How Much is Too Much? The Effects of Water Hardness on Green Onion Plant Growth

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Abstract

Similar to how people require minerals in order to maintain bone density and health, plants require minerals so that they can build sturdy cell walls and develop healthy root systems. Water hardness is understood to be a measurement of the concentration of minerals dissolved in any volume of water. This study was conducted to test the effect of water hardness on plant growth. Epsom salts were used to test how much *Allium fistulosum* (green onions) grew over eight days at different levels of water hardness. We hypothesized that the addition of salts would positively impact root growth and predicted that the onion placed in the highest salt concentration would have the highest growth. Results were compared between the controls, which were jars with green onions in soft tap water and other treatments at varying degrees of water hardness. Results indicated that the onions that were placed in soft water without additional Espom salts showed the most growth. The control had the highest mean growth of roots at 1.35 cm. A possible rationale for this outcome was that the excess minerals used had a negative effect by hindering root growth. One implication that the study has is that it can help in future similar studies that examine green onions or other plants' growth at different levels of water hardness.

Introduction

Allium fistulosum (green onions) are known for their versatility and effectiveness in providing a source of essential vitamins to humans when consumed. Their subtle taste and high vitamin C content make them a widely used vegetable in cooking (Inman). The vitamins provided by green onions are housed within their stems. Therefore, in order to yield plants of greater nutritional value it is important to consider which growing conditions are successful in promoting pseudostem growth over lateral growth (Tendaj and Mysiak 4). Hydroponic systems are becoming a more common method for cultivating vegetables around the world (Souza et al. 2). Hydroponic systems rely on water, rather than soil, to promote growth. As a result, it is important to investigate the effects that varying water types may have on the growth of vegetables in hydroponic systems.

Green onions are capable of growing in many countries, making them exposed to varying levels of water hardness. Water hardness can be classified as the amount of dissolved minerals in water. Specifically, water hardness is measured in terms of calcium and magnesium content; as calcium and magnesium ion concentrations increase, water hardness increases. Soft water is classified as having less than 17 mg/L of Ca^{2+}, slightly hard between 17-60 mg/L of Ca^{2+}, moderately hard between 60-120 mg/L of Ca^{2+}, hard water has 120-180 mg/L of Ca^{2+}, and very hard is any concentration of Ca^{2+} above 180 mg/L (Arthur et al. 1). Ca^{2+} is known to be an essential element for cell growth and development in plants (Hepler 2142). Mg^{2+} is also an important nutrient for plant growth and development as it is involved in enzyme activities and the structural stabilization of plant tissues (Guo et al. 83).

In order to better understand the effects that water hardness may have on the yield of valuable green onion crops we measured the growth of green onion roots within four hydroponic systems of differing water hardness measures. Water hardness can effectively be increased through either the addition of calcium sulfate dihydrate or magnesium sulfate heptahydrate (Barnes et al. 223). From this, we deduced that the use of Epsom salts (magnesium sulfate) would be effective in altering water hardness for our treatments. Our experiment was conducted within the Greater Vancouver region of British Columbia, which is known to have soft water ranging from 2.5-4.9mg/L of $CaCO_3$ (Metro Vancouver). Through the consideration of the vital roles both calcium and magnesium play in plant growth and development we predicted that if water hardness significantly impacts plant growth, then increasing water hardness will promote the growth of green onions.

Materials

The materials used for this experiment to test the effect of the hardness of water on plant growth included 16 mason jars of a capacity of 500 ml each, unscented Epsom salts (Magnesium Sulphate ($MgSO_4$)) tap water and 16 green onions (*A. fistulosum*).

Methods

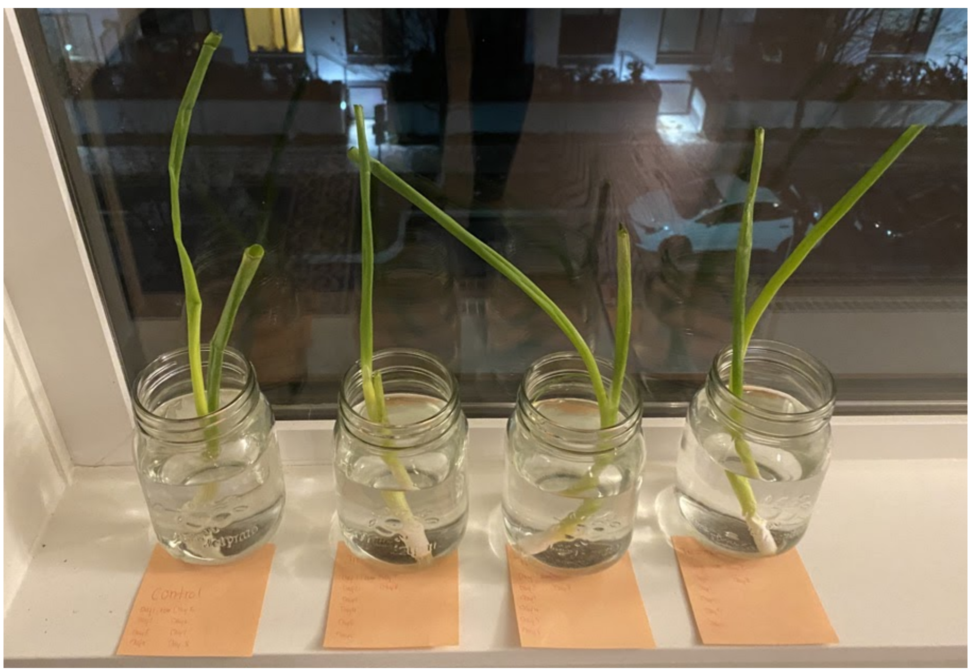

Figure 1- Initial setup of the experiment from left: 1 control and 3 experimental jars (2.5g, 5.0g and 7.0g of epsom salts)

The experiment included 4 replicas of a design involving 4 mason jars with different content of Epsom salt (see fig.1) . Each green onion root was cut up to 1 cm in length to measure its growth. The first jar was the control which had an individual green onion placed in 450 mL of tap water, since tap water is soft it is considered to have no salts. The next jar had the onion with 2.5 g of Epsom salts, followed by 2 more jars with onions containing 5.0 g and 7.5 g of salt respectively. In conjunction with the epsom salts, each jar was filled with 450 mL of tap water. These 4 replicas were placed in a location at each member's house such that the amount of sunlight and wind was the same for each of the 16 jars. Optimal room temperature was maintained for each jar during the experiment. Every day, for 8 days the growth in the roots of each of the 16 onions was noted. Since all the 4 set-ups were made around 9-11 pm on the first day all consecutive measurements were taken with a ruler at the same time for the following 8 days of the experiment.

Any other observations such as wilting and sudden sprouts were noted as observational changes. Additional changes in the onions other than the growths in roots included the growths in the stock, slight wilting of the stock as day 8 approached.

Results

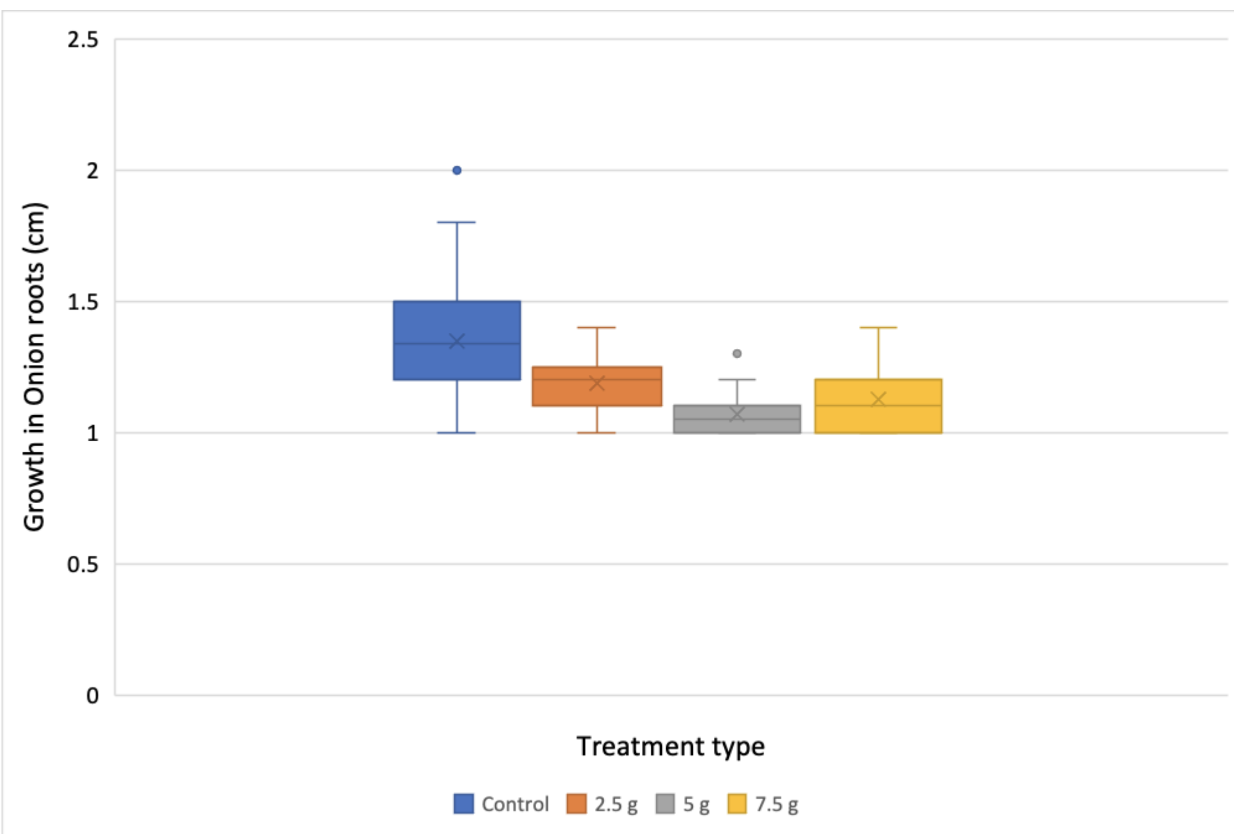

Figure 2- *A. fistulosum* root growth over 8 days for each of the four treatment types (varying amount of Epsom salt). For each treatment type the sample size was n=36 thus the total sample size was N=144. The box plot represents 25% and 75% percentiles (horizontal-line=mean). The upper and lower whiskers extend to the minimum and maximum values.

A. fistulosum root length was measured over a 8 day period in varying Epsom salt concentrations. Sampling size was 36 for each of the 4 treatments, thus the total sample size was N=144. The mean root length for the control was 1.35 cm which was the highest mean root length. Treatment 2 (5 g of Epsom salt) had the lowest mean root length of 1.07 cm (Figure 2). There is a clear difference in means between all the treatment groups (Figure 2).The standard deviation for the control was 0.2557 which was the highest mean standard deviation. Treatment 2 had the lowest standard deviation of 0.0822 (Figure 2). Figure 2 also shows the confidence intervals for the varying epsom salt treatments. The control has the widest confidence interval ranging from 1.27-1.43. Treatment 2 which had 5 grams of Epsom salt added had the smallest confidence interval range of 1.04-1.10.

A one-way ANOVA with a significance level of a=0.05 was done on the data collected. This resulted in a p-value of 5.83018E-11 and an F-ratio of 20.2545673 (df=3), thus there are significant differences between all the treatment types. A Tukey test was then performed which showed significant differences between the control and treatment 1 (Q= 6.14, p=0.00016) ,control and treatment 2 (Q= 10.45, p=0.00000), control and treatment 3 (Q= 8.27, p=0.00000), and treatment 1 and treatment 2 (Q= 4.31, p= 0.01446). The control was significantly different from all the other treatment types. Treatment 1(2.5 g Epsom salt) and treatment 2 (5.0 g Epsom salt) were statistically significantly different as well.

	Control	Treatment 1 (2.5 g)	Treatment 2 (5 g)	Treatment 3 (7.5 g)
Mean root length (cm)	1.35	1.19	1.07	1.13

Std.Dev	0.2557	0.1107	0.0822	0.1365
Confidence Interval	1.27 - 1.43	1.15 - 1.22	1.04 - 1.10	1.08 - 1.17

Figure 3 - Mean root length from an 8 day growing period of *A. fistulosum* for each treatment type (varying amount of epsom salt) with the standard deviations. The sample size was n=36 for each treatment type for a total sample size of N=144. The 95% confidence interval for each of the treatment types is also calculated.

Discussion

In this experiment, average root lengths of the different treatments were compared, with the control group showing the most growth. Treatment 1 (2.5 g Epsom salts) showed the second most growth, with treatment 3 (7.5 g) and treatment 2 (5 g) following sequentially. The one-way ANOVA test yielded a p-value of 5.83018E-11, which is statistically significant at a significance level of a=0.05. We therefore fail to reject our hypothesis and can confirm that the variation between our treatment levels was not simply due to chance.

The interpreted results contradicted our initial prediction that increased water hardness would benefit the growth of green onion plants (*A. fistulosum*). A possible explanation for this was that the Epsom salts hindered the growth of the green onions once their concentration passed a certain threshold. Mineral toxicity is a phenomenon that occurs when excess mineral concentration interferes with growth and development, and applies to plants as well as any other living organisms (White et al. 739). A study conducted by Kane et al. examined the effects of nutrient and mineral concentrations on the growth of several onion varieties, including *A. fistulosum*. The results of this study found that total biomass of the onion plants was most enhanced by their “half-strength” custom solution, rather than treatments with significantly higher concentrations of minerals such as magnesium (Kane et al. 381).

A different study by Arthur et al. that similarly examined the effects of pH and water hardness in reference to the yield of their crops found that an increase in Ca^{2+} significantly improved plant growth when conditions were neutral or alkaline (5). However, when Ca^{2+} concentrations were too high (>250 mg/L), plant growth was instead hindered (Arthur et al. 7). As mentioned in the methods & materials section, the amount of Epsom salts added was incrementally increased by 2.5 grams for each respective treatment, and the water volume was kept constant at 450 mL for all treatment levels including the control. A quick calculation then tells us that at the lowest treatment level, we would have a concentration of roughly 5,555 mg/L of Epsom salts in our jars of water. Although we do not know what percentage of this solution would dissociate into Mg^{2+}, and it may not be completely accurate to compare between calcium and magnesium at a 1:1 ratio, the water hardness concentration of our experiment is still many times larger than that of previous studies also examining similar effects of minerals on plants. This line of reasoning may therefore provide some insight as to why the growth of our green onions was most prominent at the “soft” control level.

There were several limitations of this project that may have impacted our findings. Although conditions were kept as consistent as possible, there was no controlling for all factors since each group member was conducting the experiment independently from their own home. The treatment jars were placed by the window in order to obtain sufficient sunlight, but differences in topography may have influenced the amount of light each set of replicates was exposed to. Another limitation was the size of the equipment used, and the space of the environment. As mentioned above, we ended up with a very high concentration of Epsom salts across our treatment levels. Provided we had used containers with larger volumes of water, we could have obtained a more dilute concentration of water hardness, thus potentially yielding results more in line with our prediction. Since the experiment was conducted in each group member's home, lack of space to accommodate very large containers of water was something that needed to be taken into consideration.

Conclusion

The purpose of our study was to determine whether or not water hardness has a significant effect on the growth of green onion plants. Based on the results of a one-way ANOVA test, we were able to confirm that the differences between treatment groups were significant, with the most growth occurring at the lowest level of water hardness. While the results obtained from the experiment were statistically significant, it is worth noting that these results differed from our initial prediction. Future studies should be especially mindful of ensuring that water hardness levels are reasonable by either using more precise equipment to measure very small quantities of Epsom salts, or using much larger volumes of water to dilute the mineral concentration.

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