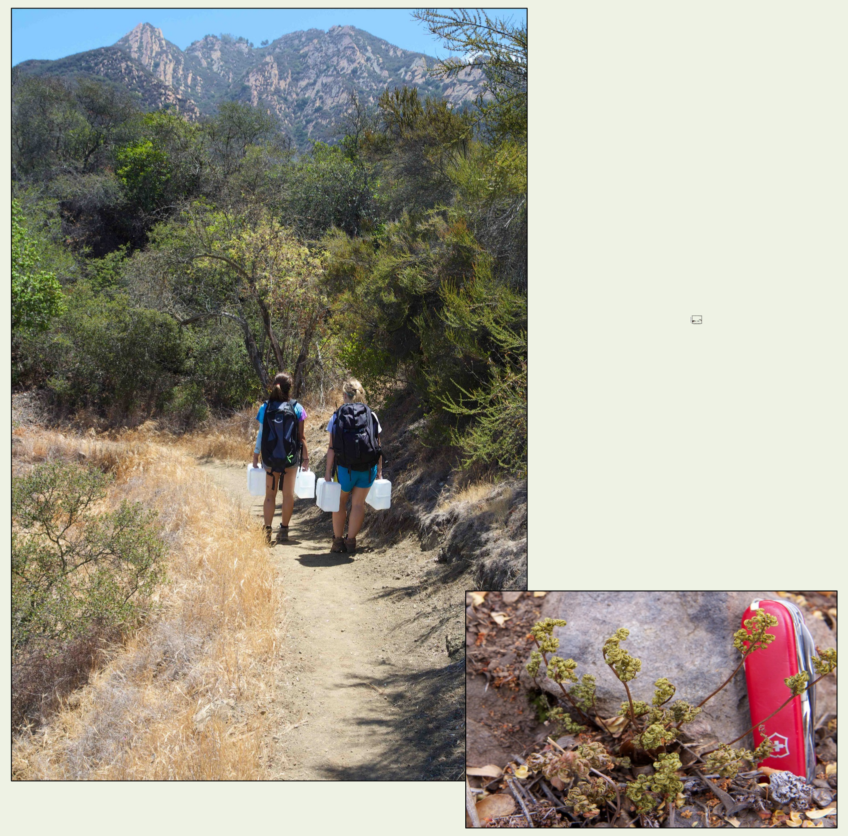
California Fern Species Collected

NorCal Species	SoCal Species
Adiantum aleuticum (Aa)	*Adiantum capillus-veneris* (Ac)
Athyrium filix-femina (Af)	*Adiantum jordanii* (Aj)
Polypodium glycyrrhiza (Pg)	*Pellae andromedifolia* (Pa)
Polystichum munitum (Pm)	*Polypodium californicum* (Pc)
Dryopteris arguta (Da, Dn, Ds)	*Pentagramma triangularis* (Pt)
Pteridium aquilinum (Pq, Pn, Ps)	*Woodwardia fimbriata* (Wf)

Description of Study Sites



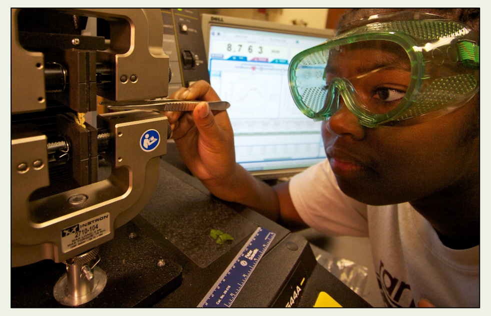
Picture 1. Even during midsummer, conditions remained favorable to ferns in the redwood forest undergrowth. *A. aleuticum* thrives in moist environments, a site that is common at Henry Cowell Redwood State Park in Santa Cruz, California



Picture 2. *P. triangularis* can survive in drier chaparral shrub communities; however, at a certain dehydration level, ~ -3 MPa, the plant curls its leaves and goes dormant except of its underground stem (rhizome). In the Santa Monica Mountains in Southern California, the ferns had already begun leaf curl by early June.

Materials and Methods

Six fern species from Santa Cruz (Picture 1) and eight from the Santa Monica Mountains (Picture 2) were examined. One frond from twelve individuals of each species was cut at the base of the stipe and stored in an airtight plastic bag with wet paper towels to maintain moisture and transferred to the lab for measurements.



Two pinnae from each frond were excised and immediately placed into the Instron Mechanical Testing Device (Model 5544A, Norwood, MA) and the Young's Modulus of Elasticity and tensile stress at break was calculated using standard software. ImageJ (NIH-Image software) analysis was used to determine the vein density of each species as well.

Pressure-volume curves were created by cutting the end of the frond underwater and allowing it to rehydrate for a couple of hours. A series of readings on a Scholander-Hammel pressure chamber and weightings with an analytical balance after each measurement estimated the turgor loss point and Bulk's modulus of elasticity. This method follows the one given in Saruwatari and Davis (1989).

Twelve individuals were randomly chosen to represent the population and readings of the microenvironment were based on them. Readings from a Sunfleck ceptometer (Model LP-80, Pullman, WA) in the four cardinal directions measured photosynthetically active radiation (PAR) that each experimental plant received at the time of sampling. A soil moisture probe (Model CD-620, Campbell Scientific, Logan UT) was also inserted into the ground at four points, estimating the water content in the soil. A Kestrel weather meter was used to find, wind velocity, air temperature, relative humidity, and dew point .

Results

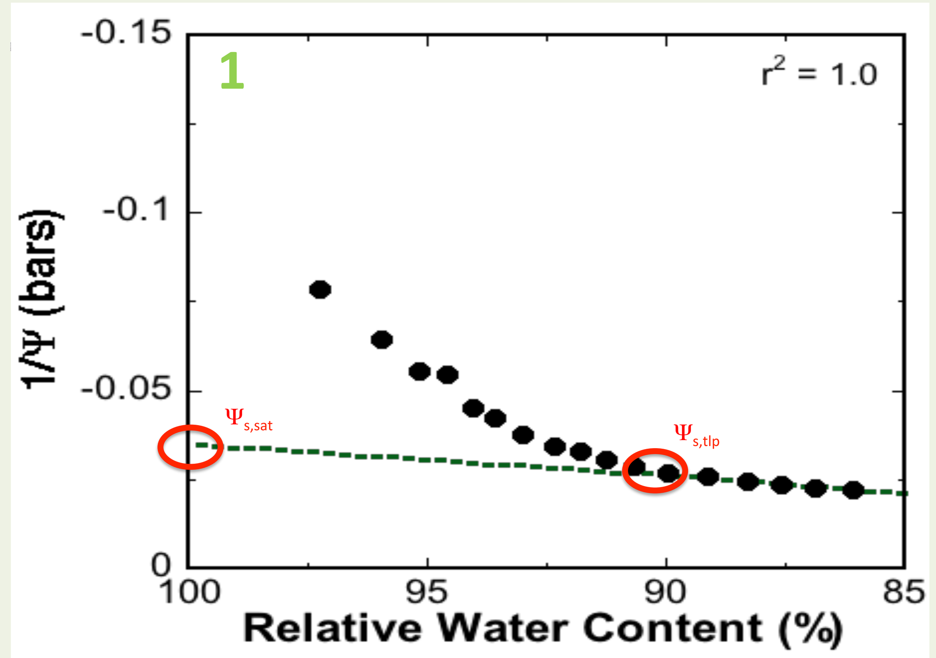


Figure 1. Example of a pressure-volume curve for *D. arguta.* From this graph the osmotic potential at the turgor loss point and saturation can be calculated.

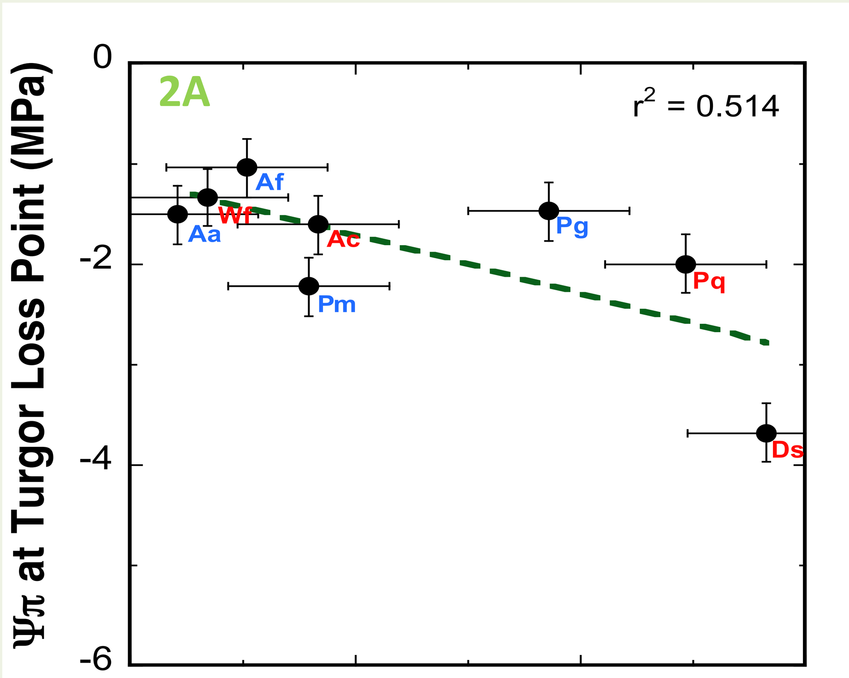


Figure 2A. Correlation between biomechanical pinna strength and osmotic potential at the turgor loss point.

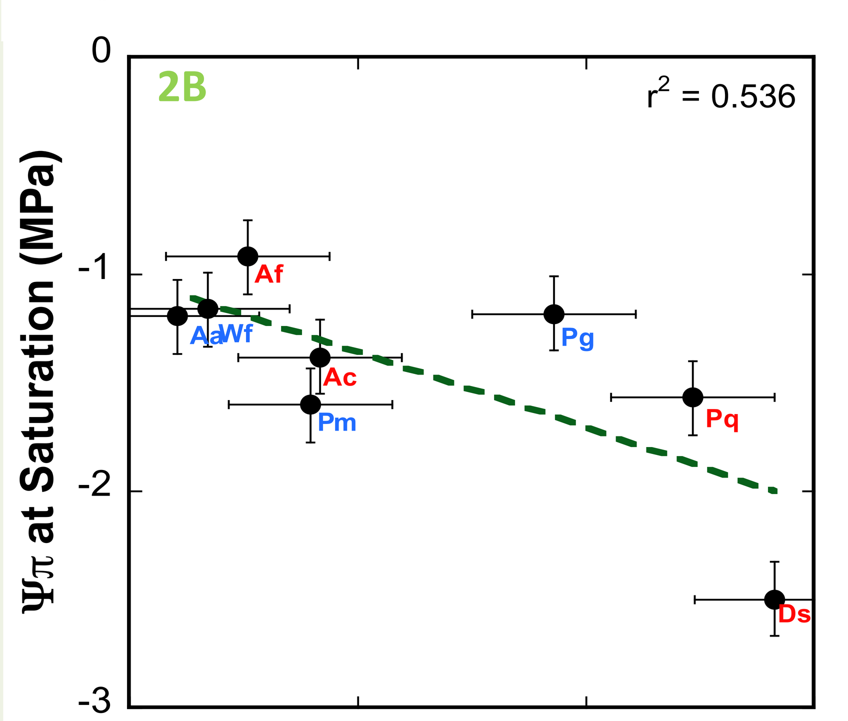


Figure 2B. Correlation between biomechanical pinna strength and osmotic potential at the saturation.

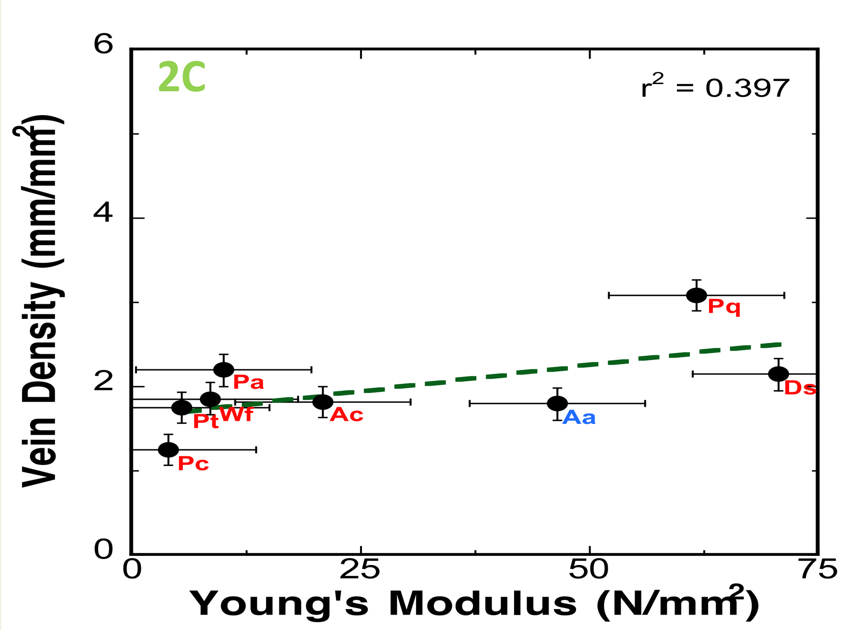
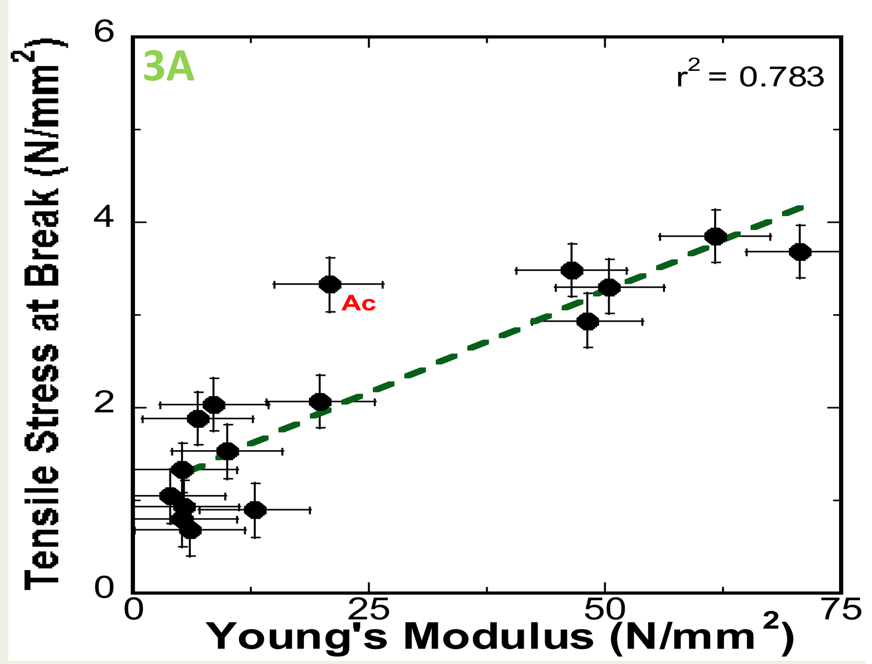
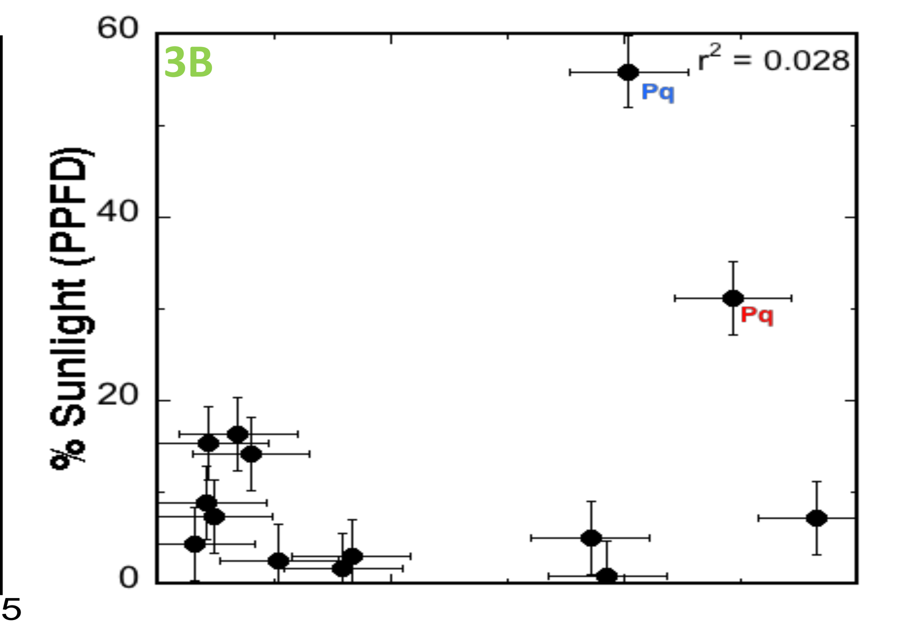


Figure 2C. Correlation between biomechanical pinna strength and vein density.

Microclimate





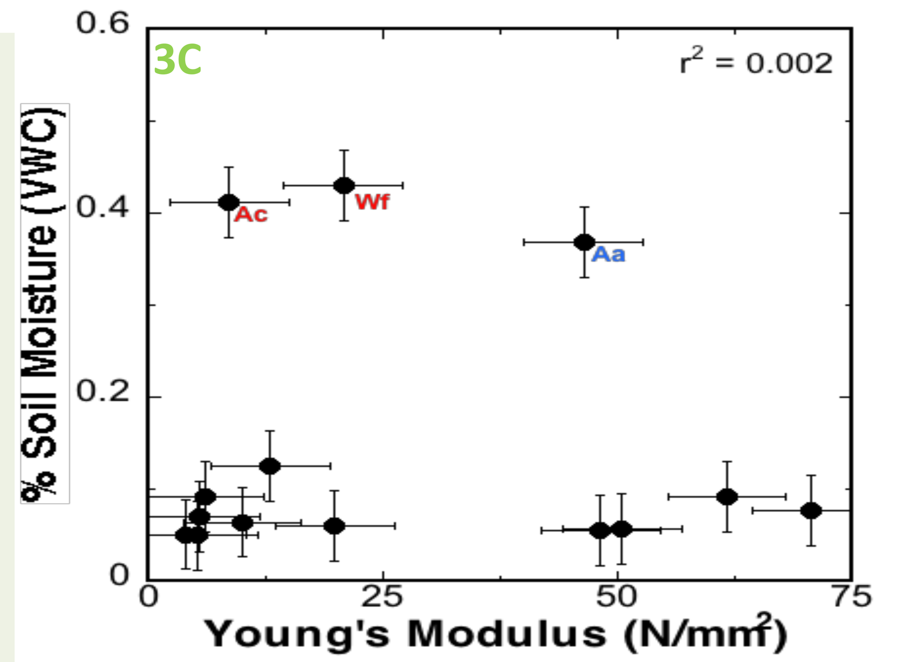


Figure 3A. Correlation between Young's Modulus and tensile stress at break.

Figure 3B. Lack of correlation between Young's Modulus and percent sunlight.

Figure 3C. Lack of correlation between Young's Modulus and percent soil moisture.

Discussion and Conclusions

The results support my initial hypothesis that pinna of fern species found in xeric conditions are mechanically stronger than those in mesic environments.

- Tissue dehydration-tolerance based on osmotic potentials at saturation and turgor loss point correspond to greater mechanical strength.
- Greater vein density corresponds to greater mechanical strength.
- Microenvironmental factors measured at each fern's habitat at time of sampling did not correlated with mechanical strength.

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