Effects of Increasing Fertilizer Amount on Green Onion Stalk and Root Growth

Authors: Katy Kazemi Arbat

Katayounk96@gmail.com

Abstract

Nitrogen, phosphorus, and potassium, or the "Big 3" are the primary nutrients that play a fundamental role in plant growth and productivity. Growth is defined as a process that brings about a permanent and irreversible change in any plant or its parts in respect to its size, form, weight, length, and volume, and the growth analysis for this experiment was aimed to capture changes in terms of root and stalk length. The objective of this study was to test the effects of increasing concentration of fertilizer on the root and stalk growth of green onions in two weeks. Eighteen green onions were divided into six groups of three where different groups received different concentrations of fertilizer and the growth of these vegetables was closely monitored and recorded. We hypothesized that if fertilizers containing big 3 (nitrogen, potassium, phosphorus) enhance growth, then increasing fertilizer amount should lead to increased growth of root and stalk of green onions. To assess our hypothesis, we performed a separate one-way ANOVA analysis of our data collected on the root and stalk length. We concluded that an increase in fertilization addition led to increased root growth however the effects of fertilizer on the growth of the stalk system were insignificant.

Introduction

Nitrogen, phosphorus, and potassium, or the "Big 3" are the primary nutrients that play a fundamental role in plant growth and productivity (Xu et al., 2020). They are the dominant rate-limiting nutrients in most natural systems and the major constituents of agrochemical fertilizers (Guignard et al., 2017). Nitrogen is essential in the formation of many proteins that make up plant tissue (Razaq et al., 2017). It is absorbed in large quantities and its application affects plant morphology, nutrient availability, and net photosynthesis (Razaq et al., 2017). Phosphorus is also linked to a plant's ability to use and store energy through photosynthesis as well as its ability to sustain optimum production and quality (Razaq et al., 2017). Phosphorus is the primary nutrient when it comes to cell division, reproduction, and plant metabolism (Razaq et al., 2017). Potassium is the third key nutrient that helps strengthen plants in resisting diseases and also plays an important role in overall crop yield and quality (Razaq et al. 2017). Nitrogen makes almost 80% of the gas in the atmosphere and microbes present in soil are constantly converting nitrogen into forms that plants can use through mechanisms such as “nitrogen fixation” and some plants don't even have such mechanisms and rely on other plants or fungi to transform nitrogen for them (Jacoby et al., 2017). Phosphorus becomes available through similar mechanisms in the soil for plants, most areas such as forests, wetlands, and tundras often remain nitrogen or phosphorus-limited (Jacoby et al., 2017). Additionally, when crops are harvested, important nutrients are removed from the soil and if the soil isn’t replenished with nutrients through fertilizing, crop yield will deteriorate over time (Jacoby et al., 2017). This is why farmers add these nutrients to their fields via fertilizers which essentially are plant foods to help restock primary elements in the soil (Guignard et al. 2017). However, too much food isn't always necessarily beneficial either. Fertilizer recommendations contain several important factors, including fertilizer form, source, application timing, placement, and irrigation management (Reid, 2006). Another important part of a fertilizer recommendation is the amount of a particular nutrient to apply (Reid, 2006). Although different plants require different amounts of these nutrients for optimal growth, it's important to know the appropriate level of fertilizers necessary for ensuring optimal plant production and quality (Razaq et al. 2017). Growth is defined as a process that brings about a permanent and irreversible change in any plant or its parts in respect to its size, form, weight, length, and volume (Hsiao & Xu, 2000), and the growth analysis for this experiment will aim at capturing changes in terms of root and stalk length. The green onion plant is made of two parts, a white bottom part that has the roots, and the green top part which grows above the soil on a long stalk. The objective of this study was to determine whether or not increasing fertilizer containing the “big 3” concentration leads to increased root and stalk growth in green onions. It was hypothesized that if fertilizer containing “big 3” enhances growth, then increasing fertilizer amount should lead to increased growth of the root and stalk of green onions. The null hypothesis on the other hand predicted that there will be no difference in the growth of green onions groups receiving different fertilizer amounts.

Methods

To test the effect of increasing amounts of fertilizer on plant growth, cut green onions were used in this experiment. Eighteen green onions were purchased from Loblaws city market in West Vancouver, BC. The stalks of each green onion were cut from below the point where the onion starts to turn green. The roots were not trimmed, however, green onions with roots approximately the same length (around 1 cm) were chosen upon purchase. The onions were divided into 6 groups of three and the initial root length and stalk length from above the point where the onions start to turn green for each of the green onions was measured and recorded. Out of the six groups, five received fertilizers with different concentrations and the last group was the control group that only received water but no fertilizer. Dr. Earth’s liquid solution of N-P-K 3-3-3 fertilizer was used for this experiment. To prepare the fertilizer water solution with different concentrations, the manufacturer's recommended amount for one gallon of water was calculated and transformed for one cup of water. To make the first solution with the recommended fertilizer concentration, 7.4 ml (two and half of a teaspoon) was added to 237 ml (one cup) of water. The amount of fertilizer for the following groups was increased by half teaspoon increments so that the second group will receive 3 teaspoons per one cup of water and the third group will receive 3.5 teaspoons per one cup of water and so on (see table 3 in the appendix for the exact amount of fertilizer added to each group). The water volumes were kept constant. What changed between groups was the amount of fertilizer added. After the solutions were prepared, initially the cut onions were placed into small shot glasses, where the bulb of the plant can stand up and the solutions were poured into the glasses so that the roots and the bulb were completely submerged in the water and the top of the stem stayed above water. The cups were placed by the windows and their growth was observed and recorded over 14 days. The onions were taken out of the solution every two days and the size of their stalk was measured and recorded. The length of the root was only recorded once at the end of a 14-day trial. The water fertilizer solution was also renewed every two days where new solutions with the same increments as before were prepared and the cut green onions were placed back into the containers. By the end of day four, the green onions were big enough to be transferred into a cup. For those onions that had more than one stalk growing or the initial stalk had split into two with different lengths, the length of the tallest stalk was recorded. After data collection was complete, the average root and stalk length of each group were calculated and recorded. To test the statistical significance of increased fertilized amount on green onion root and stalk growth, one-way ANOVA analysis was performed using the final recorded length of roots and stalks. The one-way ANOVA analysis was performed separately for root and stalk growth.

Results

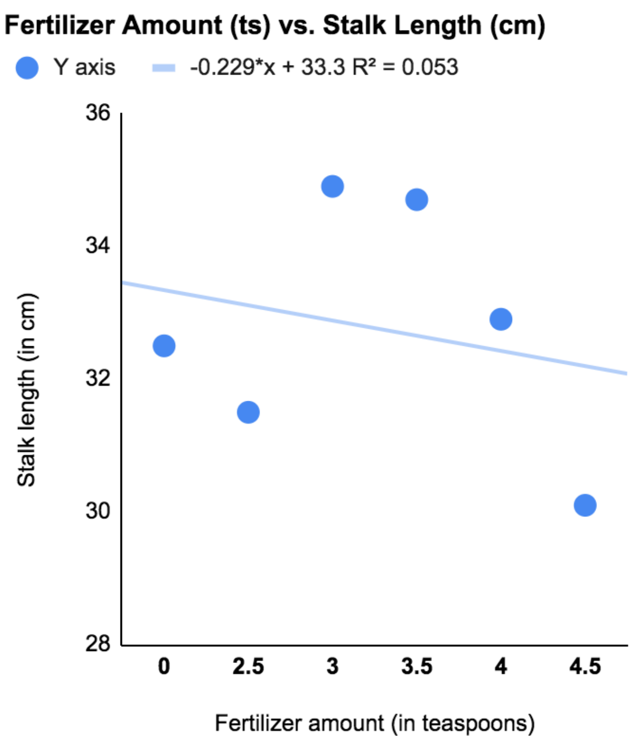
Stalk length data was gathered for fourteen days, every two days from each group growing in solution with different fertilizer concentrations. However, root data was only collected once at the end of a 14-day trial. See Tables 4 and 5 of the appendix for raw data collected of root and stalk growth length. One-way ANOVA analysis was performed separately for root and stalk growth. Tables 1 and 2 from the appendix section present the results of one-way ANOVA analysis performed for root length and stalk length respectively. Since there was only one variable in our experiment, one-way ANOVA analysis was performed using the Single-Factor ANOVA function from XLMiner Analysis ToolPak on Google Spreadsheet to analyze the data for significance. The alpha value represents an acceptable probability of a Type I error in a statistical test and since our confidence level was 0.95, the alpha value for the analysis was selected to be 0.05 for this one-tailed test. As presented in table 6 below the mean root length calculated was highest for group 3 with 3.5 teaspoons of fertilizer added and the mean stalk length calculated was highest for group 2 with three teaspoons of fertilizer added.

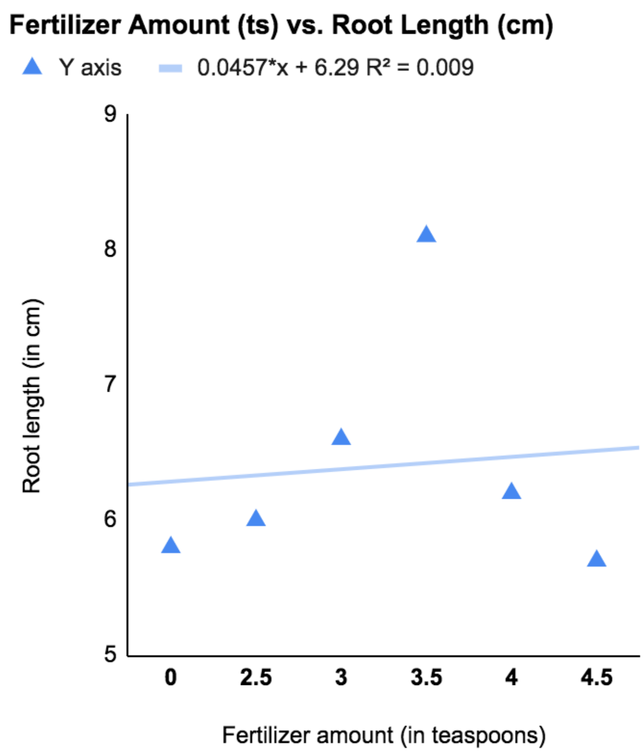
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6 (Control)
Mean root length	6.0	6.6	8.1	6.2	5.7	5.8
Mean stalk length	31.5	34.9	34.7	32.9	30.1	32.5

Table 6. *Demonstrates the mean value calculated for root and stalk length (in cm) after 14 days for each group with different fertilizer concentrations. Group 1 had the least amount of fertilizer added (manufacturer's recommended amount) and the amount of fertilizer added was increased by half teaspoon increments for each group where group 5 had the most amount of fertilizer added. Group 6 was the control group with no fertilizer added.*

Scatter plots were graphed to look at the relationship between fertilizer concentration added root and stalk growth. Graphs 1 and 2 below present the scatter plots for the amount fertilizer added versus stalk length and root length respectively. A trendline was added to both graphs to visually demonstrate the correlation between the two variables where for graph 1 there was a negative correlation and for graph 2 there was a positive correlation between two variables.

When it comes to qualitative observations, groups 1, 2, and 3 looked much fresher compared to the other experimental groups that either didn't receive any fertilizer or received way more fertilizer than the manufacturer's recommended amount. The fastest growth period was between day 6 to day 10 and the growth started to slow down again after day 10 until day 14 (see appendix for raw data).





Graph 1. *Illustrates a scatter plot of the relationship between stalk length (in cm) and fertilizer amount (in teaspoons) for 6 groups of green onions grown in varying fertilizer concentrations. A negative trendline was also added to the data series for a negative correlation between two variables.*

Graph 2. *Illustrates a scatter plot of the relationship between root length (in cm) and fertilizer amount (in teaspoons) for 6 groups of green onions grown in varying fertilizer concentrations. A positive trendline was also added to the data series for a positive correlation between two variables.*

Discussion

To determine whether or not the means of the 6 groups were significantly different in terms of root and stalk length, F calculated with F critical in addition to P-value with the alpha value were compared (See Tables 1 and 2 for ANOVA analysis summary). Since F calculated > F critical and P-value < alpha value for stalk length, the null hypothesis was rejected which predicted that there was no difference between means of different groups receiving different fertilizer amounts. However F calculated < F critical and P-value > alpha- value for root length, therefore we were unable to reject the null hypothesis predicting no difference among means of different groups with different fertilizer concentrations in terms of stalk growth. The highest stalk growth was observed for group 2 which received 3 teaspoons of fertilizer, only half a teaspoon higher than the manufacturer recommended amount. Additionally, the control group that didn't receive any fertilizer had slightly higher growth in length of stalk. If we look at the scatter plots for the amount of fertilizer added vs stalk length as well as the scatterplot for the amount of fertilizer added vs root length from the result section we can see that there was a negative correlation between fertilizer amount and stalk length meaning that increasing fertilizer amount results in less stalk length growth. We can also see the positive correlation between fertilizer amount and root length meaning that increasing fertilizer amount leads to increased root length growth. For this experiment, the dataset was relatively small, which might also be why the best fit line does not perfectly include all the data points in graphs 1 and 2. Therefore to confirm such a trend using a scatter plot, larger datasets are required for future experiments.

Although according to the ANOVA analysis the difference between means of six groups measured for root length was significant, the accuracy of the root length measurement is something that should be taken into account as it could have affected the accuracy of the out statistical analysis. Since measuring the root length of the entire root system of each green onion was a hard and time-consuming task, only the length of the longest root was chosen to be measured at the end of the 14-day trial. This approach can be problematic as one root is not the best representative for the entire root system and does not accurately account for the plant's response to different fertilizer concentrations. Therefore there is a large uncertainty associated with root length measurements and related statistical analysis. When it comes to the stalk of green onions, growth was slow in the beginning up until day 6. The fastest growth period was between day 6 to day 10 and growth slowed down again after day 10 until day 14 which may be due to varying sunlight exposure, as some days were sunnier than others and this may have reflected in the plants' growth. Additionally, group 1, 2,3 looked fresher compared to those groups that either didn't receive fertilizer or received too much fertilizer. This is just one piece of evidence demonstrating that too much fertilizer is not always beneficial for the plant. The effects of fertilizer on plant health and freshness are something that could be explored further. Having said that, this experiment looked at the effects of fertilizer containing nitrogen, potassium, and phosphorus with an equal 1:1:1 ratio on the growth of stalk and root of green onions. Future studies can further explore the effects of fertilizers containing different ratios of these nutrients on the growth of plants and how different ratios can result in the optimum growth of different types of plants.

There were some limitations associated with this experiment. To begin with, as mentioned before, sunlight exposure was not consistent throughout the course of this 14-day trial as some days were sunnier than others and this varying sunlight exposure could have affected the growth of green onions in many ways. Additionally, evaporation was something that we did not account for and since the cups were uncovered we suspect that some of the water could have evaporated leaving a higher concentration of fertilizer in the solution and ultimately dehydrating the plant. However, since the water fertilizer solutions were renewed every two days we hope that the effects of this evaporation were minimized to an extent. The amount of fertilizer added was also associated with some uncertainty since we lacked the proper apparatus to measure the exact amount of fertilizer to be added and rough amounts were measured out with teaspoons instead. The water fertilizer solution was also changed every two days to ensure optimal growth where the concentrations were subject to some degree of uncertainty. This was done since the bottom portion of the plant can get mushy if the solution is not fresh and prevent optimum growth. Finally, this experiment was conducted by growing green onions in waters whereas in reality these vegetables are grown in soil, and to test the effects of fertilizer on their growth, it's important to mimic their actual growth environment as closely as possible and repeat this experiment for green onions growing in soil.

Conclusion

In conclusion, based on our findings and statistical analysis, increasing fertilizer concentration is associated with increased growth of the root of the plant however this association is insignificant when it comes to the effects of fertilizer concentration on the growth of stalks. Our measurements and analysis of root data resulted in the rejection of the null hypothesis whereas the same analysis of the stalk data led to failure to reject the null hypothesis. Further investigation is required to confirm the result of our findings as this study was subject to many limitations and uncertainties that can be avoided in future studies.

References

Guignard, M. S., Leitch, A. R., Acquisti, C., Eizaguirre, C., Elser, J. J., Hessen, D. O., … Leitch, I. J. (2017). Impacts of Nitrogen and Phosphorus: From Genomes to Natural Ecosystems and Agriculture. *Frontiers in Ecology and Evolution*, *5*. https://doi.org/10.3389/fevo.2017.00070

Hsiao, T. C., & Xu, L. K. (2000). Sensitivity of growth of roots versus leaves to water stress: biophysical analysis and relation to water transport. *Journal of Experimental Botany*, *51*(350), 1595–1616. https://doi.org/10.1093/jexbot/51.350.1595

Jacoby, R., Peukert, M., Succurro, A., Koprivova, A., & Kopriva, S. (2017). The Role of Soil Microorganisms in Plant Mineral Nutrition—Current Knowledge and Future Directions. *Frontiers in Plant Science*, *8*. https://doi.org/10.3389/fpls.2017.01617

Razaq, M., Zhang, P., Shen, H.-long, & Salahuddin. (2017). Influence of nitrogen and phosphorus on the growth and root morphology of Acer mono. *PLOS ONE*, *12*(2). https://doi.org/10.1371/journal.pone.0171321

Reid, K. (2006). *Soil fertility handbook*. Ontario, Ministry of Agriculture, Food and Rural Affairs.

Xu, F., Chu, C., & Xu, Z. (2020). Effects of different fertilizer formulas on the growth of loquat rootstocks and stem lignification. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-019-57270-5

Appendix

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
group 1	3	18.1	6.033333333	0.2233333333		
group 2	3	19.8	6.6	2.41		
group 3	3	24.3	8.1	1.63		
group 4	3	18.5	6.166666667	2.293333333		
group 5	3	17.2	5.733333333	0.2033333333		
group 6	3	17.3	5.766666667	0.8633333333		
ANOVA						
Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11.89333333	5	2.378666667	1.872146917	0.1732026122	3.105875236
Within Groups	15.24666667	12	1.270555556			
Total	27.14	17				

Table1. *Shows one-way ANOVA analysis statistical results for root growth in length with different fertilizer concentration (with alpha value of 0.05) where F calculated, P value and Fcritical equal 1.87, 0.17 and 3.11 respectively.*

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
group 1	3	94.6	31.53333333	4.643333333		
group 2	3	104.6	34.86666667	1.213333333		
group 3	3	104	34.66666667	0.7233333333		
group 4	3	98.9	32.96666667	0.1733333333		
group 5	3	90.2	30.06666667	0.8233333333		
group 6	3	97.5	32.5	1.57		
ANOVA						
Source of Variatio	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	50.82666667	5	10.16533333	6.668221574	0.00342802257	3.105875236
Within Groups	18.29333333	12	1.524444444			
Total	69.12	17				

Table 2. *Shows one-way ANOVA analysis statistical results for stalk growth in length with different fertilizer concentration (with alpha value of 0.05) where F calculated, P value and F critical eual 6.67, 0.0034 and 3.11 respectively.*

GROUP	Fertilizer amount (in mL/ teaspoons)
1	**12.3 mL / 2.5 teaspoons**
2	**14.8 mL / 3 teaspoons**
3	**17.3 mL / 3.5 teaspoons**
4	**19.7 mL/ 4 teaspoons**
5	**22.2 mL / 4.5 teaspoons**
6	**None**

Table 3. Amount fertilizer added to each group (in mL/ teaspoons) per 1 cup or 237 mL of water

Date	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
21/3/17	Zero	Zero	Zero	Zero	Zero	Zero
21/3/19	0.77 0.80 0.75	0.82 0.80 0.79	0.82 0.82 0.75	0.76 0.70 0.75	0.75 0.75 0.72	0.75 0.78 0.75
21/3/21	3.1 2.8 3.0	3.5 3.5 2.4	3.6 3.5 3.9	2.2 3.1 3.4	4.1 2.9 3.1	3.0 3.1 3.0
21/3/23	8.2 7.5 8.9	9.0 9.2 8.9	8.7 10.2 7.2	8.5 8.6 9.0	7.5 8.2 10	8.9 6.5 9.0
21/3/25	14.2 18.2 30.2	18.5 15.3 21.3	18.3 21.0 18.9	15.3 19.5 16.6	19.2 13.5 15.7	16.4 17.7 21.8
21/3/27	26.2 29.3 30.2	29.2 28.5 31.0	30.0 29.1 28.2	26.5 24.2 29.6	27.2 24.6 22.3	29.2 22.2 20.3
21/3/29	30.1 27.5 32.2	32.5 35.2 33.7	24.9 32.1 33.5	30.2 32.4 31.6	28.3 29.8 30.1	30.3 31.9 32.8
21/3/31	29.1 32.3 33.2	33.8 34.8 36.0	35.5 33.8 34.7	32.5 33.3 33.1	30.9 30.2 29.1	33.7 31.2 32.6

Table 4. *Represent raw data for all 6 experimental groups collected in 14 days, every two days for stalk growth length (in cm) measured from where the onion started to turn green. Measurements for day one (21/3/17) were put zero since all the stalks were trimmed initially and stalk length was zero.*

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
6.2 5.5 6.4	5.1 8.2 6.5	8.4 9.2 6.7	5.5 5.1 7.9	5.7 6.2 5.3	5.0 5.5 6.8

Table 5. *Represent raw data for all 6 experimental groups collected at the end of a 14 day trial for root growth length (in cm). Only the longest root length visible was measured and recorded.*