

4-1-2013

Comparative Study of the Mechanical Strength in Two Species of Ferns: *Polystichum munitum* and *Pteridium aquilinum*

Russell P. Baetiong
Pepperdine University

Victoria M. Lekson
Pepperdine University

Olivier B. Monty
Pepperdine University

Follow this and additional works at: <http://digitalcommons.pepperdine.edu/sturesearch>

 Part of the [Plant Biology Commons](#)

Recommended Citation

Baetiong, Russell P.; Lekson, Victoria M.; and Monty, Olivier B., "Comparative Study of the Mechanical Strength in Two Species of Ferns: *Polystichum munitum* and *Pteridium aquilinum*" (2013). Pepperdine University, *All Undergraduate Student Research*. Paper 66. <http://digitalcommons.pepperdine.edu/sturesearch/66>

This Research Poster is brought to you for free and open access by the Undergraduate Student Research at Pepperdine Digital Commons. It has been accepted for inclusion in All Undergraduate Student Research by an authorized administrator of Pepperdine Digital Commons. For more information, please contact Kevin.Miller3@pepperdine.edu.

Abstract

A comparative study of the mechanical strength in two species of ferns, the winter deciduous *Pteridium aquilinum* and the evergreen *Polystichum munitum*, was done. The mechanical strength of the leaf and stipe were used as a means for comparison. Additional data such as specific leaf mass (g/cm^2) were also collected. The first hypothesis was that the evergreen fern would have higher leaf mechanical strength, while the second hypothesis was that there would be no difference in the mechanical strength of the stipe. The mechanical strength of the stipe was compared through the Modulus of Elasticity (MOE), while the leaf tensile strength was contrasted through the Modulus (Automatic) – both quantities having been determined with the Instron. The former comparison yielded a P-value of 0.1299 ($P > 0.05$) for an unpaired t-test for equal variance, and the latter yielded $P < 0.01$ for an unpaired t-test for unequal variances. There was thus no statistically significant evidence to reject our first hypothesis. Although the second comparison gave strong statistically significant difference, the direction of such difference was opposite to what had been predicted by our hypothesis. The deciduous leaf was found to have higher tensile strength than the evergreen one. This is contradictory to expectations and forces one to consider further studies to first confirm the discovery before possibly offering a rationale for the phenomenon.

Introduction

Originating in the Devonian, ferns are the second most diverse lineage next to angiosperms, comprising at least 10,000 species (Taylor et al., 2010; Wilson and Knoll, 2009). In fact, this family of plants exhibits remarkable habitat and morphological diversity, which explains its relative omnipresence. Furthermore, ferns have shown unparalleled resilience in the fierce competition for survival offered by the woody conifers and angiosperms. The latter have the advantage of height – and hence sunlight availability – and have deeper roots for the easier tapping of the water supply. Yet, ferns thrive and, as mentioned above, show impressive diversity. It would thus be most interesting to understand the properties that allow ferns to compete with angiosperms and conifers for resources like water in order to survive and remain abundant. However, as Dr. Jarmila Pittermann from UC Santa Cruz mentions, not only are ferns shallowly understood when compared to angiosperms and conifers, but also are they a mystery as far as their ‘primitive’ vascular system is concerned (Pittermann, 2012). All we know for now is that Pteridophytes strike a balance between mechanical strength, hydraulic efficiency and height above the ground (Wilson and Knoll, 2010). We further know that ferns possess poorly reinforced tracheids for water transport, even less so than conifers. We also know that for about 10X less xylem area than a conifer twig, ferns support nearly equivalent leaf area as the latter (Watkins et al., 2010). This is indicative of high hydraulic efficiency, which is accounted for by the fact that, thanks to their smaller size, ferns are able to avoid sacrificing hydraulic capacity for mechanical strength in their tracheids (Watkins et al., 2010). This is unlike conifers, which have to make such sacrifices in order to support their ascension to greater heights. While studies comparing ferns and woody plants have been performed, little is known about the fern species itself. Intra-species variation in traits is of interest to scientists like Dr. Pittermann. This experiment was actually a contribution to the freshly started work of the latter on ferns. While she proposed to study hydraulic efficiency in ferns, our team decided to research the mechanical properties of that family of plants. Two species, the evergreen *Polystichum munitum* (PN) and the winter deciduous *Pteridium aquilinum* (PA), were investigated in an exploratory study for which no precedent was found to exist. The mechanical strength of the leaves and stipe of the two species was determined and compared, while information about the specific leaf mass and leaf area were also integrated into the investigation.

Works Cited

- Balsamo R.A., Willigen B.V., Bauer A.M., Farrant J. (Jan. 2003) Leaf Biomechanics, morphology, and anatomy of the deciduous mesophyte *Prunus serrulata* (Rosaceae) and the evergreen sclerophyllous shrub *Heteromeles arbutifolia* (Rosaceae). *Am J Bot* 90, 72-77. Doi:10.3732/ajb.90.1.72.
- McCulloh K. Sperry J.S., Lachenbruch B., Meinzer F.C., Reich P.B. and Voecker S. (2010) Moving water well: comparing hydraulic efficiency in twigs and trunks of coniferous, ringporous, and diffuse-porous saplings from temperate and tropical forests. *New Phytologist* 186, 439-450.
- Pittermann, J. (2012) Novel Lessons from Ancient Plants: Water Transport in the Earliest Tracheophytes. NSF Proposal
- Taylor T.N., Taylor E.L., Krings M. (2009) PALEOBOTANY The biology and evolution of fossil plants. Academic Press, Oxford, UK.
- Watkins J.E., Holbrook N.M., Zwieniecki M.A. (2010) Hydraulic properties of fern sporophytes: consequences for ecological and evolutionary diversification. *American Journal of Botany* 97, 2007-2019.
- Wilson J.P, Knoll A.H. (2010) A physiologically explicit morphospace for tracheid-based water transport in modern and extinct plants. *Paleobiology* 36, 335-355.

Results

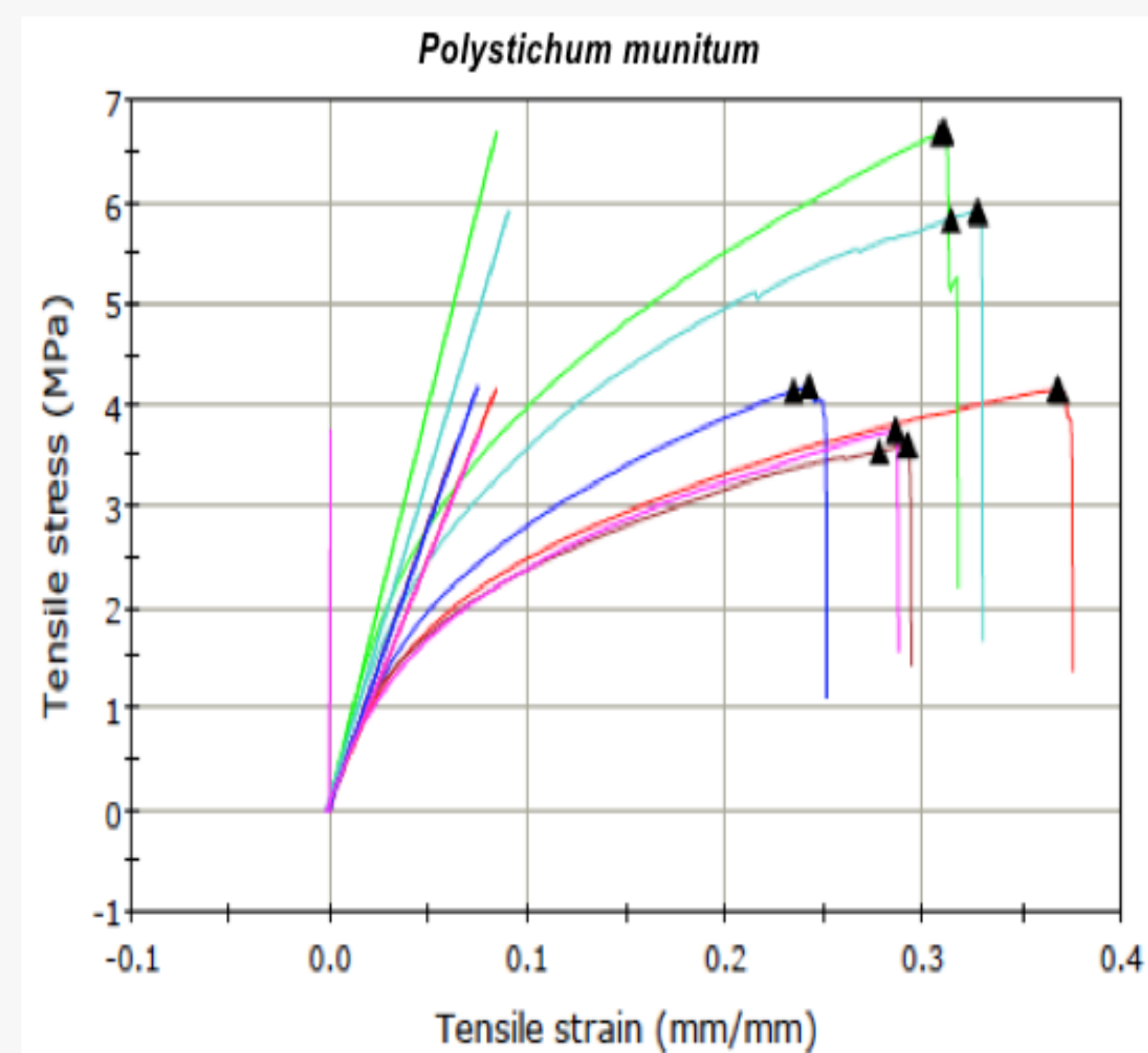


Figure 1. Plot of normalized Tensile stress versus Tensile strain for leaflets plucked from a frond of a plant of the species *Polystichum munitum* (PN). The elastic and plastic phases of deformation are clearly visible before sudden and complete rupture of the leaf.

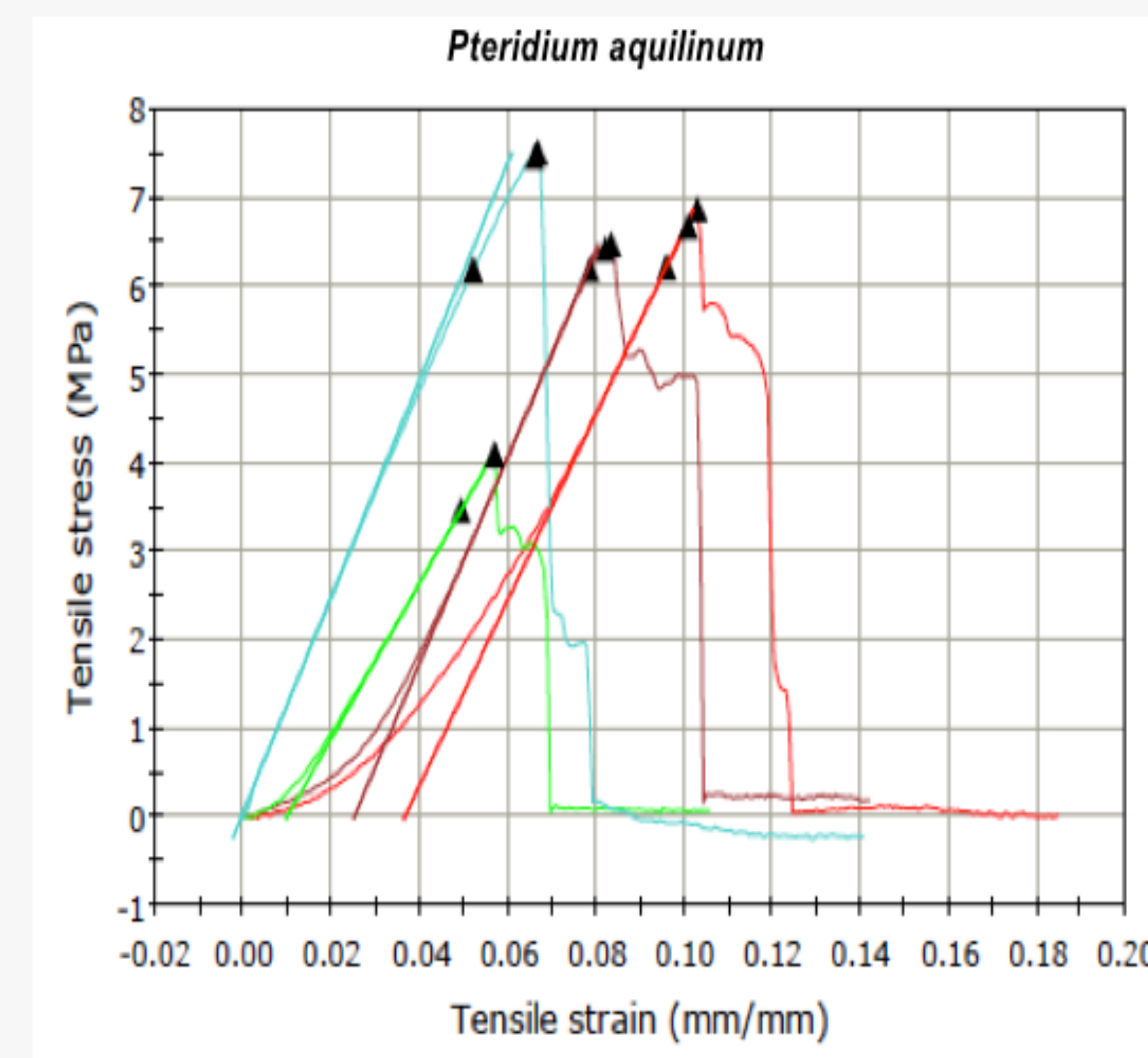


Figure 2. Plot of normalized Tensile stress versus Tensile strain for leaflets plucked from a frond of a plant of the species *Pteridium aquilinum* (PA). Despite an explainable non linear beginning, the elastic phase is visible, before sudden incomplete initial rupture as the plot oscillates before finally dropping to zero at complete rupture.

Comparison of the Mechanical Strength of the Stipe

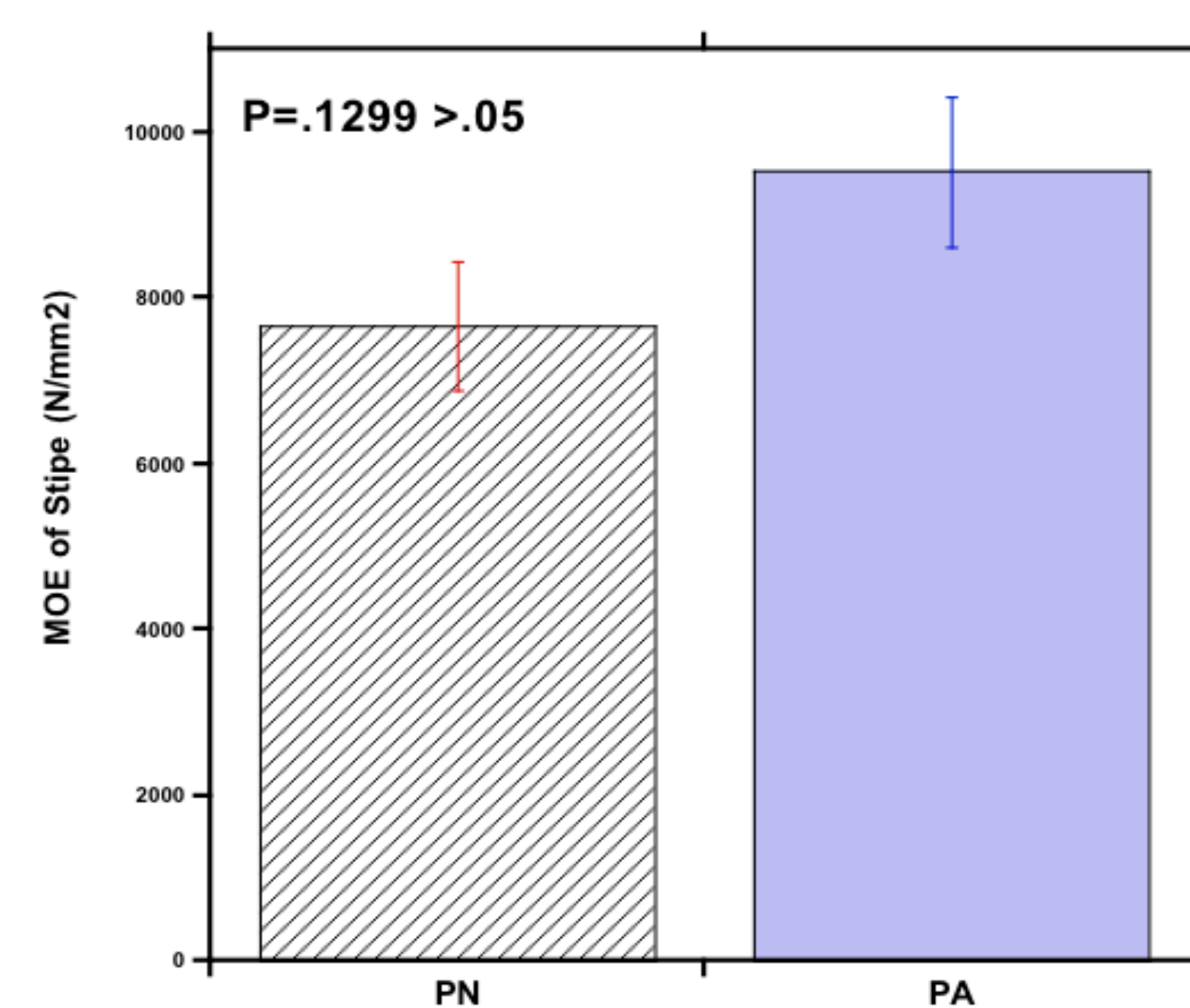


Figure 3. The mean MOE of the stipes of the two fern species, *Polystichum munitum* (PN) and *Pteridium aquilinum* (PA) were compared using an unpaired t-test for equal variances, which gave $P > 0.05$. There was no statistically significant difference.

Comparison of the Leaf Tensile Strength

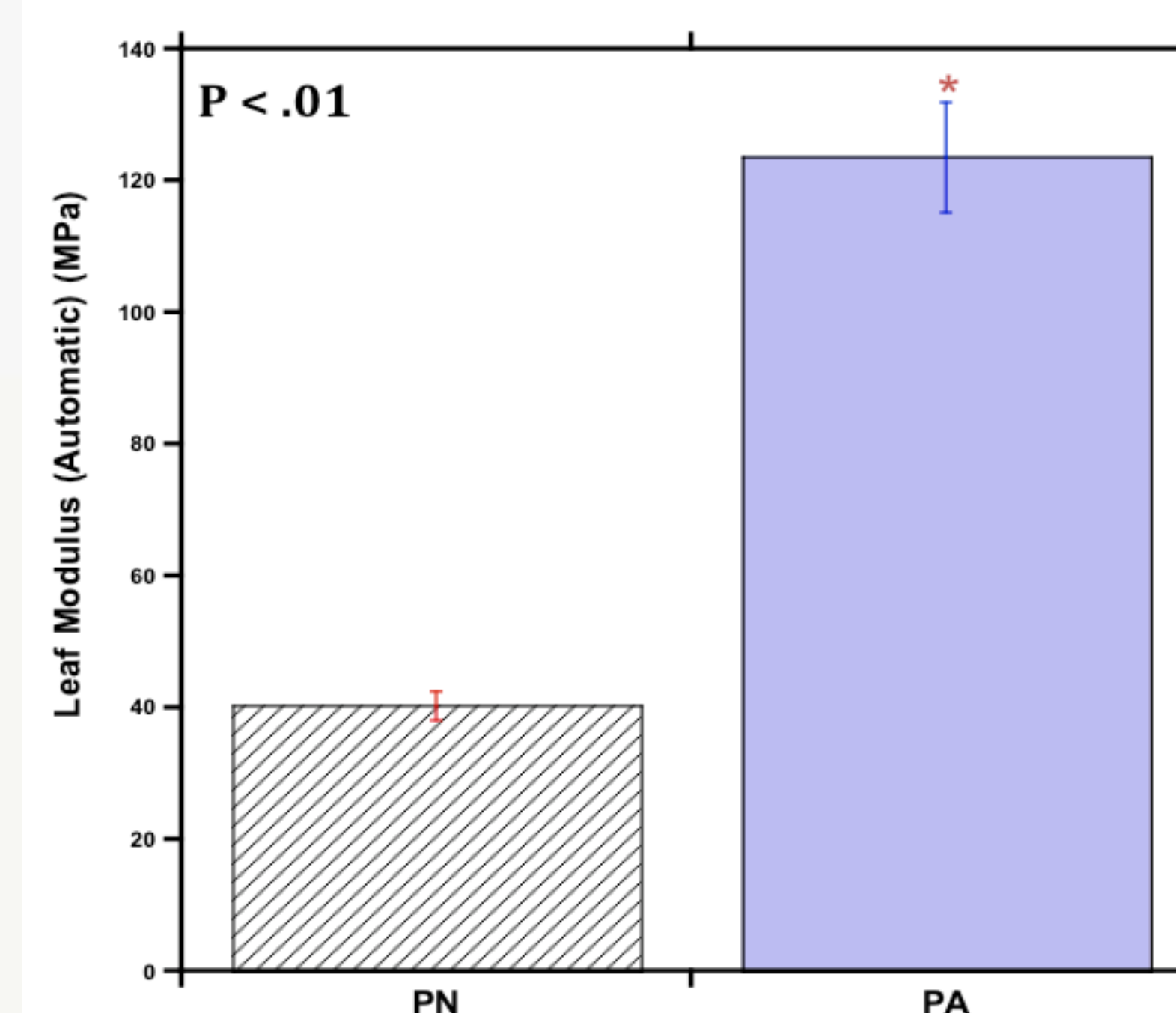


Figure 4. The mean Leaf Modulus (Automatic) for the two fern species, *Polystichum munitum* (PN) and *Pteridium aquilinum* (PA) were compared using an unpaired t-test for unequal variances, which gave $P < 0.01$. There was strong statistically significant difference.

Comparison of Mean Leaf Thickness

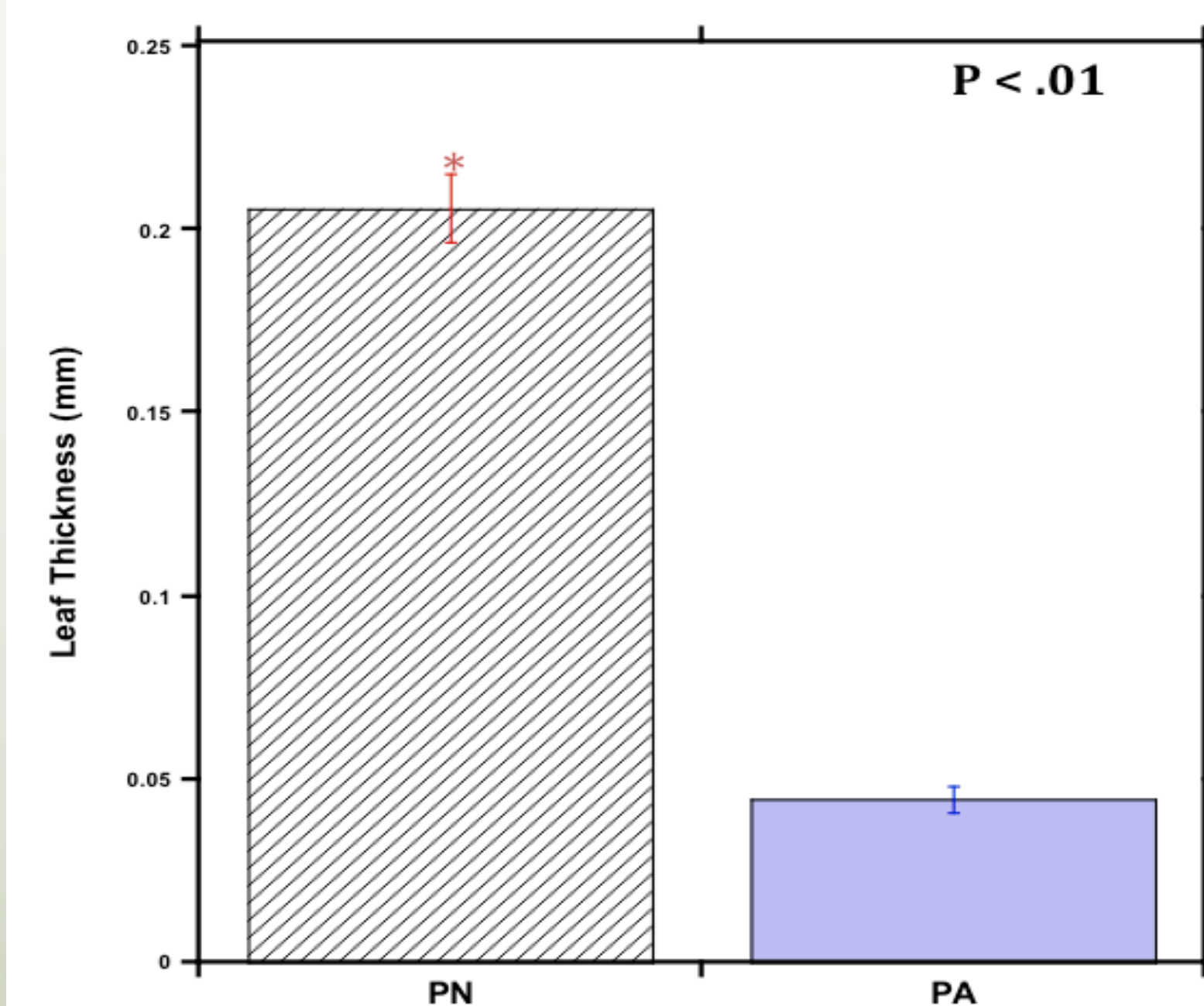


Figure 5. The mean leaf thickness of the two fern species, *Polystichum munitum* (PN) and *Pteridium aquilinum* (PA) were compared using an unpaired t-test for unequal variances, which gave $P < 0.01$. There was strong statistically significant difference.



Figure 6. Left, cross section of *Pteridium aquilinum* stipe. Right, cross section of *Polystichum munitum* stipe.

Discussion

The $P > 0.05$ obtained as shown in Figure 3 is in accordance to the first hypothesis. The rationale behind the latter was that, as Watkins *et al.* report, the mechanical strength of fern stipes resides in the peripheral sclerenchyma fibers (Figure 6) while the poorly reinforced tracheids do not contribute much to the MOE. Assuming that the thickness of the peripheral wall was approximately the same, the strength of the stipe of the two species should be statistically the same. This is indeed what was observed. To verify this proposition, the thickness of the sclerenchyma wall of the stipes of the two species should be compared in a further experiment.

On the other hand, the $P < 0.01$ for the comparison of the leaf tensile strength (Figure 4) is completely contradictory to the prediction of the hypothesis and to the widespread knowledge of the superior tensile strength of evergreen leaves relative to deciduous leaves (Balsamo R.A., Willigen, 2003). An explanation for this might lie in Figures 1 and 2. As seen in Figure 1, *Polystichum munitum* (PN) has both an elastic and a plastic phase before a sudden break (vertical drop). Indeed, during the experimental procedure, a clean break was observed in the leaves of PN at the rupture point. Contrastingly, *Pteridium aquilinum* (PA) showed only an elastic phase before suddenly and incompletely rupturing. This is characteristic of a brittle material. The incomplete rupture gave the oscillations in the curve as shown in Figure 2 beyond the rupture point (black triangle). In fact, during the experimental procedure, fibrous attachments were observed after the rupture point (black triangle) as the leaf ruptured unevenly.

The fibrous material observed after the rupture point might be the explanation for the surprising greater tensile strength of the deciduous leaf of PA. Further support for this proposal comes from the observation that the leaf stretches somewhat when pulled on.

Conclusion

Hence, we agree with Dr. Jarmila Pittermann when she says that not enough is known about ferns. In this experiment, even the widespread knowledge of evergreen leaves having more tensile strength than deciduous leaves has been challenged. The reality of the angiosperm and coniferous worlds do not seem to apply to that of the fern world. Further investigations will be necessary to understand ferns better. A potential further experiment related to this one is to analyze the material that makes the leaves of *Pteridium aquilinum*. This might reveal the identity of the fibrous material observed, assuming it is indeed real.

Acknowledgements

We would like to thank Dr. Stephen Davis for his advice and dedication to mentoring our project. Furthermore, we would like to thank Dr. Jarmila Pittermann of UC Santa Cruz for providing the fern specimens studied.



Victoria (with PA), Russell (with PN), and Olivier with Instron 5544A, which was used to measure mechanical strength.