Effects of Soil, Fertilizer, and Water on Snap Pea Plant Growth from Seed

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ABSTRACT:

The growth of a plant depends on multiple different factors and their interactions. This paper analyzes the effects of soil type, fertilizer, and watering frequency on the growth of snap pea plants from seed over a period of 17 days. Through a 2^3 experimental design to examine three main effects and their interactions, it was found that soil type and watering frequency as well as their interaction effect seemed to have a significant effect on the height of the snap pea plants measured from the end of its longest root to the tip of its shoot. Future experimentation on these factors can further reveal how different levels of soil type and water may affect snap pea growth.

INTRODUCTION:

The objective of the experiment is to examine the effects of fertilizer, water levels, and soil types on the growth of snap peas from seed, and to observe any possible interactions between factors. Different factors are commonly held as being more or less important to the growth of a plant from seed. This experiment sought to examine a few factors that would likely influence the growth of a plant to see how they affect the plant's growth and how they interact with each other.

A better understanding of how and what may affect the growth of a snap pea plant in the early stages of growth may allow a person to know what to prioritize in order to most efficiently and best ensure the growth of their plants. A 2^k experimental design allows for the quick examination of several factors that could possibly affect the response with limited cost and effort, allowing for future experiments to focus more on effects that may be found significant.

METHODS:

A 2^3 factorial design was chosen to examine factors that could possibly influence the growth of a snap pea plant over a designated period of time. Factors were chosen according to the predicted size of the effect and could be feasibly carried out and controlled for. High and low levels were chosen with consideration of the survival of the seedlings. Therefore soil type (factor A), fertilizer (factor B), and watering frequency (factor C) were chosen as factors of interest.

For the levels of each factor, the predicted size of the effect and the survival of the seedlings were the main considerations. For the soil type, Esposa organic potting mix was chosen as the low factor and Jiff organic seed starting mix as the high factor. The seed starter claimed to be tailored to starting plants from seed, so it was predicted that seedlings would grow faster and taller when planted in it. Seedlings were given no fertilizer for the low level and two spoonful of Neputne's hydrolized fish and seaweed fertilizer diluted with water as per package instructions weekly. For the low water level, seedlings were watered with two spoonfuls of tap water every other day. For the high water level, seedlings were watered with two spoonfuls of tap water daily.

It was predicted that the factors would affect the growth of the seedlings regarding their germination, the speed at which they grew, and the height of the resulting plant. The response variable chosen was the height of the plants in centimeters. The seedlings were set to grow over a 17 day period, at the end of which a record was made of whether or not they germinated, the height of the plant above the soil, and the height of the plant from the tip to the end of its longest root.

No blocking was utilized in this experiment. Lurking variables could include the viability of the seeds upon planting, uneven heating or light in the room, and how far each seed was pushed into the soil. To attempt to mitigate these effects, the effects were randomized over the trays where the seedlings grew. The trays were repositioned daily on the heat mat to try and

account for any irregularities due to their placement. To limit confounding between fertilizer and the soil types, both soil types were chosen as to not include fertilizer. As the fertilizer is diluted in water, the amount of water was kept consistent between plants that were given fertilizer and plants that were not by giving them equal amounts of fertilizer water and tap water, respectively.

G*Power was utilized to calculate an a priori power analysis with alpha 0.05, a large Cohen's *f* effect size of 0.40, a power of 0.80, and 8 groups. This gave a total sample size of 52, which was reduced to 48 for a balanced design, giving 6 replicates per group. A post hoc power analysis gives a power of 0.77. Excel was used to randomize the treatments over the 48 seedlings through its rand() function.

For the experiment, a collection of snap pea seeds were pre-germinated for 3 days by keeping them in a warm spot with a heating pad, spread out over a towel that was kept moist inside a sealed plastic container. Using cardboard trays labeled from 1-48 as according to prior calculations, each individual slot of the tray was labeled with the factor levels assigned through the randomization done through Excel. The soil types were then applied to each slot of the tray as according to these assignments, putting two spoonfuls of soil per slot. The pre-germinated seeds were then each planted one per slot in the trays, and two spoonfuls of water or fertilizer water (as designated according to each numbered seed) were then applied onto the seedlings. For the duration of the experiment, fertilizer was administered weekly for the seedlings with high fertilizer levels and tap water administered either daily or every other day, with equal amounts for each watering. The seedlings were left on top of a heat pad in an area where they would get sufficient light, with the trays shifted on the heat pad daily as to account for any uneven heating or lighting in the environment, and then left to grow for 17 days.

At the end of the growing period, each seedling was first measured from the soil level to the tallest part of the visible plant in centimeters by two people, the result then averaged. The seedlings were then dug out from the soil carefully as to not damage any part of the plant. A

record was made for whether or not the seed germinated, having any visible roots and/or shoot. The seedlings were then measured a second time from the tip of the longest root to the end of the shoot or the end of the seed if there was no visible shoot by two people, and this measurement was averaged as well.

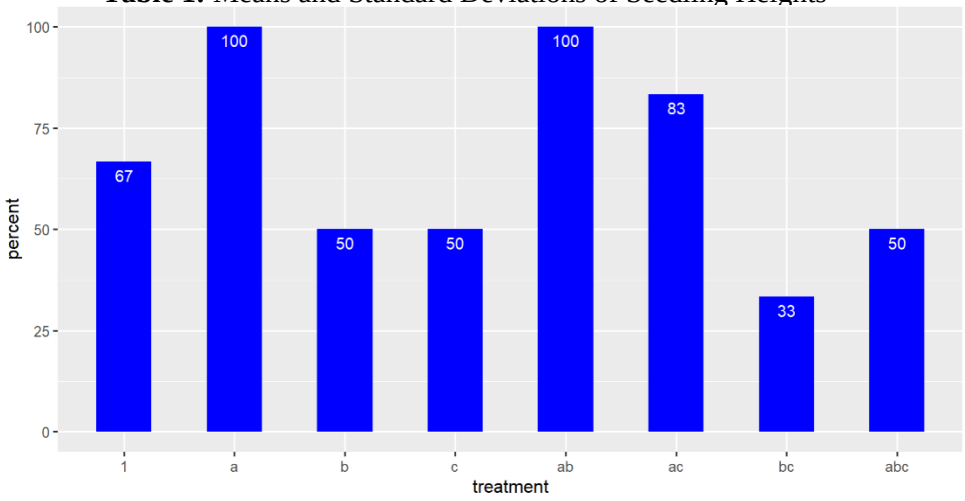
On account of many seedlings showing no obvious growth above the surface but having measurable root growth below, the response variable chosen to be analyzed was the total height of the plant from the ends of the roots to the tip of the shoot. A 3 way ANOVA was used to analyze the effects and interactions. Residual analysis and plots were used to check for the normality of the data and test for the homogeneity of variances. As there are only 2 levels for each factor, a post-hoc multiple comparisons is not necessary for the significant effects. The germination rates were also considered across the different factors. Plants that did not germinate were recorded as having a height of zero centimeters.

RESULTS:

Treatment	Mean (cm)	Standard Deviation		
1	5.15	7.28		A = soil type
a	11.9	6.12		B = Fertilizer
b	0.6	0.912		C = Water
ab	10.3	4.62		
c	1.52	1.83		
ac	3.82	3.16		
bc	2.72	4.65		
abc	3.28	4.06		

Table 1: Means and Standard Deviations of Seedling Heights

An examination of the heights of the plants, including the length of both the roots and the plants themselves, shows that plants grew the highest in the treatment group of high soil type and low water and fertilizer, and grew the lowest in the treatment group of high fertilizer and low soil and water.



An examination of germination rates also showed some differences across treatment groups, as seen in Figure 1.

Figure 1: Germination rates across treatments

Plants of both treatment groups A and AB both showed the highest germination rates, with both having 100% germination for the seeds planted. Treatment group BC showed the lowest germination rate, with 2 of 6 seedlings giving a rate of 33% germination.

A three-way ANOVA was conducted to examine the effects of soil type, fertilizer, and water on the growth of snap pea seedlings. Outliers and normality were assessed using a boxplot, histogram and homogeneity of variances was assessed by a versus fits scatterplot. As seen in Figure 2, there were two outliers. Residuals were normally distributed and there was homogeneity of variances.

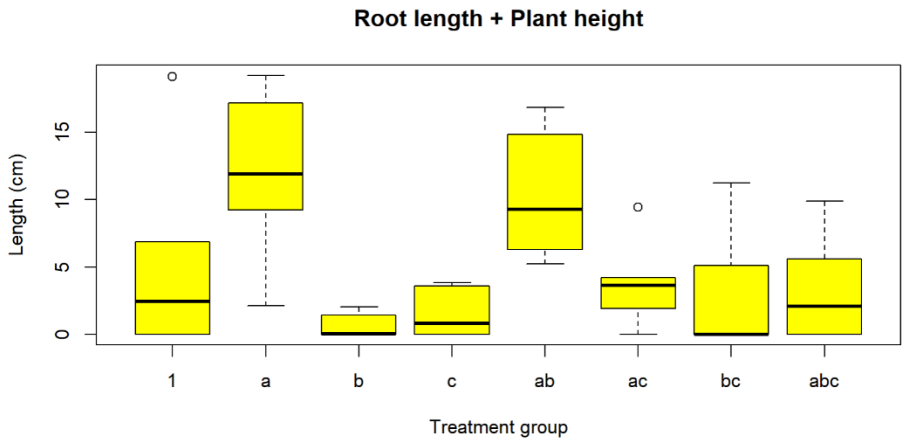


Figure 2: Boxplot of total seedling heights across treatment groups

The interaction effect between soil type and water on the height of the snap pea seedling was statistically significant, $F(1, 40) = 6.767$, $p = .012952$, partial $\eta^2 = 0.09125$. The main effect soil type was statistically significant, $F(1, 40) = 13.629$, $p < .001$, partial $\eta^2 = 0.1840$. The main effect water was statistically significant, $F(1, 40) = 10.082$, $p = 0.00288$, partial $\eta^2 = 0.1360$. The other main effects and interaction effects were not statistically significant.

DISCUSSION:

As we expected, the seed starter seemed to encourage both germination and growth in the seedlings compared to the potting mix used as the low level of factor A. On the other hand, the box plots of treatment B and C both showed lower medians than that of treatment (1), which was

surprising considering the earlier assumption that fertilizer and more water would contribute to better growth for the seedlings. With the identification of significant factors, more in-depth analysis can be planned in the future to examine more levels of each of the two factors in order to do more analysis on the effects that they may have on snap pea growth from seed.

There were some outliers present in the data, such as a plant with height of 19 centimeters with treatment (1) and a plant with height of 9.45 centimeters with treatment AC. These outliers greatly increased the means and standard deviations of these treatments. The uneven rates of germination also reduced the number of seedlings per treatment with measurable growth. For future experimentation, a sample size calculation might need to consider the germination rate of the seeds to a higher degree, or otherwise mitigate or account for the effects of uneven germination on the results.

Residual analysis on the data shows random scattering of the residuals aside for the appearance of earlier mentioned outliers (Figure 3). The histogram was unimodal and relatively symmetric, despite some right skew (Figure 4). For the Normal Q-Q Plot, points largely remained scattered along the line except for in the top right corner (Figure 5). As such, the assumptions of normality and the homogeneity of variances were deemed valid. Even so, there were some irregularities to the data that would likely be better serviced by a design that took germination rate into account to a greater extent.

The statistical significance of the soil type on the height of the plant and the large effect size found suggest its practical significance towards the growth of snap peas started from seed. Seeds that were planted in the Jiff organic seed starting mix grew significantly more than seeds planted in the Esposa potting mix. The statistical significance of the amount of water on the height of the plant suggests that plants that were watered daily grew significantly less than plants watered every other day. The significant interaction effect of AC suggests that the effects of soil type and watering frequency interact to affect the growth of the plant. This could possibly do

with the permeability of different soils and how well they absorb water. Speaking more generally, it seems that both the type of soil that the seeds are planted in and the frequency with which they are watered have some effect on the height of the snap pea plants started from seed.

CONCLUSIONS:

In this 2^3 design experiment, 48 snap pea seeds were planted and measured from root to tip after a period of 17 days to examine the effects of three factors on the growth of the plants: soil type, fertilizer, and water frequency. A 3 way ANOVA was conducted to examine the main and interaction effects. In conclusion, it was found that the main effect soil type had the largest effect on the plant growth. Plants that were planted in Jiff organic seed starting mix grew significantly more than those that were planted in the Esposa potting mix. The main effect water and the interaction effect soil type:water were also statistically significant. Future experimentation could better account for the germination of the plants to reduce confounding and errors in the data. A greater examination of the significant effects through multiple levels could better identify how soil type and water effect snap pea growth.

FIGURES:

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
A	1	279.4	279.37	13.629	0.000664	***
B	1	22.8	22.83	1.114	0.297649	
C	1	206.7	206.67	10.082	0.002880	**
A:B	1	1.1	1.05	0.051	0.822082	
A:C	1	138.7	138.72	6.767	0.012952	*
B:C	1	35.2	35.19	1.717	0.197576	
A:B:C	1	16.2	16.22	0.791	0.379074	
Residuals	40	819.9	20.50			

Table 2: Three-way ANOVA of main effects and interaction effects on height of snap-pea seedlings

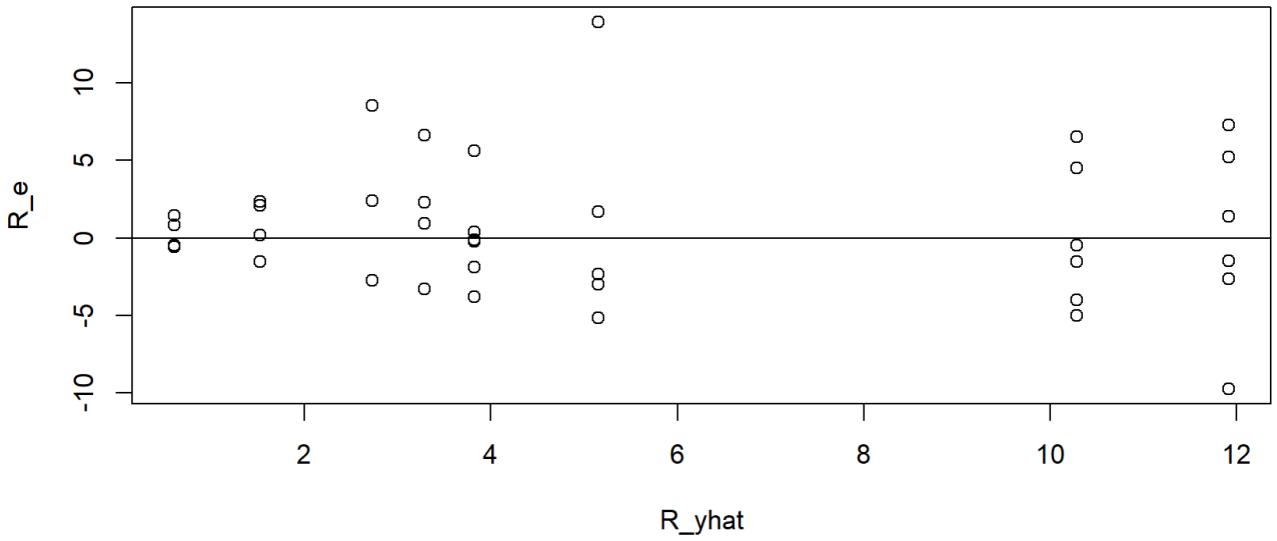


Figure 3: Residual plot

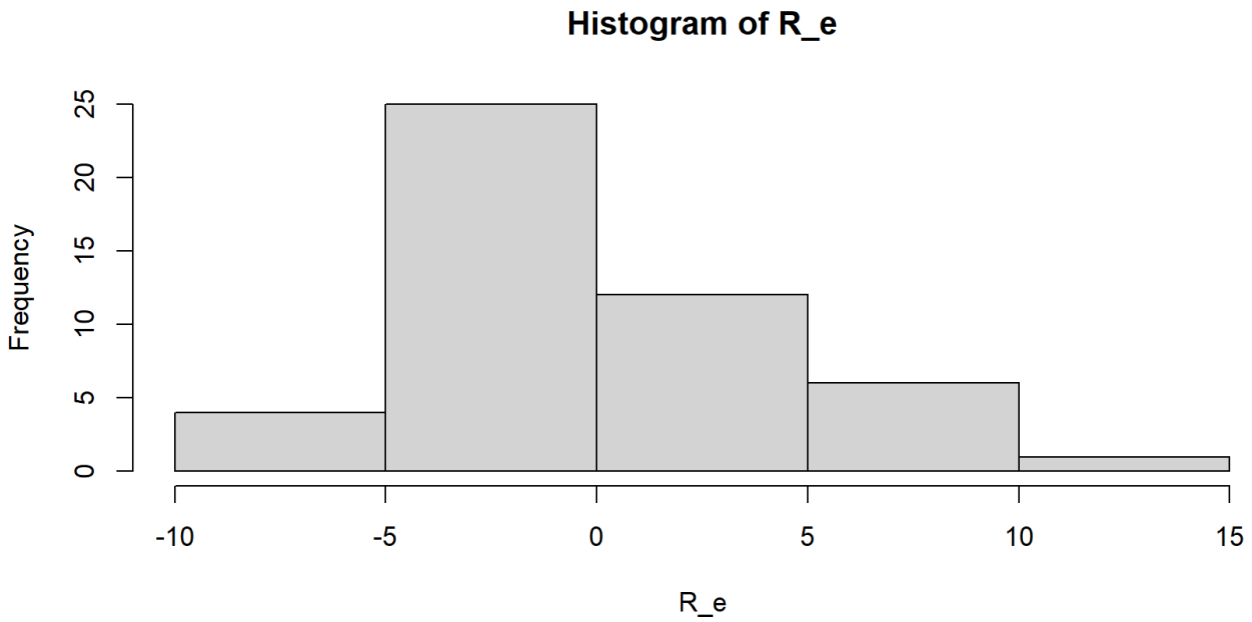


Figure 4: Residuals histogram

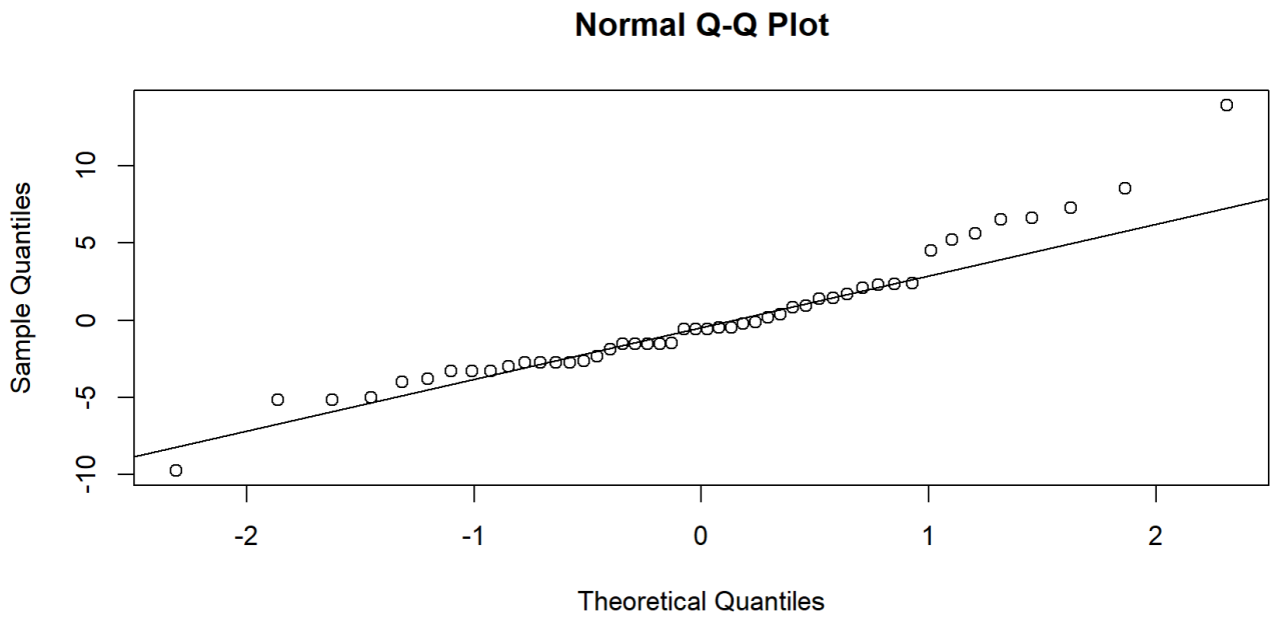


Figure 5: Normal Q-Q Plot

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