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Effect of Ambient Air Temperature on Leaf Size in Raphanus sativus

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Introduction

Ambient temperatures have a major impact on plant physiology. This fact is especially relevant to humans because global warming, caused by the accumulation of anthropogenic greenhouse gases, is predicted to cause a significant rise in temperatures over the next several decades.[5] Particularly impacted will be subsistence farmers in third world countries who have little access to the knowledge and resources needed to adapt agriculture to consistently rising temperatures. Thus, the livelihood of many subsistence farmers may rely on the ability of common agricultural staples to adapt their morphologies and physiologies to these changing conditions. Leaf size is extremely important to the physiological health of plants. The coupling of a leaf to its external temperature, relative humidity, and CO_2 concentrations are all dependent upon leaf size - making the ability of plants to adjust this phenotypic trait crucial to their ability in adapting to rising global temperatures.[4]

Because of these issues, we wish to investigate the phenotypic plasticity of leaves in the face of rising temperatures. *Raphanus sativus* (the radish plant) was chosen to study the effects of how warmer temperatures affect leaf size. *Raphanus sativus* is an excellent model organism for such studies because of its sensitivity to environmental stress, short culture time, and small size.[3] 24 radish plants were cultivated in separate pots filled with vermiculite. These plants were divided into two groups of 12. One group was grown in a lower temperature environment, and the other group was raised in an environment several degrees Celsius higher to approximate the effects of global warming. Otherwise all other potential environmental variables were held constant between the two groups. Leaf sizes were measured twice over a period of two weeks from first planting.

H: As temperature increases, leaf size will increase in order to cope with rising temperature because of enhanced transpiration cooling.

H_0: As temperature increases, leaf size will not increase.

Materials and Methods

To perform the experiment, two plant incubators were used. Both incubators were set to the same environmental conditions with the exception of temperature. A photoperiod of 12 hours was chosen for the plants. The first incubator was set at lower temperatures with day temperatures at 23.8 degrees Celsius and night temperatures of 20.7 degrees Celsius. The second incubator had temperatures 6 degrees Celsius greater than the first, with day temperatures of 29.8 degrees Celsius and night temperatures of 26.7 degrees Celsius.

Two separate potting trays of *R. sativus* were obtained, each with 12 small planting pots. Each of the total 24 pots were filled with vermiculite and placed in their respective tray. A pen was used to create holes in the vermiculite in which to place the seeds. Once each of the 24 pots contained a planted *R. sativus* seed, the pots were watered. Each pot was watered to saturation of the vermiculite, with the extra water left in the bottom of each tray in order to keep the vermiculite hydrated. Both trays were labeled as either normal or high temperature samples and placed in their respective incubator. Throughout the experiment, the plants were monitored and watered as needed in order to ensure all plants maintained the same levels of hydration.

Data was first collected on the tenth day after planting the seeds because at this point there was appreciable growth for several of the plants in both groups. The leaves of each plant were traced on a piece of paper and cut out. The paper cut outs were placed in the Leaf Area Meter for measurement and the data was recorded. An unpaired T-test was performed on the data to decide whether the results were significant. For the final data collection, four days after the first, the leaves were cut off of each plant with scissors and placed in the Leaf Area Meter. The data was handled in the same way as the first day of collection. The average size of each tray for both days of collection was calculated and plotted over time to obtain the average growth rate for the two groups of plants.

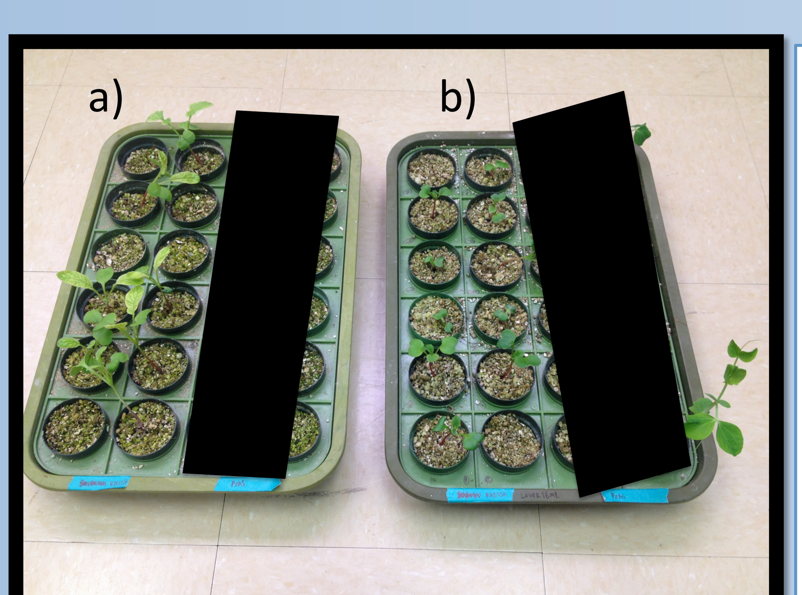


Figure 1: High Temperature vs. Low Temperature Trays with weeds blocked out (at final measurement)
a) Radish Plants grown in high temps.
b) Radish Plants grown in low temps.

Abstract:

Global warming is an increasing problem in today's society. Thus, it is important to know how plants, specifically those that are cultivated for human consumption, react to rising average temperatures. This experiment tested how the leaf size of a common crop plant, *Raphanus sativus* (radish), is affected by two different temperatures. It is hypothesized that as temperature rises, the leaf size will increase, giving the leaf greater ability to cool via transpiration because of an larger surface area for stomatal conductance. This hypothesis was tested by growing two samples of plants in separate incubators. One sample was grown at a normal atmospheric temperature, and the other at a temperature 6 degrees Celsius higher. The average leaf area of each sample was measured using the Leaf Area Meter. Comparing the average leaf sizes of the group of radishes grown in warmer versus cooler temperatures showed a significant increase in both growth rates and final leaf sizes for the plants grown in the warmer incubator. Therefore, radishes clearly show phenotypic plasticity of their leaf sizes in response to changing temperatures. This morphological adaptation may increase the plant's physiological fitness in its new environment, giving hope that common crop plants can make some adaptations to the world's changing climate, mitigating some of the negative effects of global warming for those who rely on such crops for subsistence.

Results:

Figure 2: A comparison of the mean leaf sizes for both high temperature and low temperature groups with standard error bars. "Day 1" is the first day the leaves were measured (Day 10 from first planting), "Day 5" is the final measurement of the leaves (Day 14 from first planting).

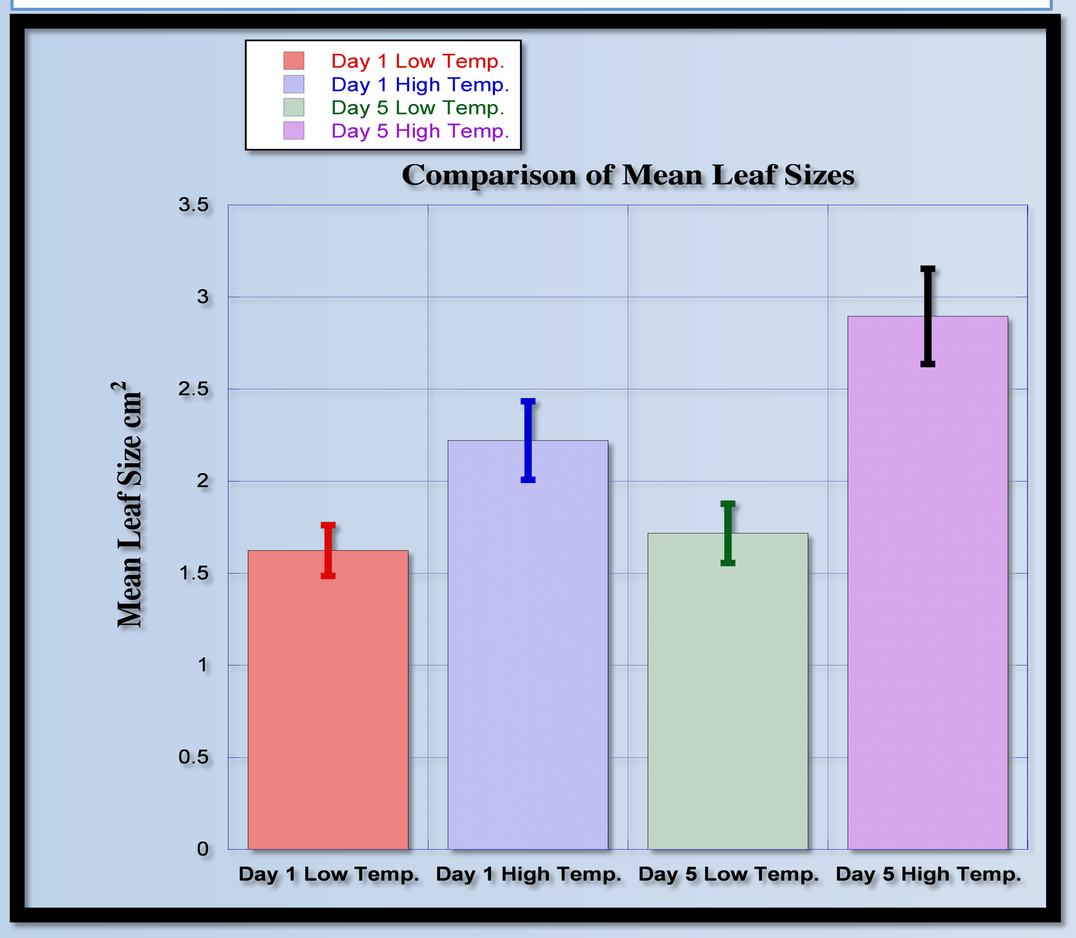


Table 1: Data from the first measurement of the leaf areas of both High Temperature and Low Temperature groups

	High Temperature	Low Temperature
Total Leaf Count	19	14
Mean Leaf Area (cm^2)	1.62	2.22
Standard Deviation (cm^2)	0.598	0.797

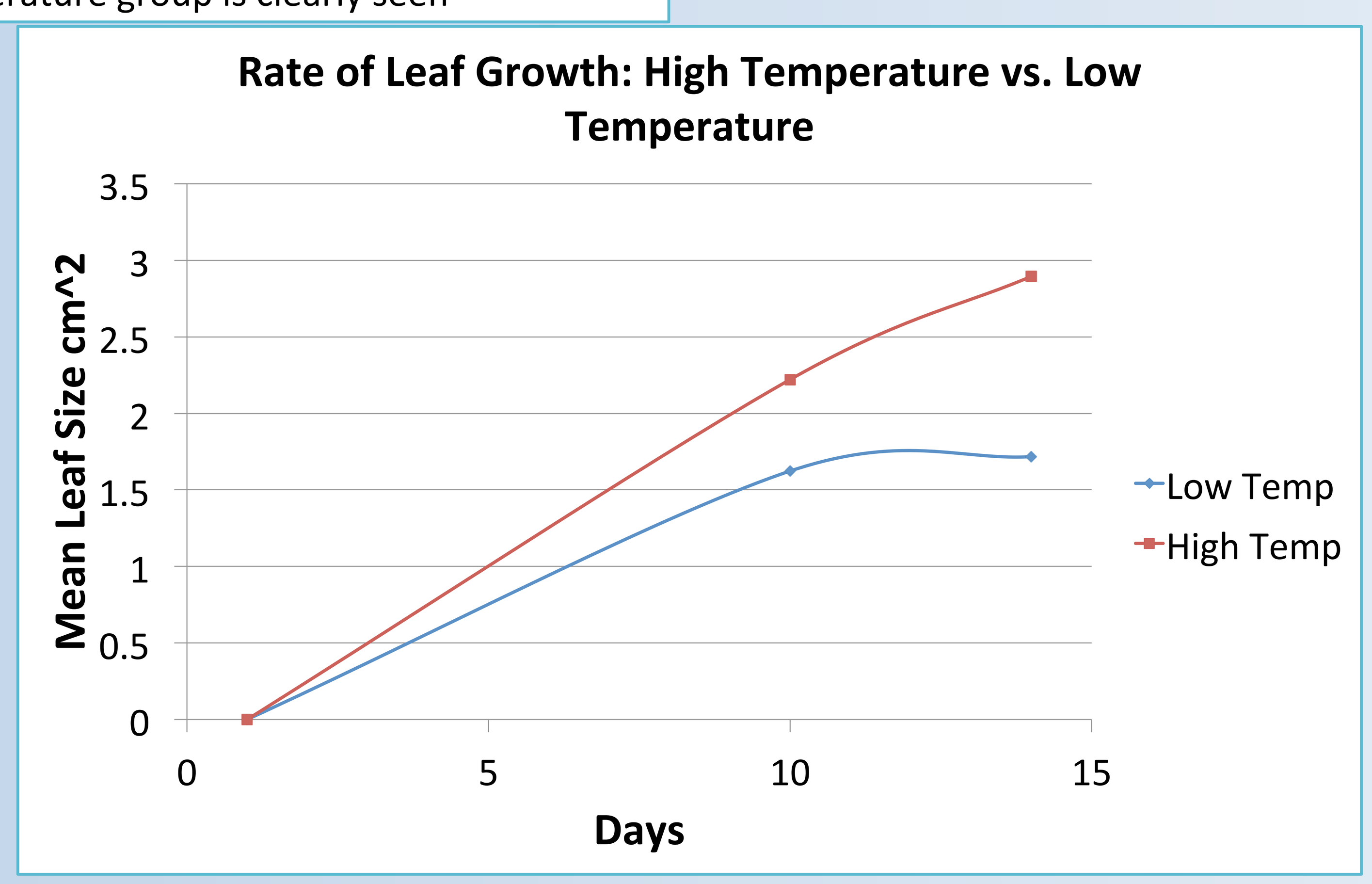
Mean Difference = 0.597 cm^2
t-probability = 0.020

Table 2: Data from the second and final measurement of the leaf areas of both High Temperature and Low Temperature groups

	High Temperature	Low Temperature
Total Leaf Count	20	14
Mean Leaf Area (cm^2)	1.72	2.90
Standard Deviation (cm^2)	0.72	0.970

Mean Difference = 1.17 cm^2
t-probability = 0.000287

Figure 3: a comparison of mean area leaf growth rates between radishes grown in the high and low temperature groups, the accelerated growth rate of the high temperature group is clearly seen



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Discussion:

In our experiment we found that temperature is a strong determiner of leaf size in *R. sativus*. One explanation for an advantage that plants gain by growing larger leaves is that they allow for greater transpiration rates which are a method by which the plant cools itself and regulates its temperature. According to Gates, leaves with greater surface area can increase the temperature of the air above the leave, resulting in higher transpiration rates due to an increased temperature directly over the plant's stomata.[2] Our results would seem to validate this conclusion because the radishes grown in the warmer environments had significantly larger average leaf sizes than the group grown in lower temperatures. However, the radishes in our experiment were not limited by water availability, a crucial component of the trade-off involved in cooling by way of transpiration. Therefore, it would be worthwhile to investigate how radishes deal with the trade-offs involved with increasing need to cool via transpiration along with limited water resources. In a similar experiment by Cracker, Siebert, and Clifford, it was found that input of solar radiation plays the most important role in leaf development of *R. sativus*.[1] Because radiation levels were held constant in our experiment, it would also be valuable to do further research into how temperature and radiation levels interact to influence leaf development.

Conclusions:

- Radish plants grown in higher temperatures (day at 29.8 °C, night at 26.7 °C) had significantly larger leaf areas than those grown in lower temperatures (day at 23.8 °C, night at 20.7 °C).
- Along with having larger leaf sizes, the leaves of radishes grown in higher temperatures had faster growth rates
- The total number of leaves for radishes grown in higher temperatures was also larger than the number of leaves counted on the radishes grown in lower temperatures
- Further research should be done on how other environmental factors interact with temperature to affect leaf size, continued study could also focus on the physiological benefits and trade-offs associated with larger leaf size in radishes
- The ability of the radish to adapt to rising temperatures demonstrates that at least one common crop plant can change along with the climate, giving hope that other common staples may be similarly plastic in their response to warming.

Acknowledgements

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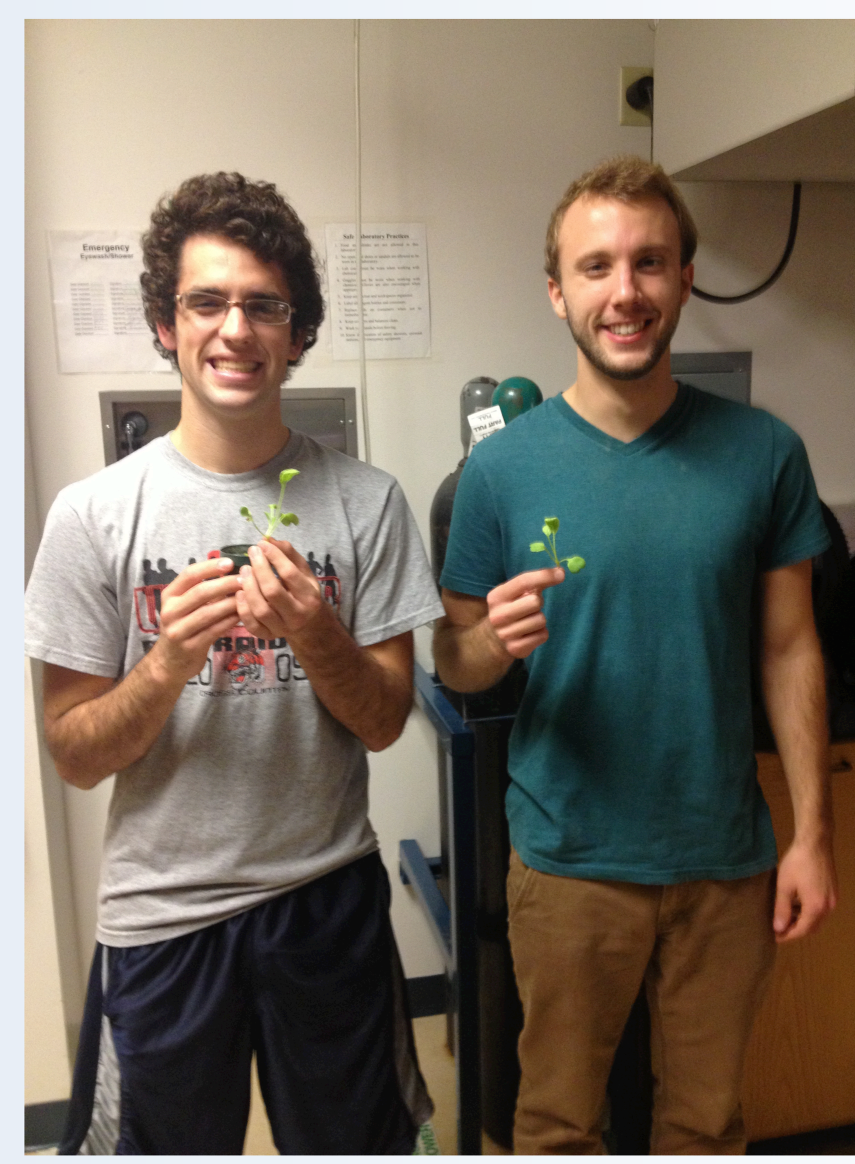

Kevin Ko