The Effects of Varying Water pH on the Growth Rate of Green Onions

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Abstract

With the human population continuing to rise, so has the demand for food. Hydroponics is an alternative agricultural practice that may provide a new and potentially environmentally favourable way to grow crops. In this study, we examined the influence of pH on the growth of green onions grown using hydroponics. Growth was based on the percent change in mass and a total of 32 green onion stems were used in 4 different pH ranges: 5.5-5.8, 6.4-6.7, 7.0-7.3, and 7.5-7.8. Since previous literature had postulated that a pH of 6.5 yields the highest growth, we hypothesized that the green onions grown in the pH range 6.4-6.7 would have the most growth and highest percent change in mass. In contrast, our results show that there was no significant difference between the percent change in green onion mass of the four different pH conditions (df = 3, F-value = 0.4506, p-value = 0.7189). However we suggest that our non-significant results could be indicative of low sample sizes and/or errors in sample weighing; furthermore, followup studies may reveal significant results congruent with previous implications.

1. Introduction

By 2100, the human population is predicted to reach 10.9 billion (UN, 2019). The amount of food required to sustain this new population will prove insurmountable by current traditional agriculture techniques (Crosson, 1982). Furthermore, as traditional agriculture such as crop rotation and agroforestry are environmentally damaging, newer and greener alternatives are being researched (Singh & Singh, 2017). Hydroponics, the process of growing vegetables in water without soil, is noted by researchers to have greatly reduced environmental impacts and are on their way to become one of the more viable agricultural models (Journal of Engineering, 2016). Alongside increased human populations, atmospheric CO_2 has also precipitously increased over the recent century (Climate Change: Atmospheric Carbon Dioxide, 2020). Water has incredibly high CO_2 solubility and as such, increased CO_2 dissolution leads to an increase in carbonic acid which in turn reduces pH, refer to Appendix (Doney et al., 2009). Studies have shown that pH has strong influences on plant growth and metabolism (Judith, 2019; Kane et al. 2006).

Green onions, also known as spring onions (*Allium fistulosum*), were used in our study as they are widely recognised for their rapid growth and ease of care. Furthermore, green onions are an important seasoning worldwide. They contain high concentrations of allicin, which reduce inflammation and have antioxidant effects, flavonoids, which are metabolites, and vitamins (Yin et al., 2003; Wang et al., 2020). Green onions grow well in soil, however, if supported with nutrients and UV light, they will also grow in hydroponic systems (Kane et al., 2005).

Correct pH levels are important in hydroponics because it can affect the availability of nutrients for the growing plants (Judith, 2019). A pH level that is too alkaline (pH > 6) can lead to deficiencies such as iron deficiencies that cause leaves to pale or yellow in young plants (Judith, 2019). This is because iron is required to produce chlorophyll, which is responsible for the green colour in plants and is the basis for photosynthesis (Khuns, n.d.). On the other hand, a pH level that is too acidic (pH < 5) can lead to calcium deficiency that could cause leaf cupping and browning, because calcium provides vital structural support to the plant's cell walls (Judith, 2019; Oldham, n.d.). Previous studies on the subject of pH and growth rate of green onions have shown that the ideal pH of green onions is roughly 6.5 (Kane et al., 2006).

The goal of this experiment was to confirm that a water pH of 6.5 would be ideal for green onions to grow in. To minimize the amount of variance across different home set-ups, all four group members grew 2 onions in each pH range, of which there were four: 5.5-5.8, 6.4-6.7, 7.0-7.3, and 7.5-7.8. We hypothesize that the ideal pH with the maximum growth rate of green onions in water will be consistent with the literature, thus we expect green onions grown in the range of 6.4-6.7 to have the highest mean percent change in mass. Therefore, our null hypothesis is that if pH did not influence green onion growth, there would be no difference in the mean percent change in mass between the four pH treatments.

2. Methods

To determine the effects of pH on green onion growth, our group used green onion stems and placed them in a water solution with different pH levels. Our group created 4 different pH ranges: 5.5-5.8, 6.4-6.7, 7.0-7.3, and 7.5-7.8. The pH ranges were chosen to test acidic, neutral and alkaline conditions. Each member was tasked to grow 8 green onions, with two in each pH range, which resulted in a total of 32 green onions grown. Each solution was made by carefully mixing the Seachem acid and alkaline buffers into four separate large containers filled with distilled water. We used a calibrated digital pH meter to confirm and adjust the pHs. The green onions were then cut approximately 2 inches above the stem and were separated into 8 different containers, with the roots intact. After applying labels on the containers that indicated the pH range, the corresponding pH solutions were poured into the containers leaving roughly an inch of green onion above the solution.

Figure 1. Experimental Set-up

The green onions were left to grow in the pH solutions for one week and placed near a window with access to sunlight. The pHs of the solutions were measured daily through the use of a digital pH meter and the growing solutions were occasionally rebalanced as needed. Every day throughout the experimentation week, green onions were removed from the growing cups, shaken to remove excess water and gently patted with a paper towel before weighing them on a digital scale that measured down to 0.01g. After the one week growth period, final weight of the green onions was recorded.

2.1. Calculations, Graphing, and Statistical Analysis

After a week of measurements, the final weight and initial weight of the green onions were compared to determine the amount of growth; which was proxied by calculating the percent change in mass, refer to the Appendix. Data was then compiled into a group compendium. Means were generated and graphed in R version 4.0.3 (R Core Team, 2013); in addition, an ANOVA statistical test was performed to compare the means.

3. Results

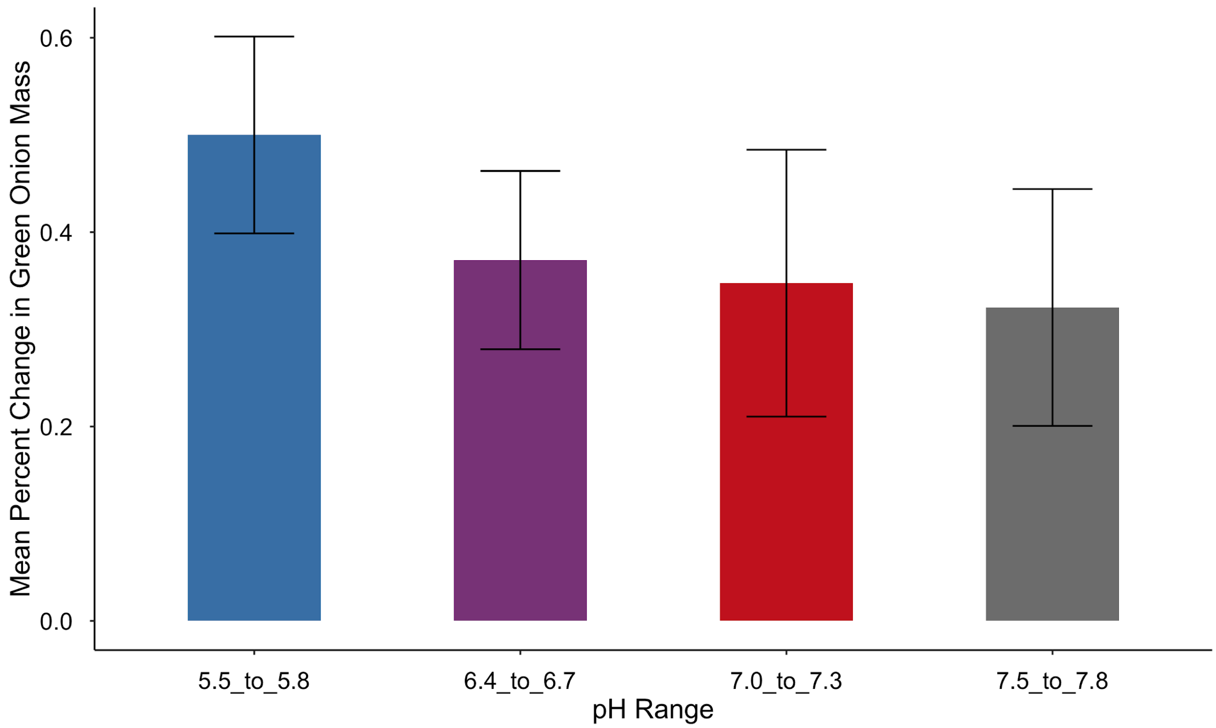

Figure 2. Mean percent change in green onion mass compared to various pH ranges. Green onions were grown in different solutions where various pH ranges were manipulated and maintained following Methods 2.1. Error bars represent standard error, n=8 for each treatment, and total N=32.

Mean growth, as proxied by mean percent change in green onion mass, compared to the various pH ranges (see Methods 2.1.) appeared to have differences in the means. Looking at Figure 2, we see the mean percent change in green onion mass of the four pH ranges with error bars showing standard error, which appear to show different means. All groups had significant variation in percent change in mass, which is indicated by the large standard error bars present. The highest mean percent change in mass was found in the pH range of 5.5 to 5.8 (mean= +50%) and the second highest mean was found in the pH range of 6.4 to 6.7 (mean= +37%). Closely behind, the third largest mean was at pH 7.0 to 7.3 (mean= +35%). Lastly, the pH range of 7.5 to

7.8 had the lowest mean percent change in mass (mean= +32%). However, an ANOVA statistical test revealed that there was no statistical difference in the means (df = 3, F-value = 0.4506, p-value = 0.7189).

4. Discussion

In our analysis, we found that the results have a p-value of 0.7189. This means that at a 95% confidence interval, our results are not statistically significant. That is to say, there is no significant difference in percent change in green onion growth when using the pH ranges 5.5-5.8, 6.4-6.7, 7.0-7.3, and 7.5-7.8. Thus, we fail to support our hypothesis that the green onions grown in the pH range 6.4-6.7 will have the highest mean percent change in mass and also fail to reject our null hypothesis.

We decided to use mass to measure how well the onions grew in each pH treatment because the length of green onion stalks may result in bias towards longer, skinnier green onion plants. As green onions vary greatly in thickness and length, it is important to measure mass as it gives a more accurate reading of how the green onion's biomass is changing. Furthermore, using mass also helped us account for root growth, which would add to the overall weight of the plant. Our green onions all had different length or number of roots which may have affected nutrient absorption because longer and more complex root structures promote water and nutrient absorption (Zhang et al., 2020).

There is a broad range of pH that researchers view as optimal for plant growth. A pH range of 5.5-6.5 has been reported to be optimal for most species (Islam et al., 1990, as cited in Kane et al., 2006), however Bugbee (2003) as cited in Kane et al. 's 2006 paper considers the optimal nutrient availability in hydroponics to occur at a pH of 5.8. This could be because at higher pHs, the availability of nutrients such as magnesium, calcium, potassium, and phosphate are slightly reduced, whereas the availability of manganese, copper, zinc, and especially iron is significantly decreased (Bugbee, 2003, as cited in Kane et al., 2006). This aligns with our results where we saw that the greatest mean of percent change in growth was observed in the pH range 5.5-5.8. Despite this explanation, we found no statistical difference in growth. This may have been due to the sample size used in our experiment (see Methods 2.). The large error bars of Figure 2 are indicative of a less than adequate sample size.

Unlike Kane et al.'s study, which used UV lights of different wavelengths, as well as nutrient solutions, our study focused exclusively on pH, and thus no nutrients were used. The UV source for our green onions came through sunlight that the plants were exposed to through window light. However, because this experiment was conducted at four different locations with different altitudes and sun availability, the amount of UV light that our green onions were exposed to could be different and thus a confounding variable in plant growth. This could also help to explain the large degree of variability that we found in our results.

A potential source of error is that there may have been excess water on or in the green onions, which would lead to an increased mass measured during weighing. In other studies such as Kane et al.'s 2006 study, water weight was accounted for by drying out the onions at 100^0C until completely dry. In future experiments, this technique could be used to account for water weight, which might help give more accurate results. Another potential source of error is that the water pH often changed overnight and would have to be adjusted the next morning, which could have affected our results. In order to maintain the right pH levels, we could implement an automatic pH controller and use a recirculating system to prevent pH fluctuations.

In addition, the physical removal of the green onion from the water cup may have influenced growth. Mitchel (1996) revealed that mechanically disturbing growing plants on a frequent basis may inhibit and stunt growth. Therefore, it is possible that the frequent weighing process (see Methods 2.) could have reduced the growth rate of the green onions. However, as all onions were handled somewhat equally, it is unknown as to whether the disturbances affected one group more than another and to the degree in which it did.

Further research could look into more drastic pH ranges such as pH of 5.0 to 5.3 and pH of 8.0 to 8.3 along with the four pH ranges we used, to see a more appreciable trend in growth levels as the onions move away from their optimal pH. A larger sample size could also be used for more effective statistical analysis. Additional research could additionally look into growing alternative crops that can also grow using hydroponics such as leaf lettuce, bok choy, and garlic chives at the same pH ranges (Tiffany, 2020).

5. Conclusion

Our results show that the mean percent change in green onion mass of our 4 different pH ranges was not significantly different (p-value = 0.7189). This means that not only do we fail to support our hypothesis, but we also fail to reject our null hypothesis suggesting that the pH does not influence green onion growth.

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7. Literature Cited

Cerozi, B. D. S., & Fitzsimmons, K. (2016). The effect of pH on phosphorus availability and speciation in an aquaponics nutrient solution. Bioresource Technology, 219, 778–781. https://doi.org/10.1016/j.biortech.2016.08.079

Climate Change: Atmospheric Carbon Dioxide | NOAA Climate.gov. (2020). Retrieved April 7th, 2021 from https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

Crosson, P.R. & Brubaker, S (1982). Resource and Environmental Effects of U.S. Agriculture (1st ed.). *Routledge*. https://doi-org.ezproxy.library.ubc.ca/10.4324/9781315659800

Doney, S. C., Fabry, V. J., Feely, R. A., & Kleypas, J. A. (2009). Ocean Acidification: The Other CO_2 Problem. *Annual Review of Marine Science*, 1(1), 169–192. https://doi.org/10.1146/annurev.marine.010908.163834

Global hydroponics market worth USD 395.2 million by 2022 - analysis, technologies & forecasts report 2016-2022 - vendors: American hydroponics, general hydroponics, lumigrow - research and markets (11/28/2016). NewsRx.

Judith. (2019, Aug 30). *pH in Hydroponics: How to Maintain the pH Levels of Hydroponic Systems*. JENCO. Retrieved April 5, 2021, from https://blog.jencoi.com/ph-in-hydroponics-how-to-maintain-the-ph-levels-of-hydroponic-systems

Kane, C. D., Jasoni, R. L., Peffley, E. P., Thompson, L. D., Green, C. J., Pare, P., & Tissue, D. (2006). Nutrient Solution and Solution pH Influences on Onion Growth and Mineral

Content. *Journal of Plant Nutrition*, 29(2), 375–390. https://doi.org/10.1080/01904160500477028

Kuhns, M. & Koenig, R. (n.d.) *What is Iron Chlorosis and What Causes it?* Utah State University Forestry Extension. Retrieved April 6, 2021, from https://forestry.usu.edu/trees-cities-towns/tree-care/causes-iron-chlorosis

Mitchell, C. A. (1996). Recent Advances in Plant Response to Mechanical Stress: Theory and Application. *HortScience*, *31*(1), 31–35. https://doi.org/10.21273/hortsci.31.1.31

Oldham, L. (n.d.) *Secondary Plant Nutrients: Calcium, Magnesium, and Sulfur.* Mississippi State University Extension Service. Retrieved April 6, 2021, from http://extension.msstate.edu/publications/secondary-plant-nutrients-calcium-magnesium-and-sulfur

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Singh R & Singh G. S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energy, Ecology, and Environment,* 2, 296–316. https://doi.org/10.1007/s40974-017-0074-7

Tiffany. (2020, May 5). 10 Ways to Regrow Food in Water. *Don't Waste the Crumbs*. https://dontwastethecrumbs.com/regrow-food-water/

World Population Prospects - Population Division. United Nations (2019). Retrieved April 7th 2021, from https://population.un.org/wpp/

Zhang, H., San, M.L., Jang, S.G., Lee, J.H., Kim, NE., Lee, A.R., Park, S.Y., Cao, F.Y., Chin, J.H., Kwon, S.W. (2020) Wide Association Study of Root System Development at Seedling Stage in Rice. *Genes.* 11(12):1395 https://doi.org/10.3390/genes11121395

8. Appendix

Carbon Dioxide Dissolution in Water

[$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO^{3-}$]

Percent change in mass was determined by the following formula:

$$\frac{Mass_{final} - Mass_{initial}}{|Mass_{initial}|} \times 100 .$$

Table 1. Raw data of the percent change in mass according to pH range

pH_range	percent_change_mass
5.5_to_5.8	37.50%
5.5_to_5.8	36.40%
5.5_to_5.8	8.71%
5.5_to_5.8	19.05%
5.5_to_5.8	57.10%
5.5_to_5.8	60.65%
5.5_to_5.8	87.11%
5.5_to_5.8	80.48%
6.4_to_6.7	26.13%
6.4_to_6.7	47.80%
6.4_to_6.7	6.54%
6.4_to_6.7	-1.79%
6.4_to_6.7	33.08%
6.4_to_6.7	50.36%
6.4_to_6.7	65.57%
6.4_to_6.7	69.34%
7.0_to_7.3	15.81%
7.0_to_7.3	22.74%
7.0_to_7.3	-7.01%
7.0_to_7.3	-17.24%

7.0_to_7.3	73.77%
7.0_to_7.3	29.89%
7.0_to_7.3	92.03%
7.0_to_7.3	62.20%
7.5_to_7.8	-2.10%
7.5_to_7.8	8.98%
7.5_to_7.8	3.92%
7.5_to_7.8	12.08%
7.5_to_7.8	25.66%
7.5_to_7.8	38.16%
7.5_to_7.8	93.98%
7.5_to_7.8	68.10%