The Effect of Water and Plant Food on Green Onion Growth

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ABSTRACT. *The growth of green onions in soil was studied over a two-week period. The factors studied were the amount of water and the amount of plant food, and our response variable being the growth of each green onion (in centimeters). Thus, we were investigating what combination of amount of water and amount of plant food maximizes the growth of a green onion. The optimization of the factors affecting growth were carried out using a rotatable central composite design with uniform precision, which allowed for the fitting of the full quadratic model. After compiling our results, although we found that neither the amount of water nor the amount of plant food has a significant effect on the green onions' growth over a two-week period, optimum conditions to maximize growth the green onions was found to be 5.07 cm when the amount of water was 272.43 mL and the amount of plant food was 5.41 grams.*

1. INTRODUCTION

Green onions are a versatile ingredient that can be found in almost every kitchen and used by people with no cooking experience to Michelin star chefs. Their versatility is what makes them such a popular ingredient. Whether it is just a garnish on top of ramen, an ingredient in a stir fry or fried rice, or the main ingredient in Pa-kimchi, a Korean green onion kimchi, green onions are always ready to be used. Because of their utility in the kitchen, we were motivated on how to grow green onions best. This would allow us to always have some on hand rather than having to purchase from the store every time. Although green onions can grow in just a glass of water, they grow better in soil. The purpose of this research is to investigate what combination of amount of water and amount of plant food maximizes the growth of a green onion.

2. MATERIALS & METHODS

2.1 Materials

The aim of this experiment was to find the best combination of water (mL) and plant food (g) that maximizes green onion growth (cm). Growth should be maximized because we are interested in determining what levels make the onions grow.

Table 1. Growth by Water and Food

Water (mL)	Food (g)	Water (coded)	Food (coded)	Growth (cm)
200	3	-1	-1	0
260	3	1	-1	4.5
200	5	-1	1	4
260	5	1	1	1.5
230	2.59	0	-1.414	2
230	5.41	0	1.414	1.5
187.57	4	-1.414	0	2.5
272.43	4	1.414	0	1.5
230	4	0	0	1
230	4	0	0	4
230	4	0	0	0.5
230	4	0	0	9.5
230	4	0	0	3
230	4	0	0	-0.5
230	4	0	0	2.5

We had 15 green onions that were divided into 15 different cups with the same amount of soil and varying levels of plant food and water, as shown in Table 1. We decided to use transparent cups so that we could see if the water was getting absorbed into the Miracle-Gro Potting Mix soil. As for the plant food, online research suggested that nitrogen results in positive growth, so we purchased one that had the highest percent of nitrogen, Miracle-Gro Water Soluble All Purpose Plant Food. When determining the amount of soil to put into each cup, our online research suggested filling our container ¾ of the way, so we filled it, packed it down, and then measured how many grams each weighed. As for plant food levels, our low level was what was recommended on the box and then we added one gram to get the center level, and one more for the high level. Thus, we had an interval of 1g between the center runs and the factorial runs, which we used to calculate the amounts necessary for our axial runs. For the water levels, we tested how much water it takes to get through all of the soil and set that as the low level. To get the factorial levels, we then subtracted and added 30 mL, then calculated the axial amounts accordingly.

2.2 Experimental Design and Procedures

This was a rotatable, central composite design that used randomization. The two levels for plant food and water were put into JMP®, Version 17.0.0. SAS Institute Inc., Cary, NC, 1989–2023 and the software automatically determined the random order that was then when planting and watering. This experiment was run over the course of two weeks where half the amounts were run at the start of week one and the remaining half was used at the start of week two. We made sure to put all of the cups in the same area outside, such that they got the same amount of exposure to the sun and wind. We also made sure to fill the cups with soil from the same bag and plant food from the same bag which accounted for any bag-to-bag variation.

Figure 1. Experiment Set-up

3. RESULTS AND DISCUSSION

3.1 Regression Model

The optimization of the variables affecting growth were carried out using a rotatable central composite design with uniform precision, allowing for the fitting of the full quadratic model. The response, Y, was initial length subtracted from final length after two weeks of growth. The selected factors were water amount, X_W, and plant food amount, X_F. The amount of soil was fixed at ¾ of a cup for all the experiments based on prior research. The matrix corresponding to the aforementioned design is shown in Table 1, and the final model obtained in coded units is:

$$Y = 2.857 + 0.073X_W + 0.037X_F - 1.75X_WX_F - 0.272X^2_W - 0.397X^2_F$$

A statistical analysis was carried out on the results and is shown in Table 2. As observed in Table 2, when Water is set at 230 mL and Food at 4 g, predicted growth is 2.857 cm. Additionally, for every 30 mL increase in Water, the predicted growth increases by 0.073 cm. Furthermore for every 1 g increase in Food, the predicted growth increases by 0.037 cm. At the 5% significance level, none of the interaction effects were significant.

Based on the Half Normal Probability Plot, see Figure 2 in the Appendix, there is slight curvature in the observations suggesting that normality is violated. As seen in Figure 3 in the Appendix, a Lack of Fit test was run on the full quadratic model showing non-significant results at the 5% significance level. Therefore, a full quadratic model is adequate for the data.

Table 2. Statistical Analysis of Effects

Term	Estimate	t Ratio	p-value
Intercept	2.867	2.74	0.0228
Water	0.073	0.08	0.9418
Food	0.037	0.04	0.9709
Water x Food	1.75	-1.27	0.2363
Water x Water	0.272	-0.27	0.7900
Food x Food	0.397	-0.40	0.6983

3.2 Optimization of the Response

There were a total of 5 unique setting combinations for the water level and plant food amount: 4 factorial runs, 4 axial runs, and 7 center runs (for a total of 15 runs) to drive prediction variance down. These settings represent the different experimental conditions tested to evaluate their impact on green onion growth. A table of summary statistics can be seen below in Table 3:

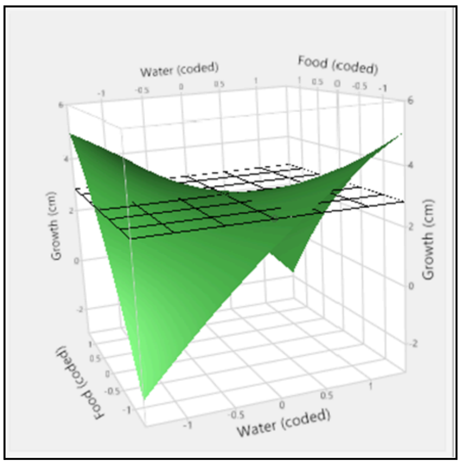
Table 3. Summary Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Water Level (mL)	230.0	26.44	187.57	272.43
Plant Food (g)	4.0	0.84	2.59	5.41
Growth (cm)	2.57	2.55	-0.5	9.5

Utilizing the CCD rotatable design, a response surface model was constructed using the provided data to identify the optimal settings for maximizing green onion growth. The analysis revealed that the water level should be set at approximately 230.067 mL (0.00238 in coded units), while the plant food amount should be set at 4.0411 g (0.0412 in coded units). These specific values were determined to be the settings that resulted in 2.858 cm of growth, the highest level of green onion growth in the study, as shown in Figure 4.

Interestingly, the optimal solution found for maximizing green onion growth corresponds to a saddle point in the response surface model, as shown in the JMP output in Figure 5. A saddle point is a critical point on the surface where the response does not exhibit a maximum or minimum, but rather a saddle-like shape. This means that small changes in the factors near the optimal settings can result in both increases and decreases in the response. While the saddle point indicates an optimal setting within the given range, it is important to note the potential sensitivity of the response to slight deviations from these values, as exhibited by the surface profiler below in Figure 6.

Figure 6. Surface Profiler



Understanding that this optimal solution represents a saddle point highlights the need for careful experimentation and further investigation to fully capture the intricacies of the factors affecting green onion growth. It emphasizes the importance of considering factors beyond the immediate optimal settings to ensure reliable and consistent green onion growth. Additional studies and experimentation may provide deeper insights into the underlying mechanisms and interactions that contribute to maximizing green onion growth, enabling further optimization of the cultivation process, or analysis of other factors affecting the growth, such as climate and sun exposure.

If we were to maximize desirability, then the levels for food and water would be set at axial runs, 1.414 for water and -1.414 for food, as shown in Figure 4. Setting the levels for water and plant food at 272.426 mL (1.414) for water and 2.586 g (-1.414) for food, respectively, corresponds to the extreme factor levels and allow for the evaluation of the system's sensitivity to variations in the water and plant food amounts. These specific levels are chosen to explore the behavior of the response surface and maximize desirability.

Choosing these levels for maximum desirability indicates that the response surface may exhibit a nonlinear relationship between the factors and the desirability of green onion growth. These levels are positioned to capture potential curvature effects and explore any optimal regions that may not be apparent when focusing solely on the central region. However, it will be pertinent to explore the desirability at extreme levels of the factors once again, but in contrast to what was set before. It appears that maximum desirability could also be set at the negative extreme value for water, and the extreme value for food.

Although we are not quite at maximum desirability, we are extremely close. In fact, the predicted growth for these settings, which are water at 187.574 mL and food at 5.414 g in natural units, is 4.965 compared to 5.069. This similarity and opposing extremes is displayed in the surface profiler in Figure 6, and is the cause for our saddle point solution. We can explore these contrasting settings further in the contour plots in Figures 7 & 8.

Figure 7. Contour Profile 1

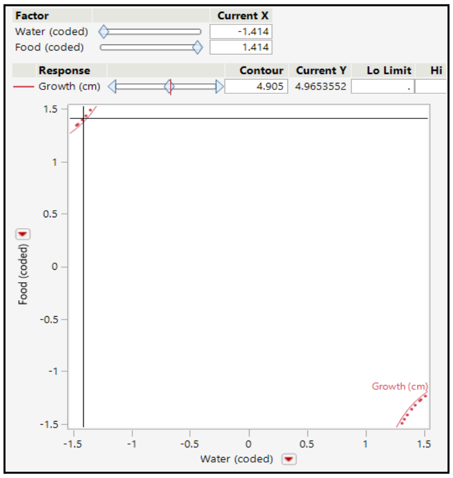
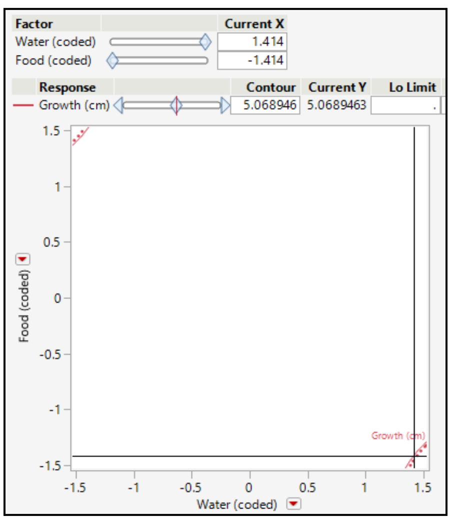


Figure 8. Contour Profile 2



4. CONCLUSIONS

After compiling our results, we have found that neither the amount of water nor the amount of food given to a green onion has a significant effect on its growth over a two-week period. Our goal was to maximize the amount of growth that took place, and the settings of the factors that maximized our growth occurred when water level was at 272.43 mL, and 5.41 g of plant food was given. If there are further investigations into green onion growth, I would suggest broadening the range of both water and food to include more extreme values. We could accomplish this by leaving the center amount of water at 230 mL, but choose something like 130 mL for the lower level and 330 mL for the higher level. Different levels of plant food could similarly be investigated. Furthermore, it could be beneficial to investigate different types of plant foods rather than the levels of a single one. We could also investigate the growth of the green onions in terms of mass gained, since there were some plants that grew additional stems in addition to gaining height. It is also worth noting that the green onions were only measured at the beginning of the two week period and the end. It could be informative to allow the green onions to grow longer, to be able to study the effect of time on growth. Thus, our conclusion is limited only in terms of the height of green onion plants, being grown within the range of 187 mL and 273 mL of water and between 2.6 g and 5.4 g of food over a two-week period. Considering all of this, a follow-up experiment would be required to make any conclusions outside of these ranges.

5. REFERENCES

- https://miraclegro.com/en-us/shop/plant-food/miracle-gro-water-soluble-all-purpose-plant-food/miracle-gro-water-soluble-all-purpose-plant-food.html

6. APPENDIX

Figure 2. Half-Normal Plot

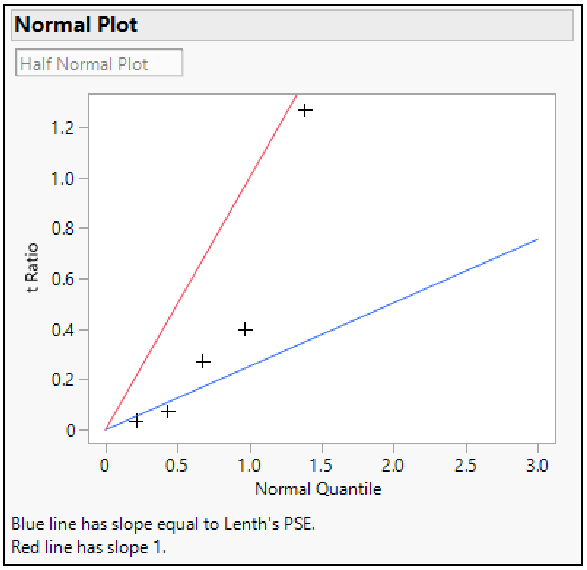


Figure 3. Lack of Fit Test

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	2.603092	0.8677	0.0791
Pure Error	6	65.857143	10.9762	**Prob > F**
Total Error	9	68.460235		0.9690
				Max RSq
				0.2017

Figure 4. Desirability Graph

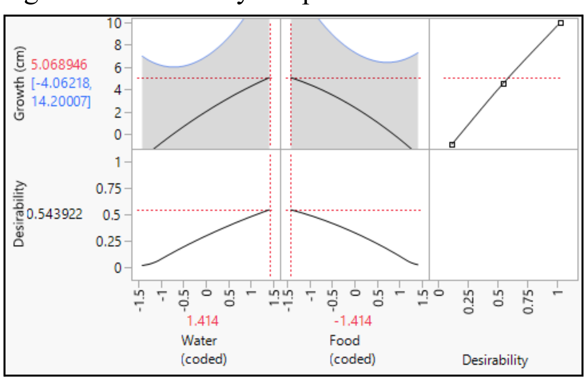


Figure 5. Critical Values

Solution

Variable	Critical Value
Water (coded)	0.0022376
Food (coded)	0.0411671

Solution is a SaddlePoint

Predicted Value at Solution 2.8579249

Figure 9. ANOVA

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	14.039765	2.80795	0.3691
Error	9	68.460235	7.60669	**Prob > F**
C. Total	14	82.500000		0.8576

Figure 10. Parameter Estimates

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.8570889	1.042435	2.74	0.0228*
Water (coded)	0.0732611	0.975182	0.08	0.9418
Food (coded)	0.0366305	0.975182	0.04	0.9709
Water (coded)*Water (coded)	-0.272303	0.992591	-0.27	0.7900
Water (coded)*Food (coded)	-1.75	1.379012	-1.27	0.2363
Food (coded)*Food (coded)	-0.39734	0.992591	-0.40	0.6983

Figure 11. Effect Tests

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Water (coded)	1	1	0.042931	0.0056	0.9418
Food (coded)	1	1	0.010733	0.0014	0.9709
Water (coded)*Water (coded)	1	1	0.572478	0.0753	0.7900
Water (coded)*Food (coded)	1	1	12.250000	1.6104	0.2363
Food (coded)*Food (coded)	1	1	1.218936	0.1602	0.6983

Figure 12. Andrew Planting Green Onions

Figure 13. Bella Preparing Cups

Figure 14. Nathan Measuring Soil

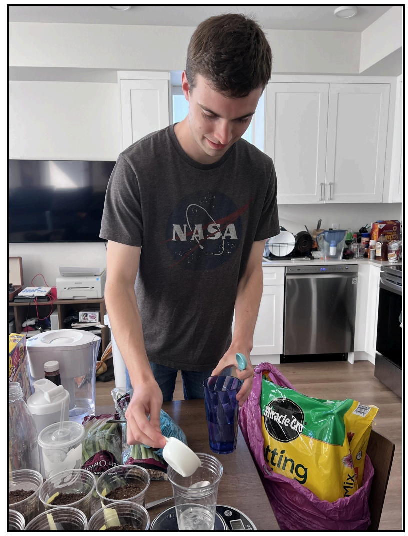


Figure 15. Rachel Measuring Plant Food

Figure 16. Cups Prepared for Green Onions

Figure 17. (Almost) Team Photo