Radish Growth in Alternate Climate Models

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Abstract

Considering the core of the human food source is plants, it is important to take into account the International Panel on Climate Change's models for future climatic scenarios in terms of future crop success. To test different climate scenarios predicted by the IPCC, radishes were planted in eight different climate treatments, one of them being the current climate conditions, and analyzed for differences in length and mass of the root and shoots of the plants. The climatic variables that were manipulated were temperature, precipitation patterns, and soil nutrient content. It was shown that temperature has a statistically significant impact on below ground mass and length in treatments with no nutrients added. The root to shoot mass ratio for treatments without nutrients was statistically significantly larger in the current average temperature for the region than the elevated temperatures for the region predicted by the IPCC. This study highlights the importance of agricultural studies for future climatic situations if changes follow the models predicted by the IPCC to avoid mass crop failure and starvation among people.

Introduction

Our current agricultural system that provides food for the entire world is worked around the current climate conditions during growing seasons. A change in climate conditions during the growing season could have an effect on crop growth success and yield. The Intergovernmental Panel on Climate Change (IPCC) has developed models that show up to a 1.5-2.0 degree Celsius increase from current temperatures in the United States between 2020 and 2029 (IPCC, 2007). The models produced by the IPCC also show a possible increase of 5.0-6.0 degree Celsius in the United States between 2090 and 2099 (IPCC, 2007). It is very likely that hot extremes, heat waves and heavy precipitation will become more frequent (IPCC, 2007). Changes in climate can also increase plant vulnerability to infection, infestation, and weeds (Rosenzweig et al., 2001). It is important to consider how these climatic changes will impact crop growth considering agriculture is the main method of providing sustenance to the world's population.

To test the impact of different climate scenarios on crop growth, radishes (Raphanus raphanistrum) were chosen to model the outcome. Radishes were chosen as the model crop for a few outstanding reasons. Radishes have a short growth cycle of about 24-30 days in favorable growth conditions, along with a fairly low optimal growth temperature (Kotska-Rick and Manning, 1993). The crop is also small, allowing for large numbers of treatments and replications, making it optimal for multifactorial studies (Kotska-Rick and Manning, 1993). The distinct distribution of biomass between the shoot and the root of the radish is a sensitive indicator of differences in climatic conditions during the growing of the plant (Kotska-Rick and Manning, 1993).

The climatic changes that are most pressing for agricultural crop yields are changes in precipitation, temperature, and soil nutrient content because optimal levels of each are required for successful growing. The radishes were chosen to be grown in eight different climatic conditions, including the present climate condition, to simulate possible future crop yields.

Methods

Experimental Design:

Ninety-six radish seeds were planted in Miracle Grow potting soil in individual paper cups. They were then divided into eight groups of twelve to receive eight different growing conditions. Each group was marked with masking tape as treatment 1-8 and plant A-L (Example: Plant 1A, 1B, 2A, 2B). Ten-gallon aquarium tanks were used to contain each of the eight groups with growth lights placed over the top of them. The growth lights were measured with a photometer to read 110 lux (+/- 5 lux). Four of the eight groups were on a temperature controlled plant warming pad to simulate a rise in average temperature compared to the current average temperature. The current average temperature was 20 degrees Celsius and the plant warming pad was set to 26 degrees Celsius to simulate the most drastic change in average temperature predicted for our region by the IPCC. Half of the treatments received Expert Gardener plant food to simulate soil with nutrients as compared to nutrient poor soil, represented by the treatments without nutrients added. After planting, half of the treatments received daily watering of 5 mL to simulate a stable water supply and half of the treatments were watered once every three days with 15 mL to simulate drought and then flood. All watering was done using a pipette to ensure accurate measurement. All of the individual treatment scenarios can be referenced in Table 1.

Table 1. Summary of temperature, nutrient, and water scenarios for each treatment.

Treatment	Temp: 20°C	Temp: 26°C	Daily Water (5mL)	Intermittent Flood (15mL)	Nutrients Added
1	X		X		
2	X		X		X
3	X			X	
4	X			X	X
5		X	X		
6		X	X		X
7		X		X	
8		X		X	X

Data Collection:

After eleven days of growing the radishes in each treatment, the plants were removed from the aquariums and placed on trays for data collection. First, the number of plants within each treatment that germinated was noted. Using a spoon, the plants were removed gently to keep root and shoot intact. Excess dirt on the roots of the plants was removed into a bucket for disposal. Using a metric ruler, the length of the root and the shoot of each plant was recorded in millimeters. Once the lengths were recorded for each plant, the mass of each root and shoot was recorded in milligrams.

Data Analysis:

Averages for mass, root to shoot mass ratio, and length of the root and shoot of each plant were calculated by treatment. Percentage of germinated plants were recorded by treatment as well. The data was statistically analyzed using the ANOVA formula to look for statistically significant differences in growth by variable. ANOVA was used to look for statistically significant differences in treatments without added nutrients' above ground length, above ground mass, below ground length, and below ground mass paying attention to the different water and temperature variables. An ANOVA was also used to analyze root to shoot mass ratios of the treatments. A T-Test was used to see if there was a statistically significant difference in germination rates between the treatments with nutrients added and the treatments without nutrients added.

Results

The raw data was organized into a table for easier statistical analysis and to begin looking for patterns in results. The raw data can be referenced in Table 2.

Table 2. This table contains raw data collected for each treatment. AG= above ground, BG= below ground.

Treat-ment	Av. AG Length	Av. BG Length	Av.AG Mass	Av.BG Mass	# Germinated	Not Germinated	% Germinated	Photometer	Avg. :Root Mass Ratio
1	8.15	2.91	0.192	0.068	11	1	91.6%	110 lux +/-5	.218
2	N/A	N/A	N/A	N/A	0	12	0%	110 lux +/-5	N/A
3	8.5167	5.6	0.167	0.031	12	0	100%	110 lux +/-5	.211
4	N/A	N/A	N/A	N/A	0	12	0%	110 lux +/-5	N/A
5	7.5583	2.74	0.0129	0.0010	10	2	83.3%	110 lux +/-5	.132
6	3.7500	2.475	0.055	0.0010	7	5	58.3%	110 lux +/-5	.181
7	9.1833	3.167	0.179	0.017	12	0	100%	110 lux +/-5	.102
8	0.75	0.75	0.017	0.002	2	10	16.7%	110 lux +/-5	.203

The ANOVA analysis of above ground length of treatments with no nutrients added showed that there was no statistical difference in the way that the different temperature and water variables interacted with the above ground length. The ANOVA analysis of above ground mass of treatments with no nutrients added showed that there is no statistical difference in the way that the different temperature and water variables interacted with the above ground mass. The ANOVA analysis of below ground length of treatments with no nutrients added showed that there was a statistically significant difference in the way that the temperature variable, water variable, and how the temperature and water variable interacted with each other impacted plant growth (Figure 1). The ANOVA analysis of below ground mass of treatments with no nutrients showed that there was a statistically significant difference in the way that the temperature variable impacted plant growth (Figure 2). The ANOVA analysis of the root to shoot mass ratios of treatments with no nutrients showed that temperature had a statistically significant impact on the ratio (Figure 3). There is a higher ratio in Treatment 1 and Treatment 3, which received the current 20 degree Celsius temperature, possibly indicating that there would be more food matter. However, this is hard to say because the plants only grew for eleven days.

A T-Test was used to see if there was a statistically significant difference in the number of germinated plants between the treatments that received nutrients and the treatments that did not receive nutrients. The treatments that received nutrients had statistically significantly lower germination percentages than treatments that did not receive nutrients (Figure 4).

Figure 1. Boxplot of the differences in below ground length of no nutrient treatments. A= Treatment 1, B= Treatment 3, C= Treatment 5, D= Treatment 7. The Y-axis is measured in millimeters.

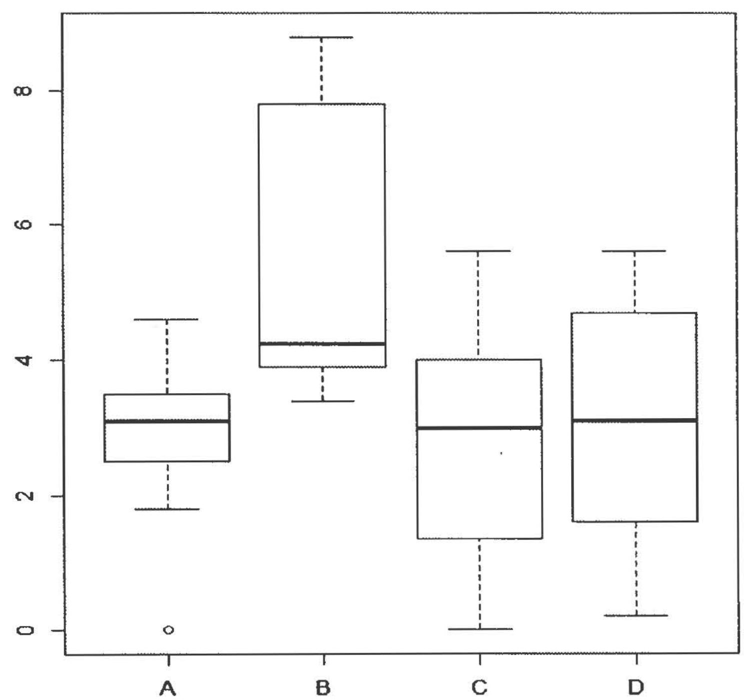


Figure 2. Boxplot of the differences in below ground mass of no nutrient treatments. A= Treatment 1, B= Treatment 3, C= Treatment 5, D= Treatment 7. The Y-axis is measured in milligrams.

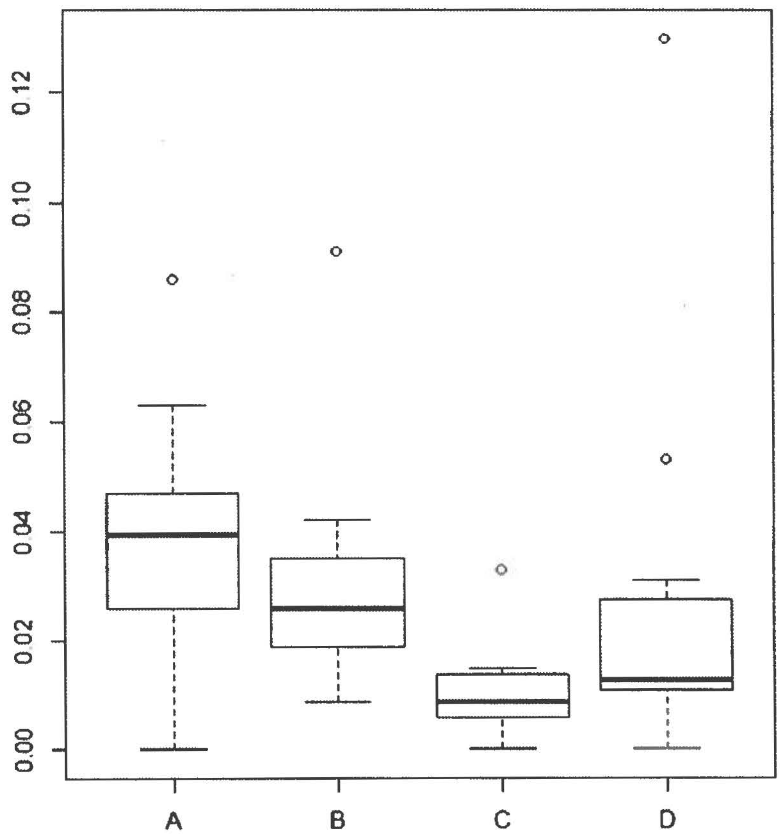


Figure 3. Boxplot of the root to shoot mass ratio of the treatments without added nutrients. A= Treatment 1, B= Treatment 3, C= Treatment 5, D= Treatment 7.

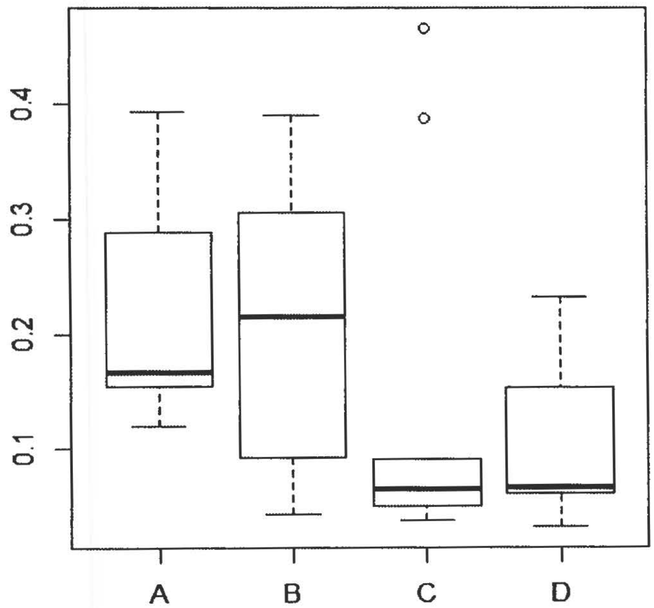
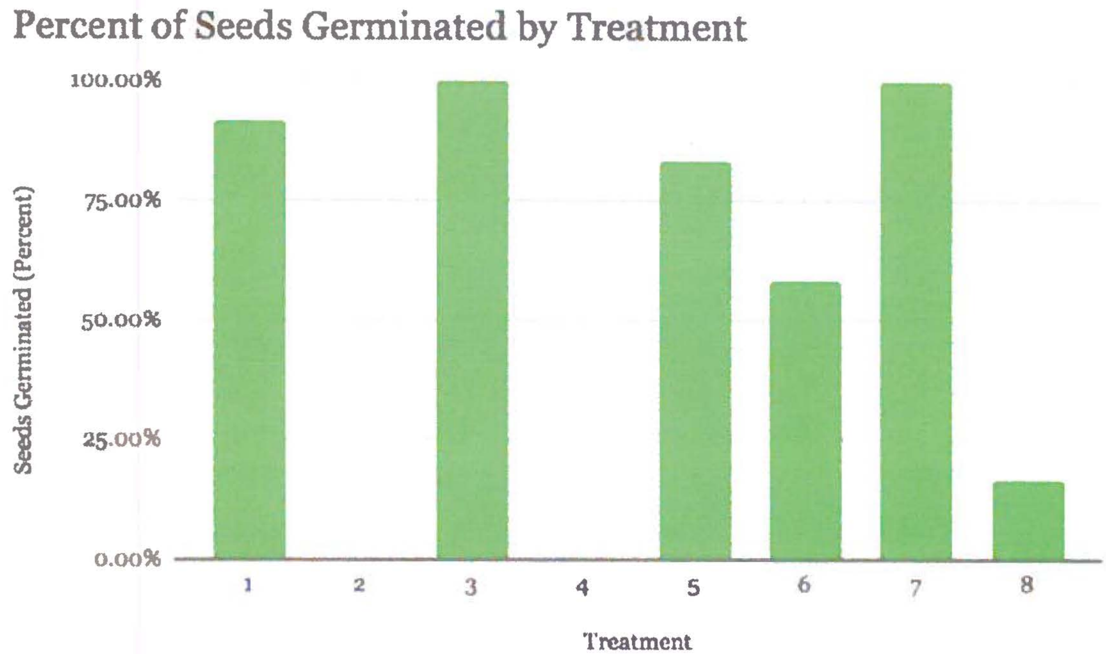


Figure 4. Bar graph of the percent of seeds germinated by treatment. Refer to Table 1 for which treatments had nutrients added.



Discussion

For each of the statistically significant ANOVA results, the variable that impacted plant growth in all of the results was temperature. Below ground length, below ground mass, and root to shoot mass ratio for treatments with no nutrients added were all statistically significantly impacted by temperature. Seeing how temperature has proven to be a variable that can impact plant growth, it is important to take all measures possible to stabilize the average global temperature to avoid future fluctuations in crop growth. The IPCC predicts the worst case scenario in 2090-2099 is that the average temperature for this region is raised to 26 degrees Celsius (IPCC, 2007). This was the temperature used against the current average temperature in the region, so this data is applicable to possible future climate situations. Radishes favor a fairly low optimal growth temperature (Kotska-Rick and Manning, 1993). This was consistent with the results of the ANOVA analysis of the root to shoot mass ratio of the treatments with no nutrients. The radishes that received the treatments with the 20 degree Celsius variable had a higher root to shoot mass ratio than the treatments that received the 26 degree Celsius variable.

There were considerable limitations to this study. After the experiment was over halfway through, it was discovered that the drought simulation was not a true simulation. Radishes show best growth when watered once every three days (Wan and Kang, 2005). This may be why we didn't see any statistically significant results within just the water variable impacting the different growth measurements. The Expert Gardener plant food severely impacted germination. It is possible that the amount of nutrients added to the soil was too much for the seed to handle, leading to small numbers of germinated plants that received nutrients. This was an interesting result because prior research showed that higher levels of nitrogen in the soil lead to greater plant mass (Pell et al., 1989). The plants should have been grown for longer than twelve days as well. If left to grow completely, the results might be even more valuable. Removing soil from the roots of the plants was very difficult. Some roots had more soil still attached than others when weighing. The roots were also very fine and easily broken.

This study leaves a lot of room for future studies and changes in experimental design. Future studies should include carbon chambers to imitate future atmospheric composition as predicted by the IPCC to see if that also impacts plant growth. Future studies should also consider longer growth time and true sun instead of growth lamps if possible. Nutrient analysis of the radishes in different treatments would also be valuable because it would show if there is any difference in nutrient content in different climate treatments. Expanding the temperature variable to 20 degrees Celsius, 22 degrees Celsius, 24 degrees Celsius, and 26 degrees Celsius to determine at what temperature it starts negatively impacting plant growth.

The impact of the various climate scenarios on plant growth eludes to the fact that plants may not grow the way they do now if the climate keeps changing. Plants are the core of our food sources, so continued pressure to slow climate change and an increase scientific studies for adaption is crucial.

References

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