

10-1-2012

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Recommended Citation

van Loon, Aaron; Manes, Brianna; Stucky, Taylor; and Addington, Thomas, "The Relationship Between Leaf Mechanical Strength and Photosynthetic Rates" (2012). Pepperdine University, *All Undergraduate Student Research*. Paper 45.
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The Relationship Between Leaf Mechanical Strength and Photosynthetic Rates

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Abstract

Photosynthesis is the process by which plants convert light energy to chemical energy, helping sustain life in the biosphere. There are many factors that affect the rate of photosynthesis such as atmospheric CO₂ concentration, temperature, and sunlight. In this experiment, we attempt to determine what effect, if any, the mechanical strength of a plant has on its rate of photosynthesis. To perform this experiment we used both the LI-COR 6400 and the Instron Mechanical Testing Device. With the LI-COR we measured photosynthetic rate of our plant subjects in real time during the prime photosynthetic hours, 10-12am. The Instron allowed us to determine mechanical strength based on Young's Modulus. We hypothesized that as mechanical strength increased the rate of photosynthesis. Our stress vs strain graphs and photosynthesis data actually showed no correlation. However, our results did corroborate previous research that proved that the order of mechanical strength of our species from strongest to weakest was: *Rhamnus ilicifolia*, *Rhamnus californica*, then *Ceanothus spinosus*.

Introduction

A crucial element of plant biology research is determining the key physiological trade-offs that occur in different species of plants that cohabitate the same climate type. Identifying these trade-offs leads to new insights into plant evolutionary processes, adaptability, and survival.

Much research has been done attempting to find correlations and trade-offs between physiological aspects of plants. Examples of this include correlations between mechanical strength and adaptations to temperature stress [3], between photosynthetic rate and adaptations to water stress [2], and between mechanical stress and plant growth and development [4]. However, in recent literature, there seems to be no significant argument for a correlation or trade-off between mechanical strength and photosynthetic rate. Much is known about mechanical strength and photosynthetic rate alone, but they seem to have never been studied in relation to one another in much detail.

Research completed in the summer of 2012 by Pepperdine University student Taylor Stucky shows a strong difference in mechanical strengths according to Young's Modulus of plants in the nearby Mediterranean ecosystem. These were *Rhamnus ilicifolia*, *Rhamnus californica*, and *Ceanothus spinosus*, of which *R. ilicifolia* had the highest mechanical strength, *R. californica* the lowest, and *C. spinosus* the middle [5].

In this research, we compared the photosynthetic rates and mechanical strengths of these three plants, and thereby have drawn tentative conclusions regarding the selective advantage of mechanical strength.

Hypotheses

Species with higher mechanical strength have higher levels of photosynthesis.

Conclusions

- **H:** There is no strong correlation between Young's Modulus and photosynthetic rate
- *R. ilicifolia* has the highest mechanical strength, *R. californica* the lowest, and *C. spinosus* the middle.
- Photosynthetic rates vary greatly within and between species.



Fig. 1. To determine the photosynthesis rate of each species the LI-COR 6400 machine was used. The flow rate was set to 100 $\mu\text{mol m}^{-2} \text{s}^{-1}$, the CO₂ levels to 400ppm, and the temperature in the cuvette to the ambient temperature. Measurements were taken between the hours of 10 am and 12 pm

Methods

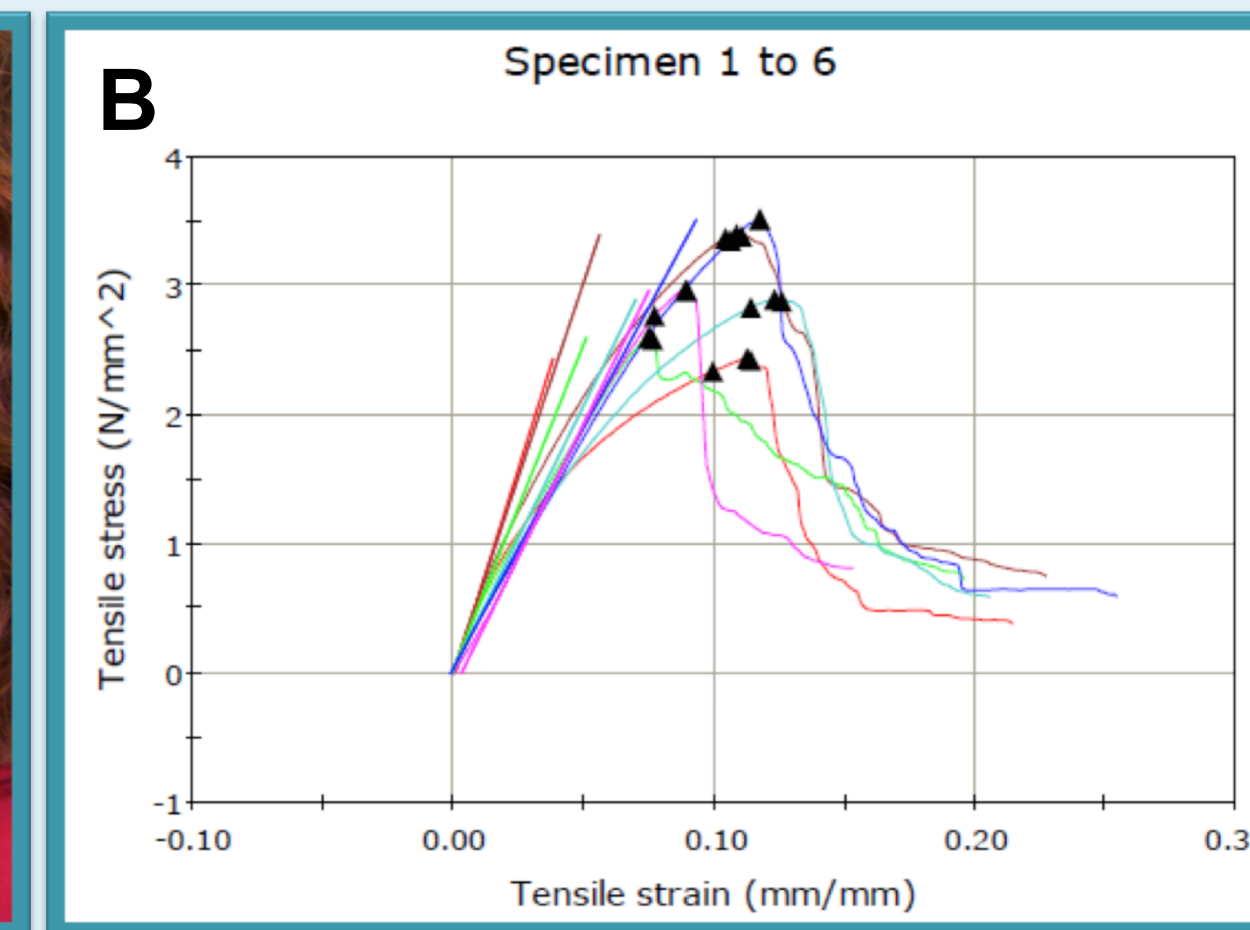
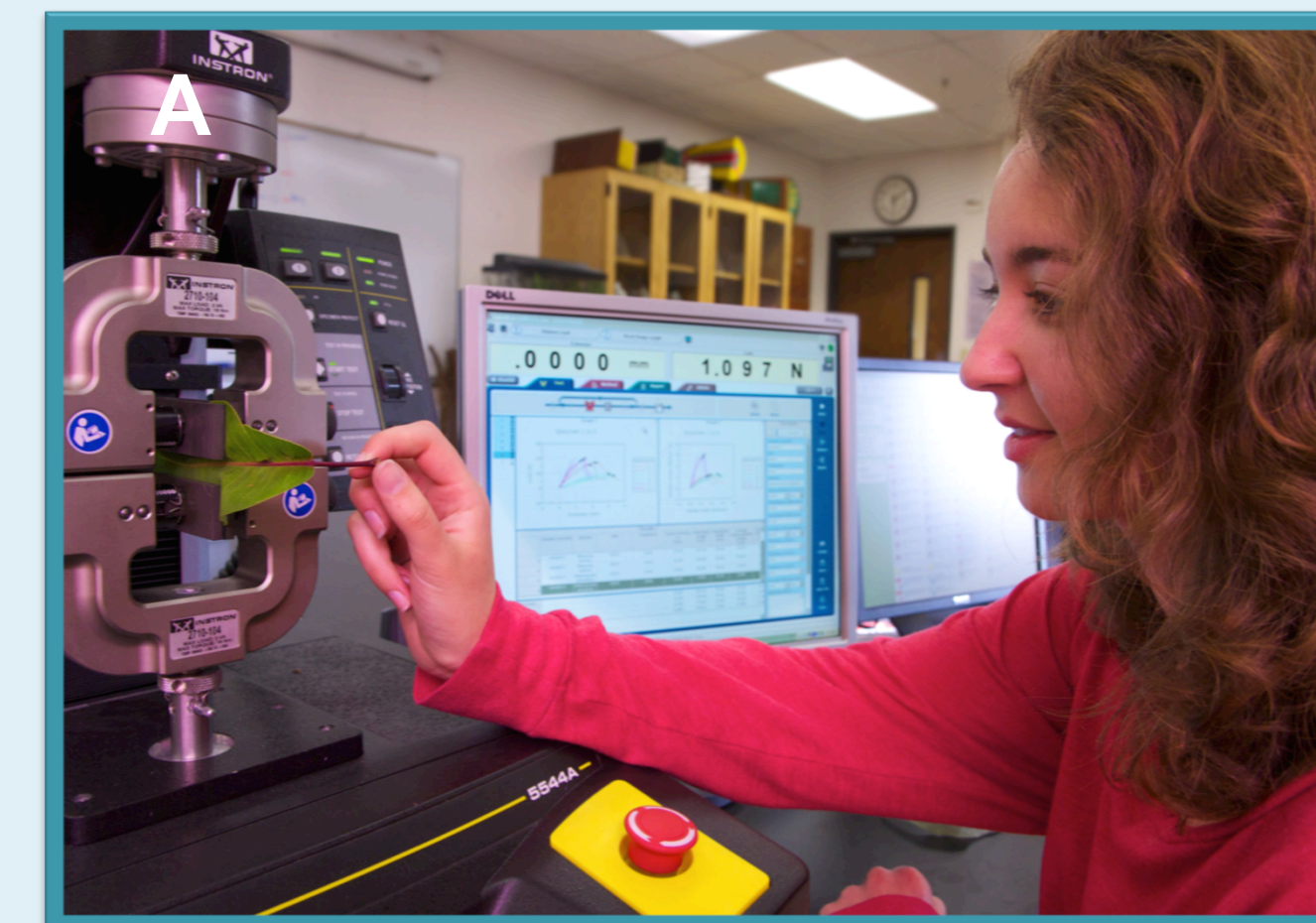


Fig. 2. (A) An Instron Mechanical Testing Device was used to measure Young's modulus and tensile stress at break in leaves [1], (B) *C. ilicifolia* data for six leaves of initial stress versus strain curve (Young's modulus) and tensile stress at break (black triangles). Leaves were tested in the horizontal orientation.

Study Site

R. californica and *R. ilicifolia* samples were collected near King Gillette Ranch and *C. spinosus* samples were collected in Malibu Creek State Park in the Santa Monica Mountains of California.

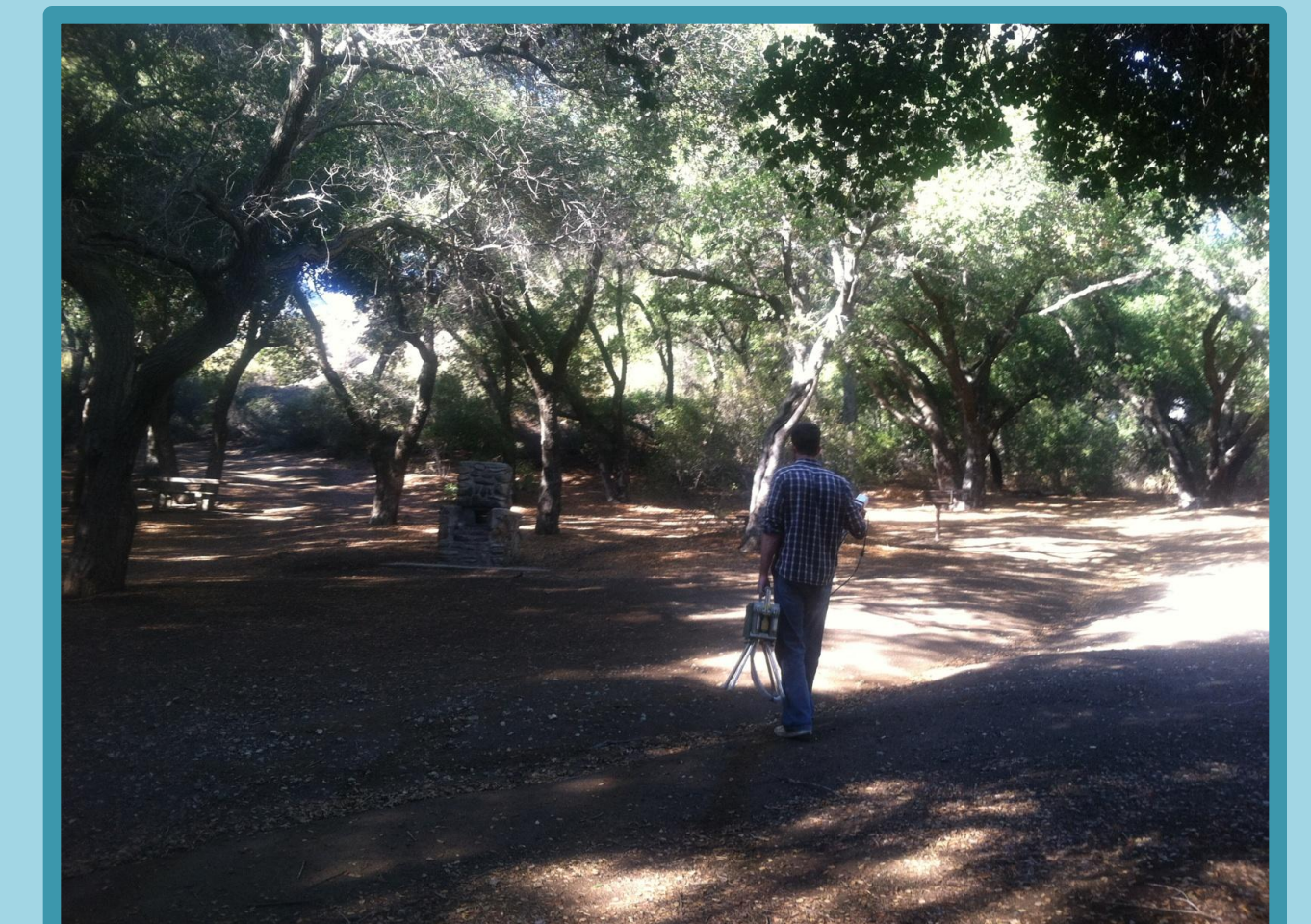


Fig. 6. Malibu Creek State Park entrance

Results

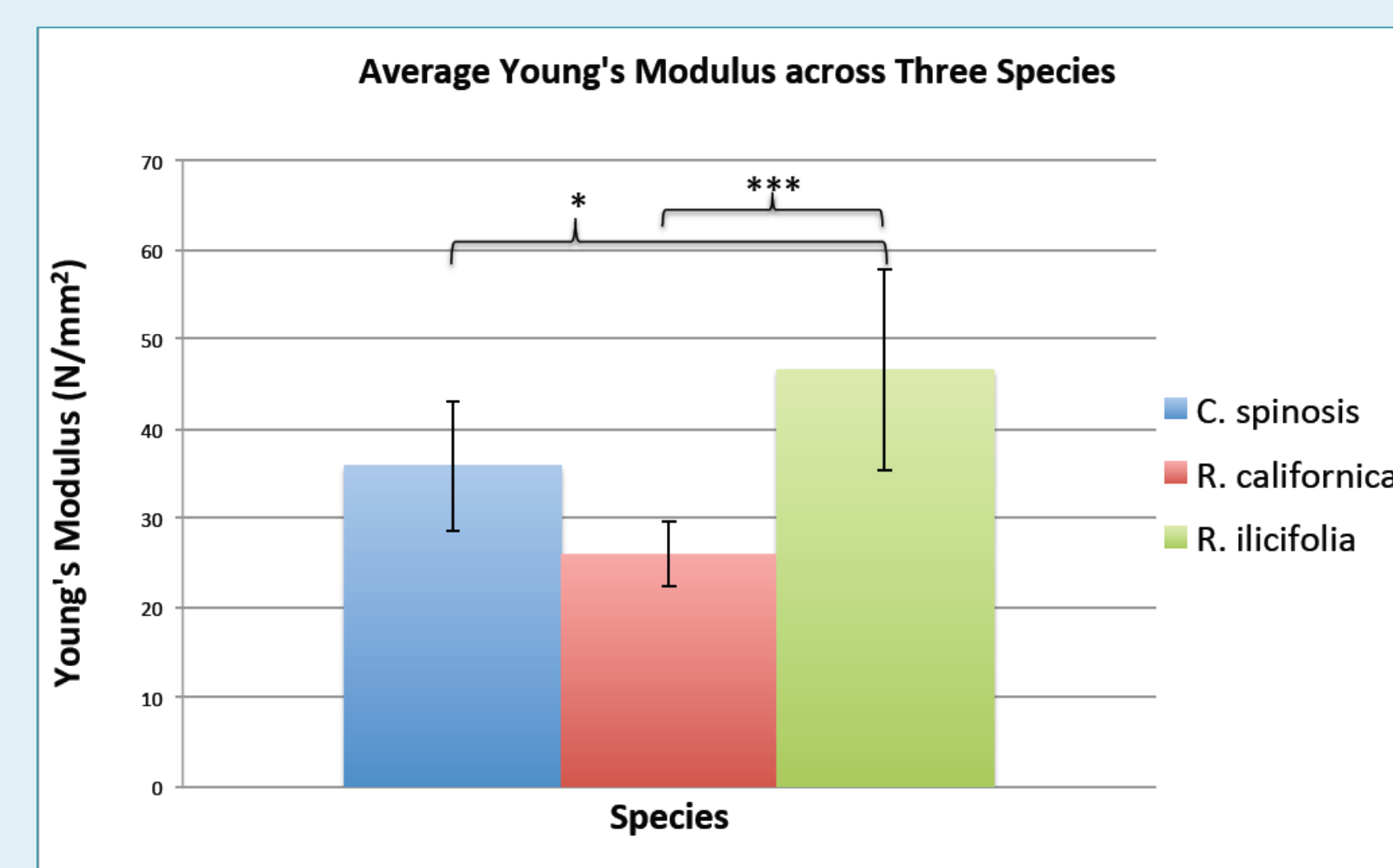


Fig. 3. Mechanical strength across species showing that they have different strengths for a fair comparison when graphed with photosynthesis. Error shown is +/- one SD. Results calculated using a one-way ANOVA with Tukey's post-hoc test, using a p-value of 0.05. (*p<0.05, **p<0.01, and ***p<0.001).

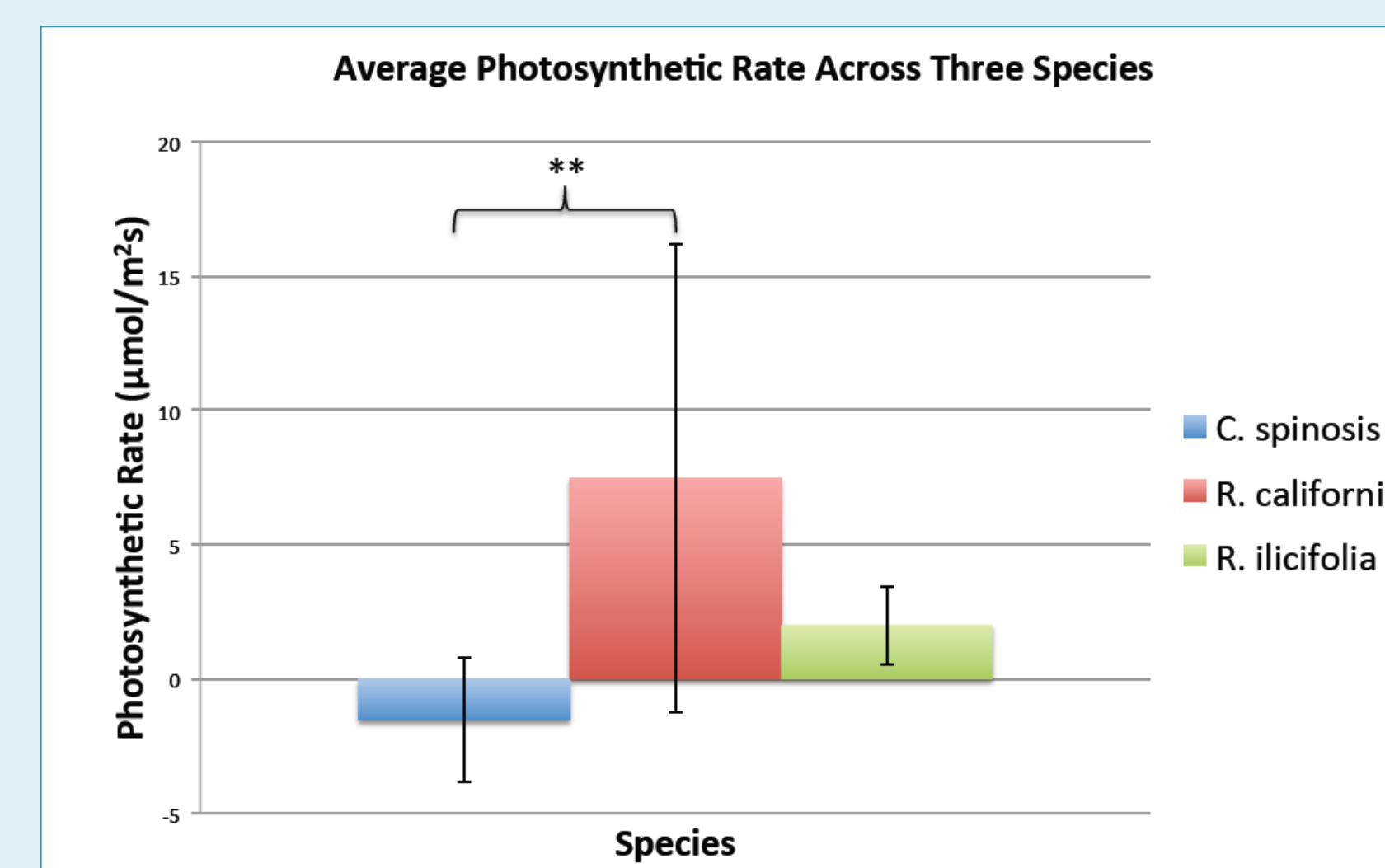


Fig. 4. Photosynthesis across species showing that values are not consistent. Error shown is +/- one SD. Results calculated using a one-way ANOVA with Tukey's post-hoc test, using a p-value of 0.05. (*p<0.05, **p<0.01, and ***p<0.001).

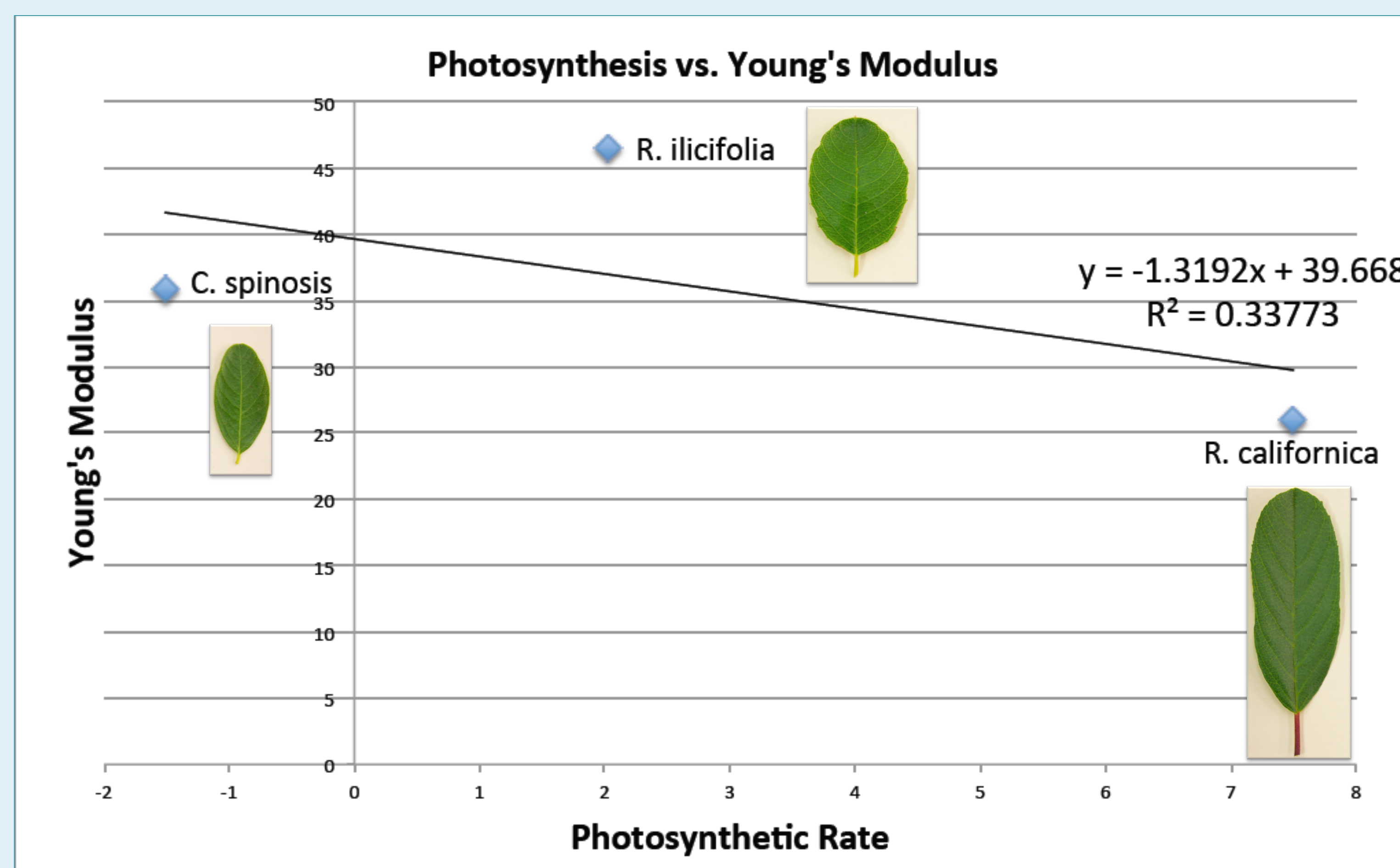


Fig. 5. Correlation between mechanical strength and photosynthesis across species

Discussion

Our hypothesis predicted that plants with more mechanical strength, higher Young's modulus of elasticity, would have higher photosynthetic rates. Our results show no strong correlation between photosynthetic rate and modulus of elasticity, with an R² value of only 0.33773 (Figure 5), however the very slight trend shown is opposite of the prediction we had made. The very slight correlation between Young's modulus and photosynthetic rate is actually that lower Young's modulus of elasticity will have a higher photosynthetic rate. If the correlation were stronger, interesting conclusions about a trade-off between photosynthetic rate and mechanical strength might have been able to be drawn. However, our data is only a miniscule sample of research that could be done on this subject. Perhaps other plants tested would show a significant correlation.

It is good to note that our results supported conclusions drawn by Pepperdine University student Taylor Stucky in her SCCUR 2012 presentation showing that *Rhamnus ilicifolia* had the highest mechanical strength of the three species tested, *Rhamnus californica* the lowest and *Ceanothus spinosus* the middle with statistically significant differences between *R. ilicifolia* and *R. californica* and *R. ilicifolia* and *C. spinosus*. We would try to determine relative levels of photosynthetic rate across these three species, but the alarmingly high error in the results hampers any attempt to do so.

Literature cited

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Acknowledgements

We would like to thank Dr. Stephen Davis as well as the Natural Science Division of Pepperdine University for their help and support.

