Summer 2013

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Recommended Citation

Gillespie, Breahna, "Leaf Mechanical Strength Corresponds to Water Relations in Twelve Species of California Ferns" (2013). Pepperdine University, *Featured Research.* Paper 56.
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Leaf Mechanical Strength Corresponds to Water Relations in Twelve Species of California Ferns

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Abstract

In angiosperms and gymnosperms, mechanically strong leaves are positively correlated with dehydration-tolerance. In general, leaves that are stronger mechanically tend to be evergreen while those that are not are usually mechanically weak and deciduous in response to water stress. Avoiding water stress, especially in a chaparral Mediterranean-type climate, which receives less than 500 mm of water per year, requires energy-intensive adaptation. Ferns residing in the chaparral are presumed to adopt a similar strategy: either they maintain or abscise their pinnae in drought. It was reasoned that ferns with lower water potential and able to survive in drier conditions should be mechanically stronger than those in a mesic environment. Twelve species were collected from mesic and xeric regions in California. Tissue water relations, assessed by pressure-volume curves, were compared with pinna strength and vein density to identify adaptation to water stress. We hypothesize that dehydration-tolerance is positively correlated with mechanical strength as seen in angiosperms and gymnosperms.

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. Ecologically, they are found in a variety of habitats.

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 Site

Picture 1. Even during midsummer, conditions remained favorable to ferns in the red wood 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 conditions; however, at a certain dehydration level, the plant is forced to drop its leaves and die back to the underground stem (rhizome). In the Santa Monica Mountains in Southern California, the ferns had already begun to curl by early June.

Materials and Methods

Six fern species from Santa Cruz (**Picture 1**) and eight were collected from the Santa Monica Mountains (**Picture 2**). One frond from twelve individuals of each species were 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

Water Potentials

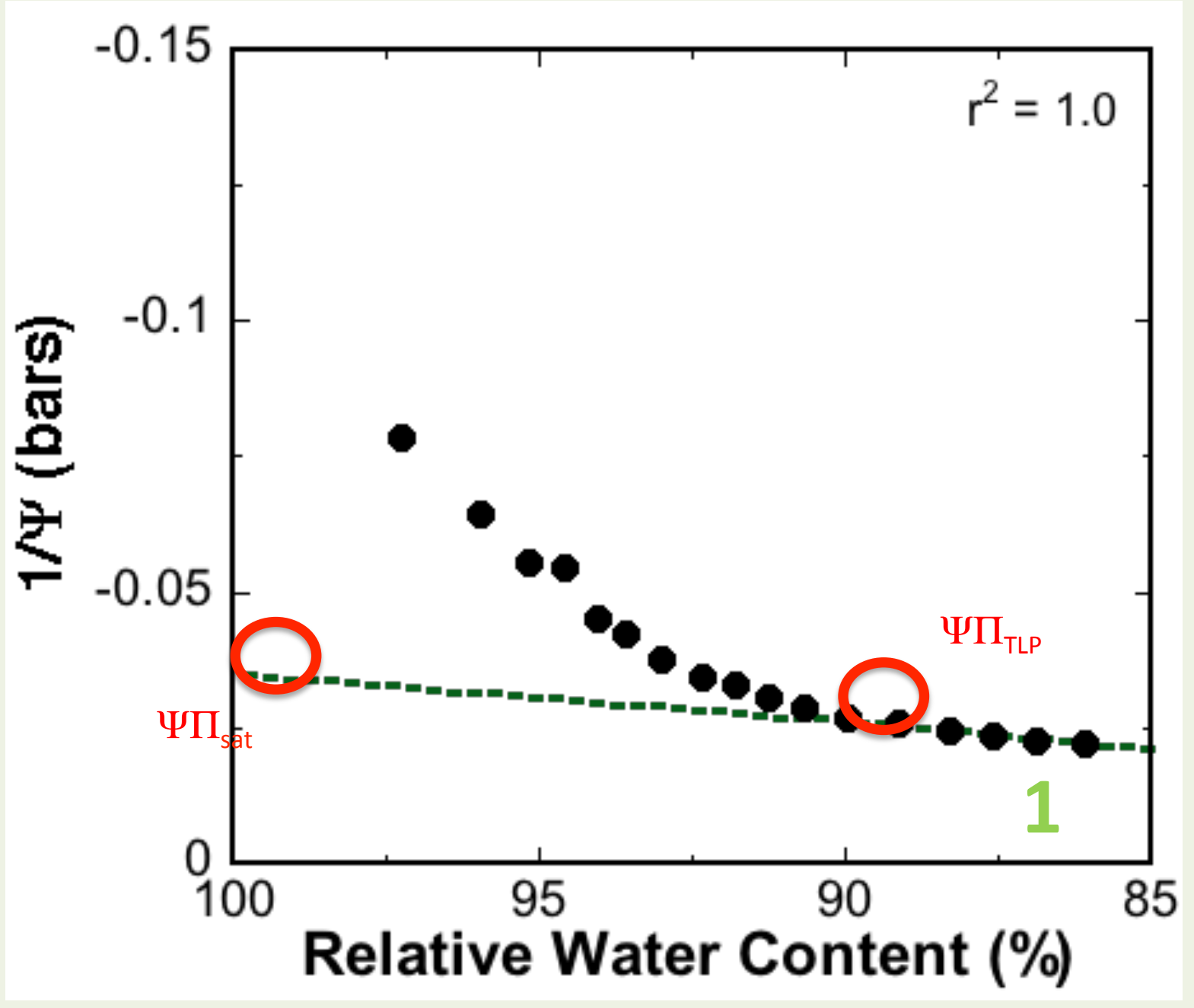


Figure 1. Example of a pressure-volume curve for *D. arguta*. From this graph the osmotic potential at the turgor loss point and saturation can be calculated.

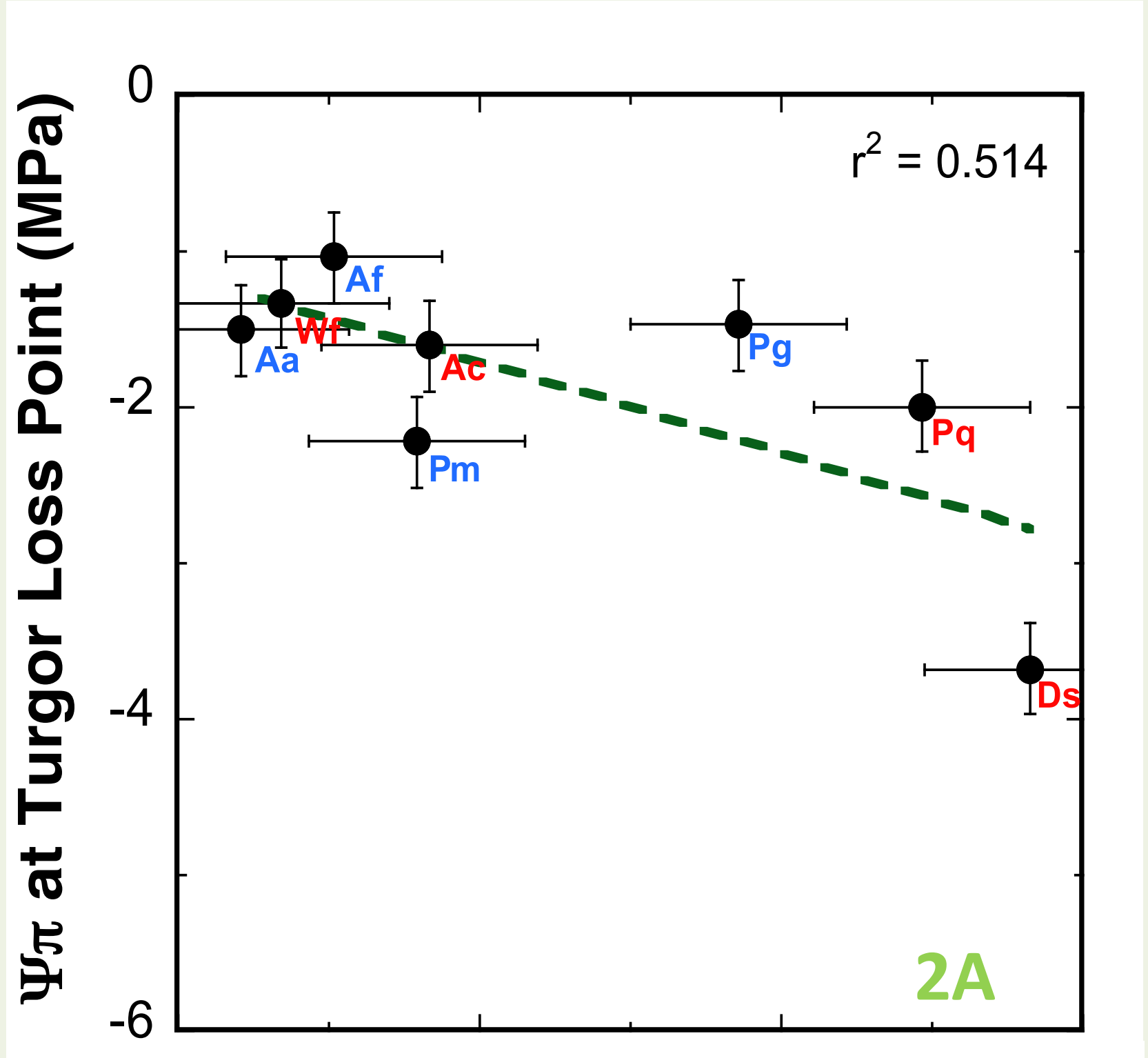


Figure 2A. Correlation between biomechanical pinna strength and osmotic potential at the turgor loss point.

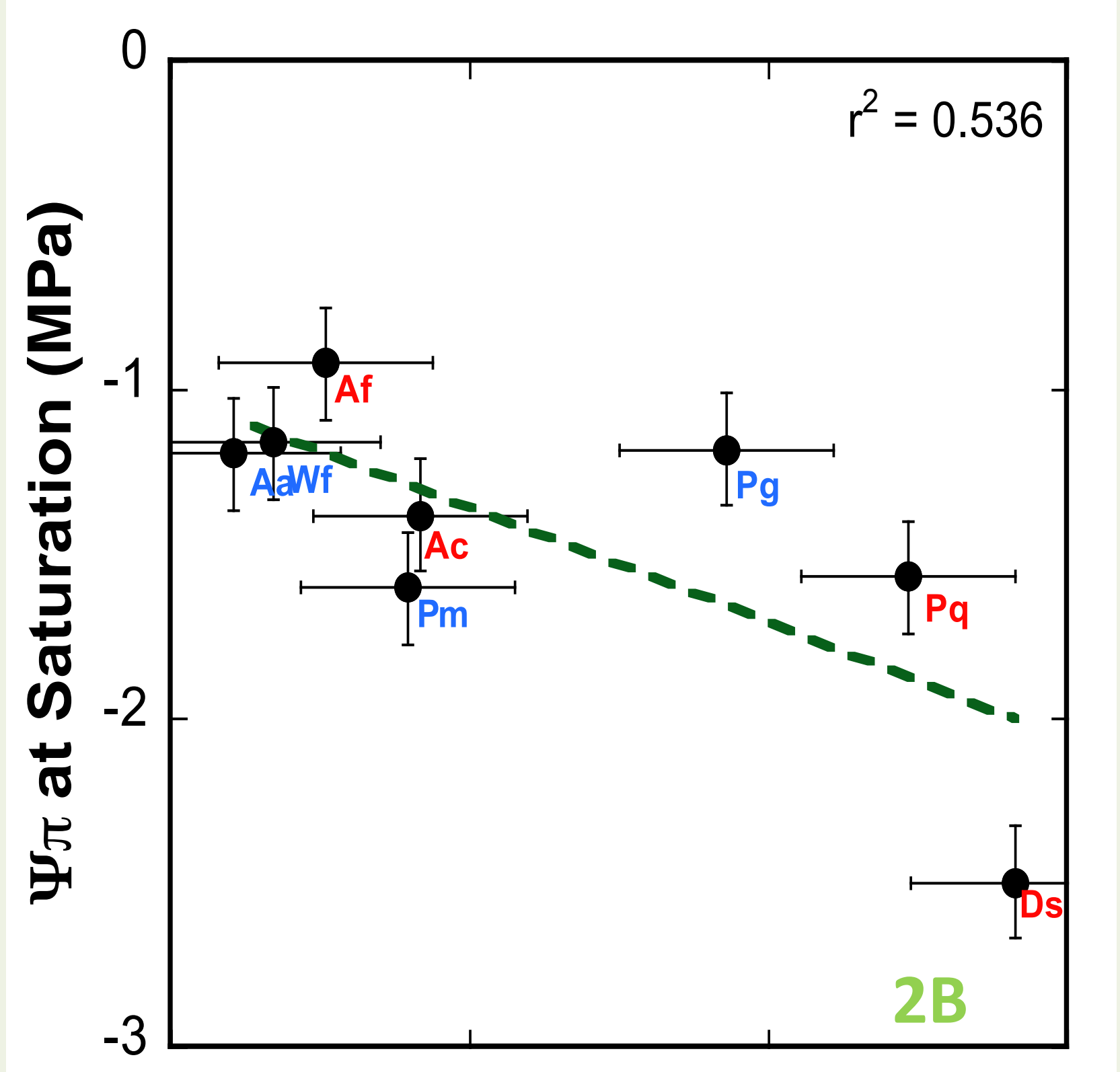


Figure 2B. Correlation between biomechanical pinna strength and osmotic potential at the saturation.

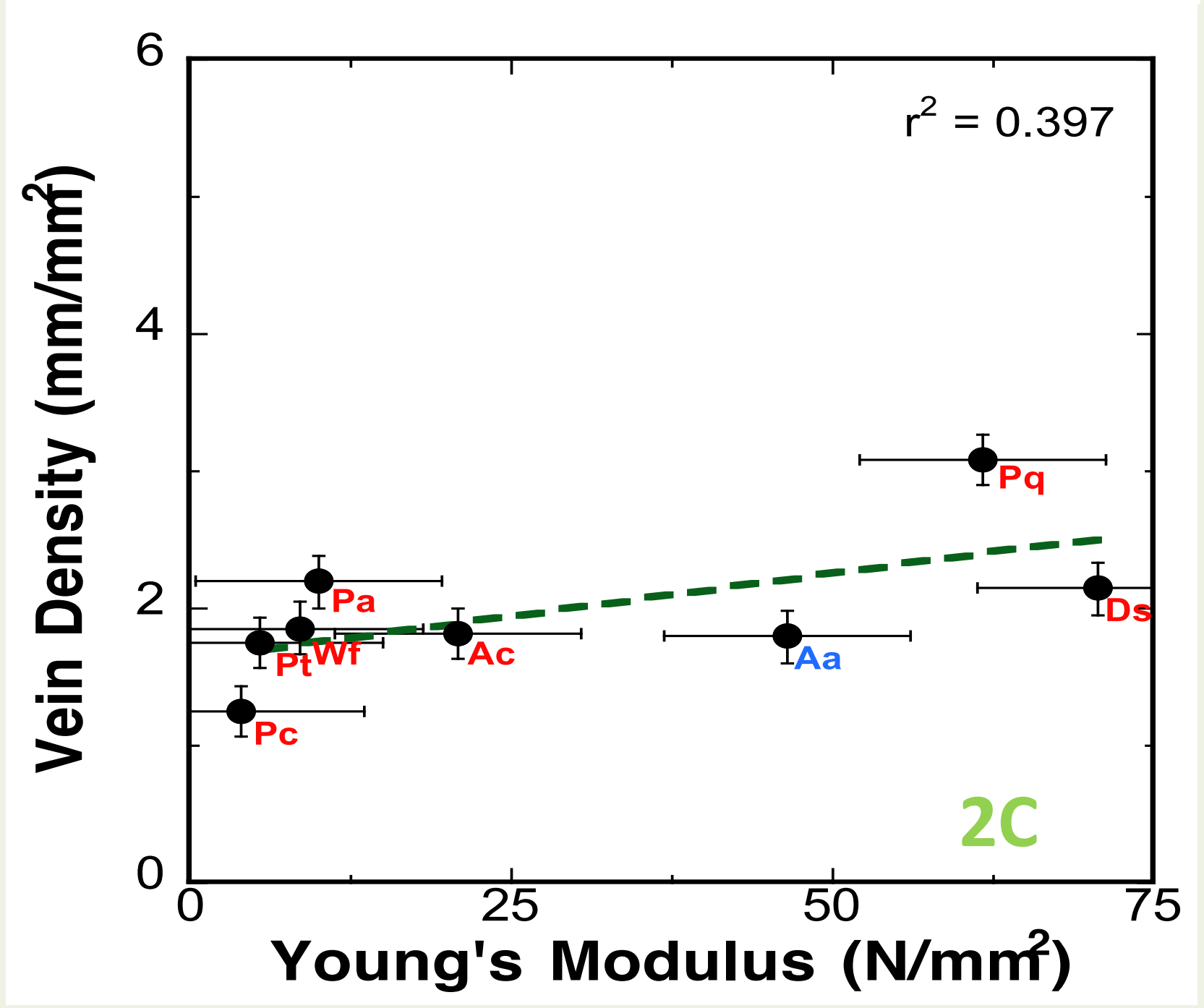
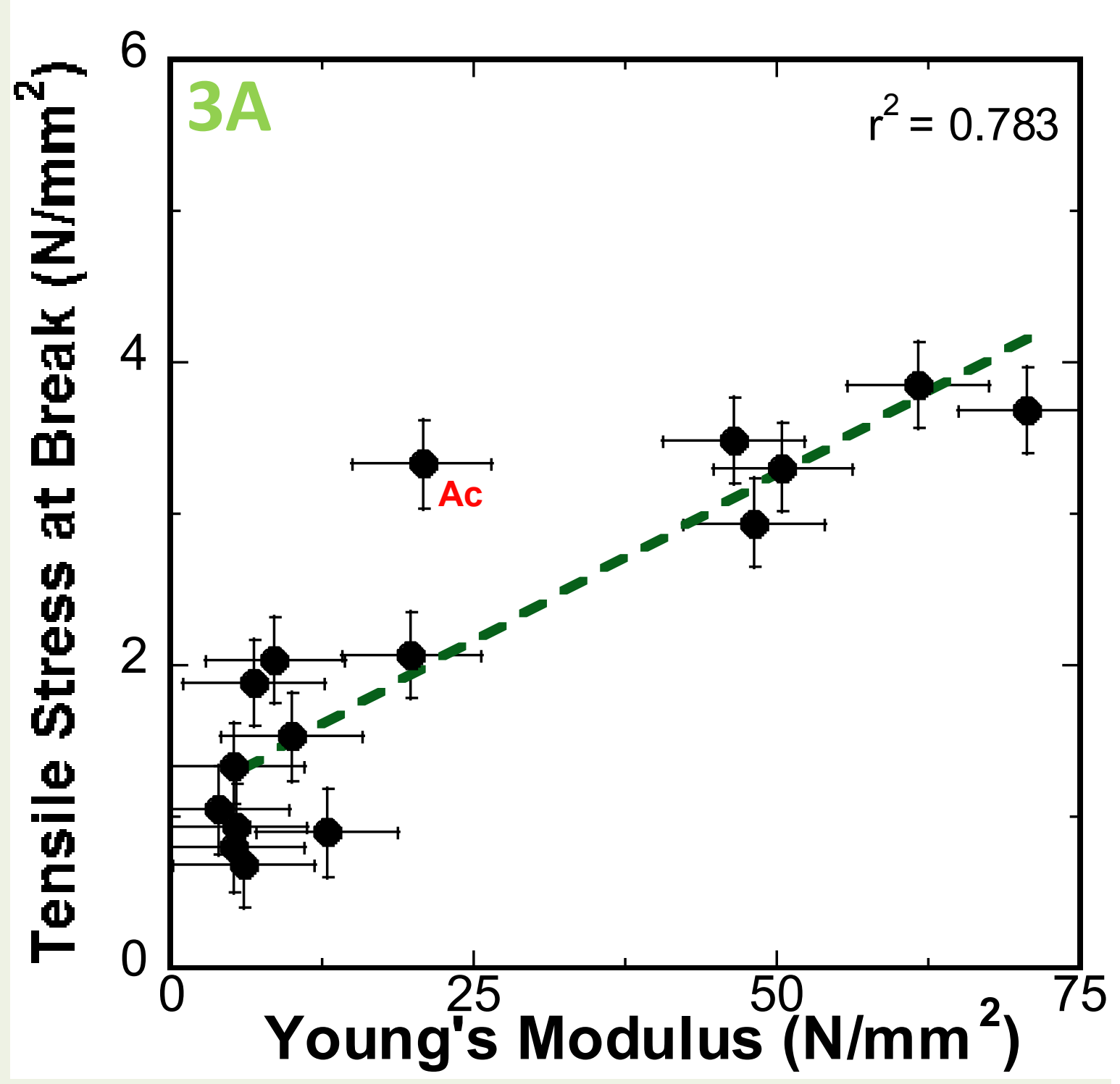
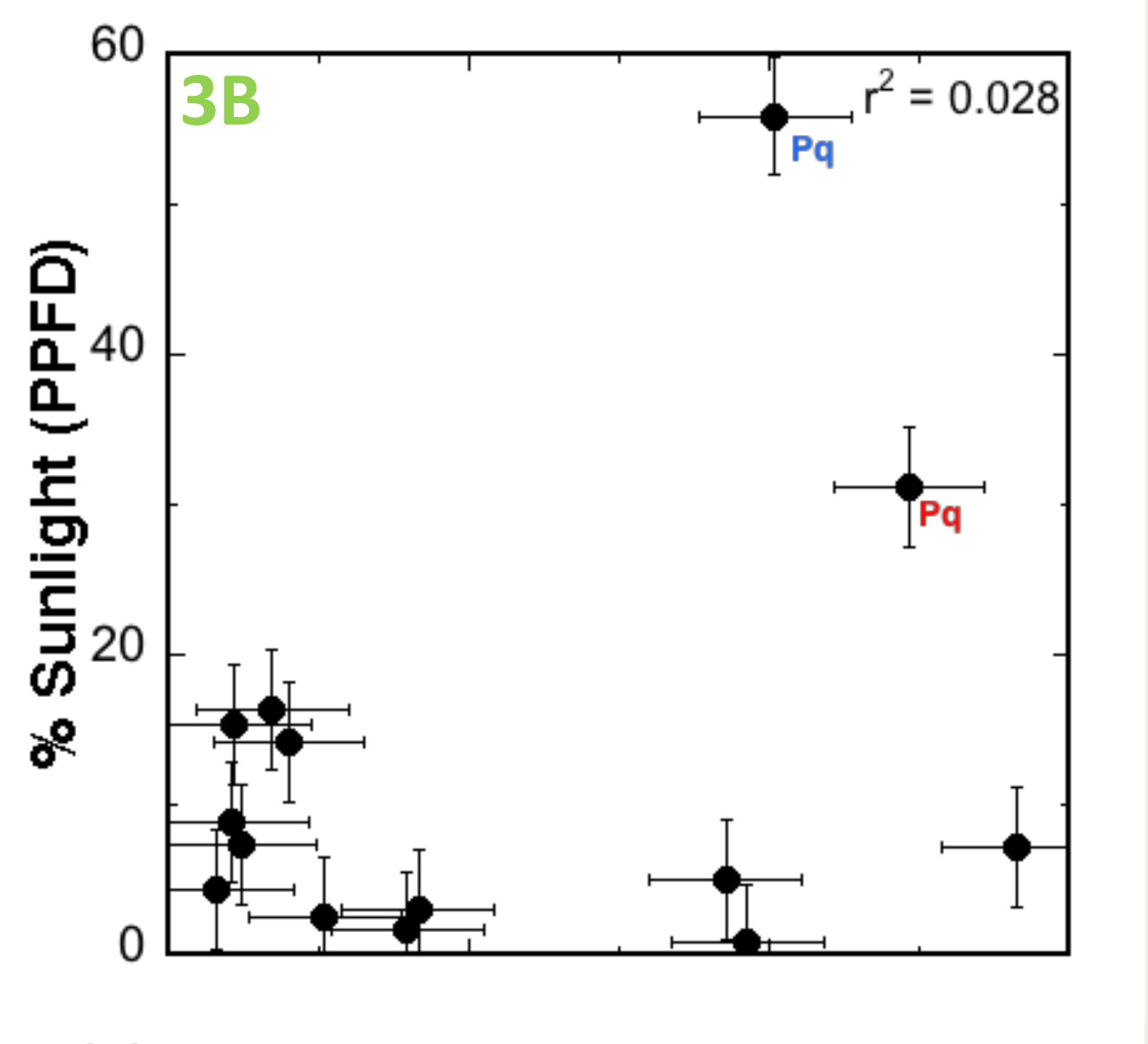


Figure 2C. Correlation between biomechanical pinna strength and vein density.

Microclimate





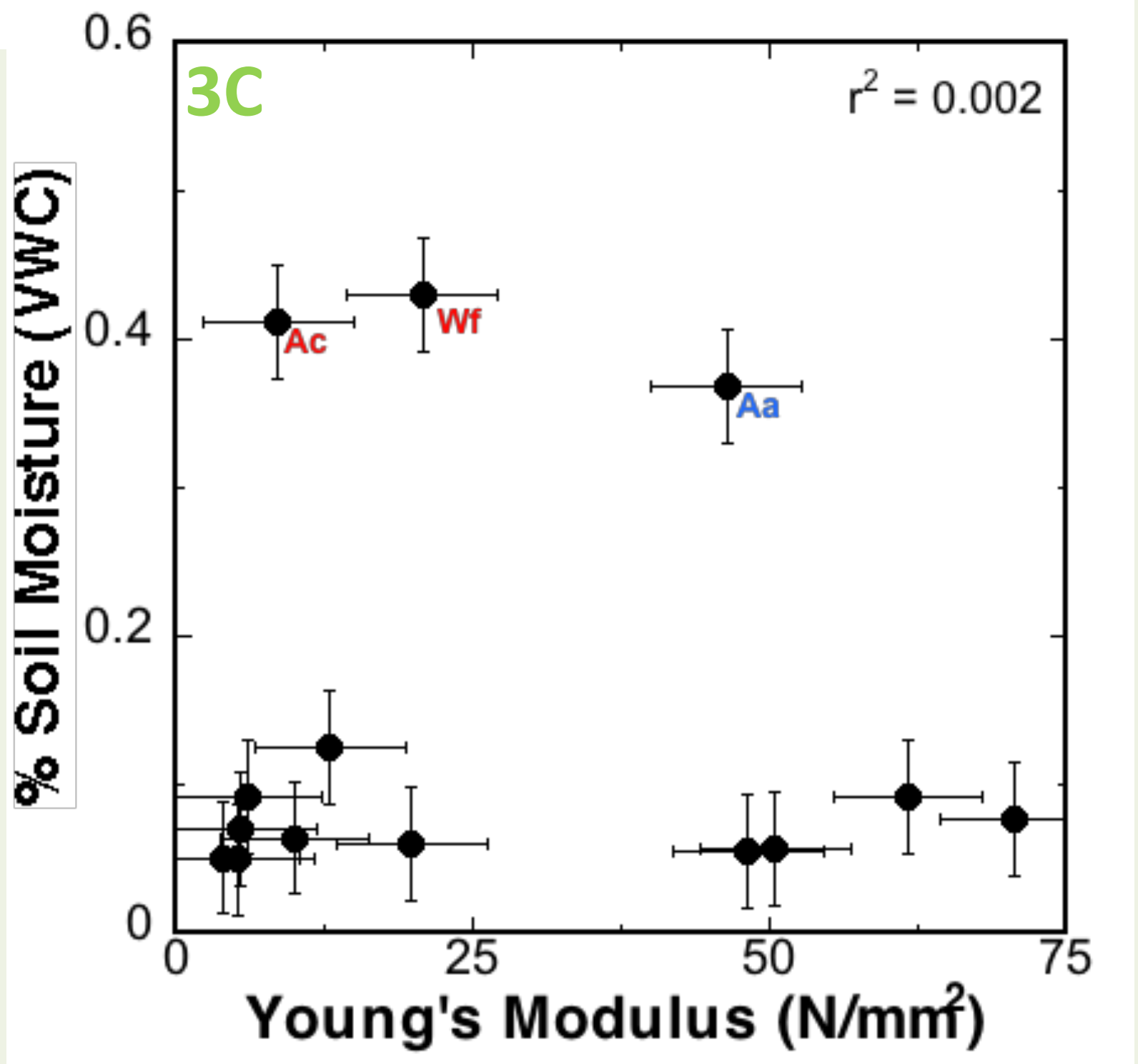


Figure 3A. Correlation between Young's Modulus and tensile stress at break.

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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Acknowledgment

This research was funded by the National Science Foundation, Research Experience for Undergraduates REU-Site Grant #DBI-1062721 and the Natural Science Division of Pepperdine University. Special thanks to Helen Holmlund, Amir Mohmorud, Nathaniel Greundemann, Colyn Byrne and Drs. Jarmila Pitterman, Frank Ewers, Marcia Ewers.