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Effects of Soil Moisture on Photosynthesis and Fluorescence in *Heteromeles arbutifolia*

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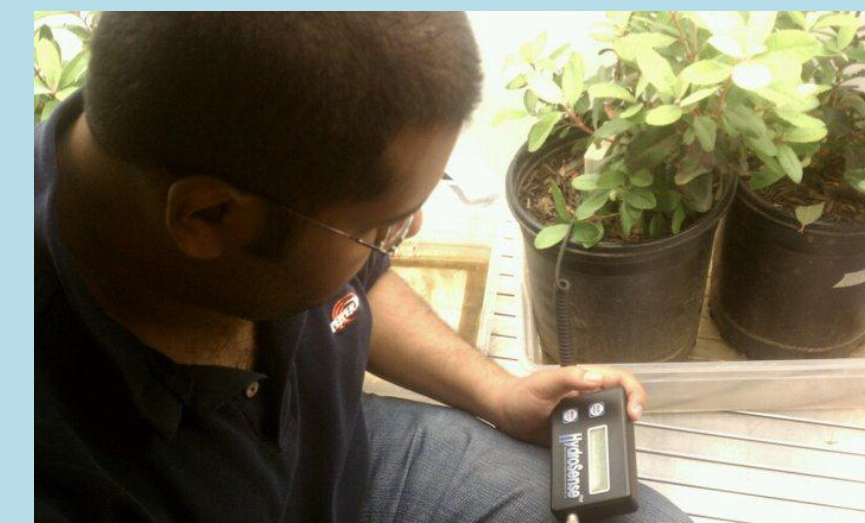
Abstract

Some plants have evolved to increase their chances of survival by being drought-adapted. Among those plant species is *Heteromeles arbutifolia*, native to California. Logically, the fact that *Heteromeles arbutifolia* tolerates the low supply of water makes this plant more likely to be within environments where the level of sun exposure is high. Thus, we hypothesized that lowering soil moisture will cause an increase in xylem pressure, causing an increase in photo-protection and fluorescence, and a decrease in photosynthetic rate. This has not been tested before on a native chaparral plant such as *Heteromeles arbutifolia*. The experiment was held as following: six *H. arbutifolia* were evenly divided up into a treatment group and a control group. Both groups were given equal hydration at the beginning of this experiment. From then on the control group maintained a constant daily rate of hydration as the experimental groups received no water. Data of photosynthesis, photo-protection, fluorescence, xylem pressure, and soil moisture were taken for both groups throughout the entire experiment. Data collection showed statistically significant results of comparing non-photosynthetic quenching to photosynthetic quenching in water-stressed plants and water-saturated plants. Significant correlations were drawn between the following: the fraction of non-photosynthetic quenching to xylem pressure, the fraction of non-photosynthetic quenching to soil moisture, the fraction of non-photosynthetic quenching versus the time since the last event of irrigation, and xylem pressure and the time since the plant was last irrigated. It was concluded that photo-protection rate increases with water stress, which supported the initial hypothesis in part. However, the study also concluded that there was not a significant difference between the two groups regarding the fluorescence rate.

Introduction

Among the Plantae Kingdom, there are many plants that are drought-adapted which are drought adapted. One of those plants is *Heteromeles arbutifolia*, or commonly called Toyon. *Heteromeles arbutifolia* is a coastal sage scrub plant that is native to the state of California. There are several processes that plants perform during their life time, such as photosynthesis (which converts light energy into chemical energy) and photoprotection (mechanisms decrease the damage resulted from exposure to large quantities of light radiation). According to our understanding of the purpose of photoprotection mechanisms, plants that perform photoprotection mechanisms due to the exposure to sunlight radiation will exist within environments where water supply is low. However, the relationship between photoprotection mechanisms and water supply is debatable within the scientific community. It has been reported that levels of xanthophylls and B-Carotene (which both play major roles in dissipating energy) increased in wheat plants (Tambussi, 2002). Another study on potato plants found that low water supply had almost no effect on photoprotection mechanisms (Jefferies, 2006). So the question is: does the variation in water supply affect the mechanisms of photoprotection? If it does, will it affect the rates of photosynthesis and fluorescence? To answer this question, six *Heteromeles arbutifolia* plants were the subjects of this study in which they were divided up into two groups supplied with different amounts of water to record the difference in photoprotection, photosynthesis, and fluorescence using the LI-6400XT Portable Photosynthesis System.

Methods



Six five-gallon *Heteromeles arbutifolia* plants, all being similar in height and foliage amount, were obtained from Boething Nursery off of the 101 and Mulholland Drive. The plants were all initially irrigated, filling the five-gallon soil pot up to the rim from the top of the soil so that the water dripped all the way through the bottom of the pot. Then they were separated into two study groups of three plants each. One group, plants 1-3, received daily irrigation where the other group, plants 4-6, received no more water for the duration of the experiment.

The plants then were tested periodically throughout three weeks to see if there was any difference with the individual plants' rates of photosynthesis or fluorescence. To do this, a leaf off of each plant was placed into the cuvette on the Li-6400 gas exchange device to measure fluorescence and photosynthesis. Then each test was run with these parameters: 200 flow rate, 1000 actinic, 22°C block temperature, 385 ppm CO₂, and the lights on to be able to measure fluorescence.

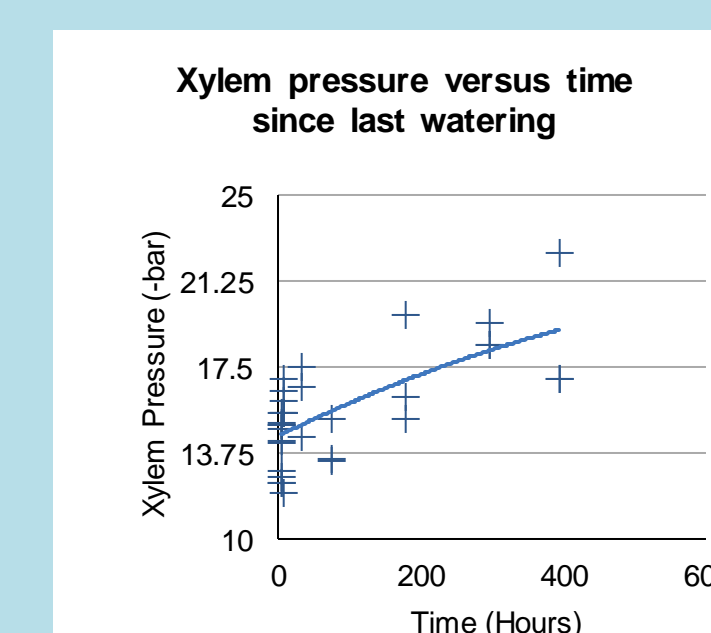
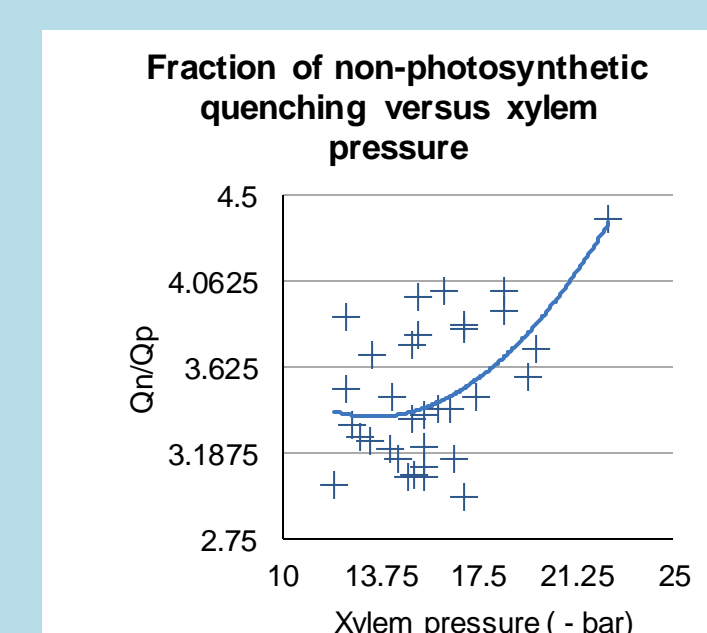
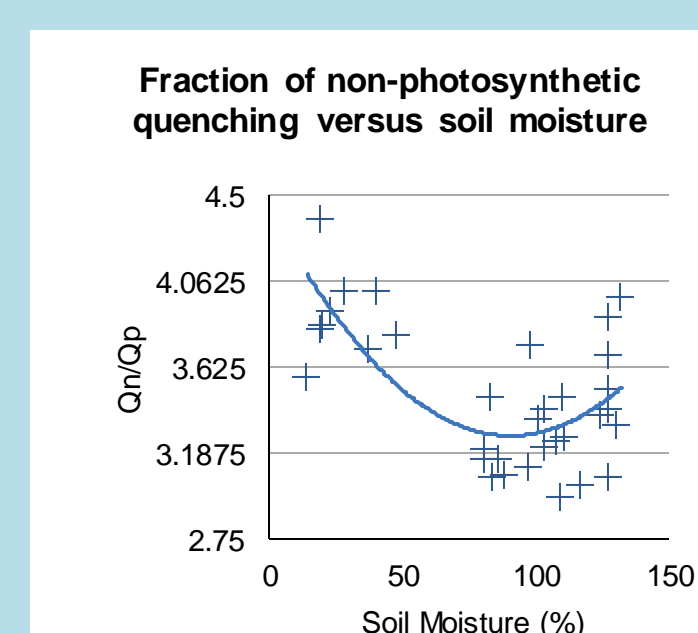
The plants were also tested for their xylem or water pressure with the Scholander-Hammel Pressure Chamber. Two leaves were removed from each plant with a razor blade. Each leaf sample was then placed into the pressure chamber with the petiole in the lid of the chamber. The machine then measured the relative water pressure of the plant.

Each plant was then tested for its relative soil moisture. A soil moisture probe was placed into the soil of each plant, close to the plant and away from the sides of the pot. The two groups, the three irrigated plants and the three water deprived, were compared to each other based on these parameters.

Data and Results

	Water saturated (Initial)	Water stressed (Initial)	Water saturated (Final)	Water stressed (Final)
soil moisture (%)	107.3	89.6	122.3	19.3
xylem pressure (-bar)	13.3	15.15	14.05	18.83
qn/qp	3.274	3.329	3.641	4.010
fvm	0.499	0.468	0.399	0.415
Fv/Fm	0.250	0.248	0.238	0.243

Table 1: Mean starting and final values of water-saturated and water-stressed plants. For each category, values represent the mean of three plants.



The ratio of non-photosynthetic quenching to photosynthetic quenching in water-stressed plants and water-saturated plants was statistically significant. In comparing the fraction of non-photosynthetic quenching that was fluorescence from the three final values of each group, no statistically significant correlation was found. There is a positive correlation between the fraction of non-photosynthetic quenching to xylem pressure and the former with soil moisture. The strongest correlation occurs between the fraction of non-photosynthetic quenching versus the time since the last watering. The average xylem pressure of the three water-stressed plants was -18.83 bars and was -15.15 bars for the water-saturated plants. There was a strong correlation between xylem pressure and the time since the plant was last watered. For these data, xylem pressure was recorded and graphed as a positive value.

Conclusion

- Our data provided us with some direct answers to our original hypothesis, but still has left us with some questions.
- We had initially hypothesized that there would be an increase in the photo-protection mechanisms in water-stressed plants. We were presumably going to measure this through means of fluorescence, but this proved fallible.
- Although this data was not recorded, the Fv'/Fm' may have been dependent upon the age of the leaf. While we used a consistent gauge of selecting leaves 5-leaves-down from the meristem, it became clear that this came with inherent discrepancies in leaf size and leaf color.
- The best gauge of photo-protection is found in the value qn/qp, which relates the amount of non-photosynthetic quenching (photo-protection) to photosynthetic quenching. When we tested for an increased qn/qp ratio using the values from the end of the test we obtained a p-value of p= .036. We tested against the null hypothesis of 'qn/qp in un-watered plants > qn/qp in watered plants', and so our data supported our hypothesis in that there was an increase in the photo-protection of the *Heteromeles Arbutifolia* with water stress. This is also evident through graphs (Fig. 1, 2,), which show strong correlations between qn/qp and soil moisture and qn/qp and xylem pressure.
- We had also hypothesized that the fluorescence of the plants would increase in the water-stressed plants. We know that the amount of fluorescence did occur, as evidenced from the above data. There was no significant difference in the make-up of non-photosynthetic quenching.
- We can only conclude that there was an increase in photo-protection, but not by what means this occurred. There could have been increases in the proportions of heat-dissipation and xanthophyll cycling, but we did not test for these. Our data shows that *Heteromeles Arbutifolia* does respond to decreased water supply, specifically when increasing the ratio of light dissipated in photo protection versus that used in photosynthesis.
- Our data suggests that there is no one method by which these plants protect themselves from light damage. It is presumably a combination of fluorescence, heat dissipation, xanthophyll cycling and physiological factors, which make this plant drought tolerant.
- In a future experiment, we will quantify xanthophyll content in water-stressed plant and see how the rate of increase of this value compares with the rate of increase of qn/qp. We could also find a more precise means of measuring leaf temperature. Both of these would further allow us to understand the process of photo-protection.

Literature Cited

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