Experimental Analysis on Determination of Significant Factors in Growing Mung Bean Sprouts (Length) in a Home-Based Set Up (Non-Soil Germination)

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Abstract

The mung bean (Vigna radiata) or "munggo" is a tiny, high nutrient, green bean from the legume family that is frequently consumed as a crispy sprout known as mung bean sprouts or "toge" in the Philippines. It is used in a variety of different meals. Furthermore, Mung bean germination is a straightforward procedure and can be done in soil or water and generally germinates in four to five days. Since there is demand for mung bean sprouts and large production is quite inappropriate for low-volume consumers and the current pandemic situation, an experimental analysis was conducted to know the right factors to consider in producing high quality yield of mung bean sprouts (in terms of length) in a home-based set up (non-soil). Through 2^k Factorial Design of Experiment, 16 runs were involved having 3 factors which are the soaking time (A), rinse interval (B) and light exposure (C), and 2 replicates. Moreover, it was found that single factors A and C significantly affects the length of sprout with an inverse proportional relationship. Light exposure had the highest effect contribution value at 82.4%. All 2FI and 3FI were insignificant thus, soaking time and light exposure impact were generalized to the response.

Keywords
Design of Experiments, Factorial Design, Mung Bean Sprouts, Significant Factors

1. Introduction

The mung bean *(Vigna radiata),* alternatively known as *monggo* or munggo in the Philippines, is a small, green bean that belong to the legume family and commonly consumed and grown as a sprout called mung bean sprouts. Mung bean sprouts, known as *toge* in the Philippines, are edible with crisp and crunchy texture type of culinary vegetable that usually linked with salads and sandwiches. It is also integrated to other dishes such as spring rolls, vegetable egg rolls, sauteed bean sprouts and many more. Moreover, these sprouted beans are high in nutrients, rich in vitamins and minerals such as proteins and antioxidants and believed to aid many ailments. Other nutritionists recommend include these sprouts in diet meals since they are low in calories and high in various vitamins. Lastly, the demand for mung bean sprouts is not only directly related to population increase, but also to an increasing number of individuals who are enthusiastic about using mung bean sprouts as an alternative, side dish, or main dish in respective meals and offered in some restaurants in the country (Bual, Cunanan, Bedruz, Billones, & Vicerra, 2019).

With this progressive demand, mung bean sprout cultivation is a good motivation. They can be grown both indoors at home and outside planted out in the garden. They may be cultivated by planting sprouting beans in the shade and watering them until the hypocotyls grow tall. Furthermore, they're quite simple to grow; one way to grow the is through

soaking for a few hours, simply allow them to rest in a jar and washing them a few times each day. As a result, they are perfect for home gardeners, chefs, and health-conscious consumers (Grey, 2020).

The germination of mung beans constitutes a simple process. It can be planted in soil or water and usually germinates in four to five days; however, the actual pace of germination varies depending on the amount of moisture provided during the germination stage in some circumstances. Watering the bean seeds every four to five hours speeds up germination (Mclelland, 2021). Proper soil preparation is required for outdoor germination of mung beans. The soil should be loose and well-composted, with compost and fertilizer mixed in. Furthermore, the soil pH should be between 6.2 and 7.2, and seedlings should be planted in a sunny area. Dimension is also important while putting it in soil. Seeds can be sown directly in rows, 1 inch (2.5 cm) deep, 2 to 4 inches (5 to 10 cm) spacing, and 30 to 36 inches (75 to 90 cm) apart (Ravenscroft, 2021).

It is feasible to avoid using soil while growing mung beans indoors. Sprouting may be accomplished with the use of common home objects such as containers, cloth/towels, and tap water, and this study used these basic utensils as part of the experiment material. Furthermore, the basic methods of indoor sprouting involve soaking of mung bean for around 12 hours, rinsing thoroughly and draining as much water as possible which is the key component to growing neat sprouts (Sprout People, 2021). The average germination time is about 2 to 5 days, but it is in preference, and it may grow for as long as the consumer wants.

1.1 Objectives

The main objective of this research is to determine the significant factors in growing mung bean sprouts in a home-based set-up/environment. This research will consider the most practical factors and procedures that can done indoor.

2. Literature Review

Vigna radiata, basically known as mungbean, is likewise known all through the world by an assortment of names including "gram", "maash", and "moong". Domesticated to a lot of eastern Asia and the Indian subcontinent, the mung bean is a customary staple utilized as both a sweet and appetizing part to entrées and treats in Chinese, Filipino, and Indian foods. Natural mung bean seeds mature into a vegetable cover crop that makes an ideal occasional cover yield and sidekick plant known to renew drained soils of fundamental nitrogen and weed concealment, while likewise being famously cut down and plowed once again into the dirt as a natural and all-normal "green fertilizer" to enhance spring soils prepared for planting (Mountain Valley Seed Co., 2021).

Green grams are high in protein, fiber, and essential supplements. Growing upgrades the nourishment of mung beans as well as makes them effectively edible. Fledglings contain more significant levels of folate, Vitamin C, K, magnesium, phosphorus, and enemies of oxidants then the un-grew beans (Swasthi, 2021). Mung beans are basically developed for human food, as bubbled dry beans, stew, flour, sprouts and juvenile units as a vegetable. The dry beans are now and then utilized for creature food, basically poultry, when they are either simmered or bubbled while its biomass is utilized as grain (Kaysha, Shanka, & Bibiso, 2020).

Mung bean has been consumed in many variants like seared, bubbled, powdered, and grew. Be that as it may, mung bean sprout is the most nutritious structure as it contains 200% more protein when contrasted with other consumable variants. The dietary benefit per 100 g of mung bean sprout is that it contains 7 g protein, 18 g starch, 24 g fat, 0.026 g sodium, 0.06 g potassium, 0.02 g iron, 0.029 g calcium, 103.5 calories of energy and other significant nutrients (Hanif, et al., 2019). For a crunchy and scrumptious expansion to any sautéed food, salad, or sandwich, it is easy to develop mung bean sprouts at home utilizing dried beans from neighborhood supermarket and a few normal households (Master Class, 2021). For instance, container can be used as planting bed as long as it provides drainage and aeration, rustproof and easy to sanitize. Stainless steel and plastic are commonly used. Size depends on the amount of bean to be sprouted since mung beans increase in size about 6-fold when sprouting is completed. Thus, it is important to avoid crowding in a container. Light is not necessary in germination process (College of Agricultural Sciences, 2010). Sprouting mung beans can take anywhere from 2 to 5 days, depending on how big you want them. Expect that the beans will expand 2 to 4 times their original quantity by the time they are fully sprouted (Overhiser, 2021).

Seed germination is the course of plant seed developing into a plant. The interaction influenced by some natural components, like water, temperature, light, just as plant chemicals. Germination pre-treatment, pre-germination to put

it plainly, portrayed as the medicines for seeds to actuate germination prior to planting. Seed preparing, for example, can expand the rate and consistency of rise in numerous vegetable and blossom species or to set up the plant to react to approaching abiotic stress forcefully. One of seed preparing treatment is seed inundation in water which has diverse precondition (Muttaqin, Putri, Putri, & Matra, 2019).

Seed germination relies upon both inside and outer conditions. The main outer factor is light or haziness. Light or dimness can be an ecological trigger for germination and is a sort of physiological lethargy. Most seeds are not influenced by light or dimness, however many seeds, incorporating species found in timberland settings, won't sprout until an opening in the overhang permits adequate light for development of the seedling (Jamhari, 2018).

3. Research Design and Methodology

3.1 Problem Statement

Since there is a good demand for mung bean sprouts and large production (e.g. with the use of farming technology or requires an amount of landscape) is quite inappropriate for low-volume consumers, the paper aims to know the right factors to still achieve high quality yield of mung bean sprouts (in terms of length in centimeters) in a home-based set up, especially during the pandemic, using household items and less costly materials as an alternative.

The study will also further explore the following hypothesis imposed by the researchers:

1. The soaking time (pre-germination), rinse interval per day and light exposure per day significantly affect the growth (in terms of length) of the sprout.
2. There are significant interactions between the factors

3.2 Factorial Design

The researchers used 2^k Factorial Designs with 3 factors being considered, as the experimental design. There are significant interactions between the factors.

The Table 1 shows the equivalent value of each level per factors. The factors' low-level values represent the lowest conceivable and acceptable level in each of the processes or factors. The stated high-level values of each component, on the other hand, are the maximum acceptable or current value.

Table 1: Values of each Level per Factor

Factors	Low Level (-1)		High Level (+1)	
	Actual	Unit	Actual	Unit
A-Soaking Time	1	Hour	12	Hour
B-Rinse Interval per Day	4		8	
C-Light Exposure per Day	0		10	

The minimum and maximum values were determined by a review of related literature and then tested to ensure that sprouting was achieved for each procedure. As a result, exceeding these numbers will result in a faulty output.

3.2 Sampling Procedures and Runs

Adapting the 2^3 Factorial Design with 2 replications, there were 16 containers/set-ups which was considered as the total runs (1 container/set-ups, 1 run). Based on the experimental procedure run by the Design Experiment software, there were 8 set-ups for each level of soaking time (1 hour and 12 hours). Also, 8 set ups for each level of rinse interval per day (4 hours and 8 hours), and 8 for each level of light exposure per day (no exposure-0 hours and 10 hours).

3.3 Sampling Procedures and Runs

The figure below (Figure 1) shows the overall process of the experiment (excluding the preparation phase). The assigned germination time was 4 days (excluding the soaking phase). After the germination phase, measurement of sprout length took place. Refer to Appendix 7.1 for the overall view of the schedule of soaking phase, germination phase (rinsing and light exposure) and measuring phase.

Figure 1: General Process of Experiment

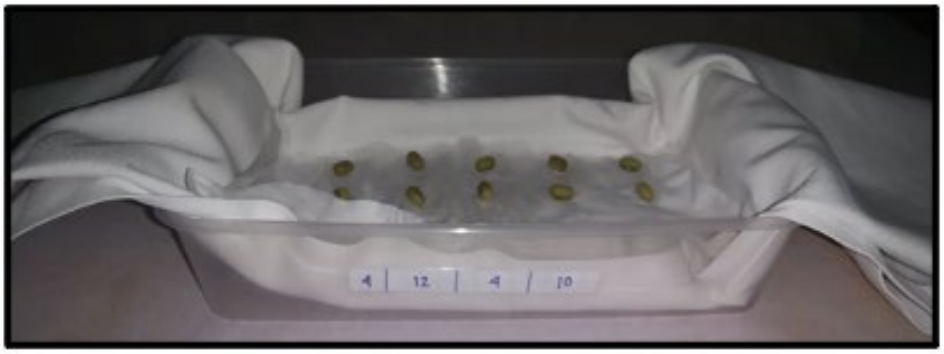

Figure 2: Sample Set-up for each Container/Run

The sample set-up for each container is being shown in *Figure 2*. One set up includes a plastic container (17cm by 12cm), cloth (cotton), label (run, soaking time, rinsing interval, light exposure time), and 15 mung beans (1 inch apart, row and column – as shown in *Figure 3*). Because the beans will grow after soaking and overcrowding may result in undesirable sprouting, they should only take up about two-thirds of the container (Marv, 2021).

Figure 3: Sample Set-up for each Container/Run

4. Data Collection

The experiment yielded 16 average sprout length values at varying amounts of the three factors (Table 2).

Table 2: Result of the Experiment

Std. Order	Run	Soaking Time (hours)	Rinse Interval (hours) per Day	Light Exposure (hours) per Day	Length of Sprout (cm)
1	5	1	4	0	9.5
2	13	1	4	0	17
3	9	12	4	0	13.6
4	7	12	4	0	13.2
5	12	1	8	0	18
6	6	1	8	0	15.4
7	10	12	8	0	8
8	15	12	8	0	9.6
9	3	1	4	10	2
10	2	1	4	10	2.3
11	8	12	4	10	1
12	4	12	4	10	0.5
13	16	1	8	10	4
14	1	1	8	10	3
15	14	12	8	10	1.3
16	11	12	8	10	1.5

5. Results and Discussion

5.1 Effects Model (Pre-ANOVA Analysis)

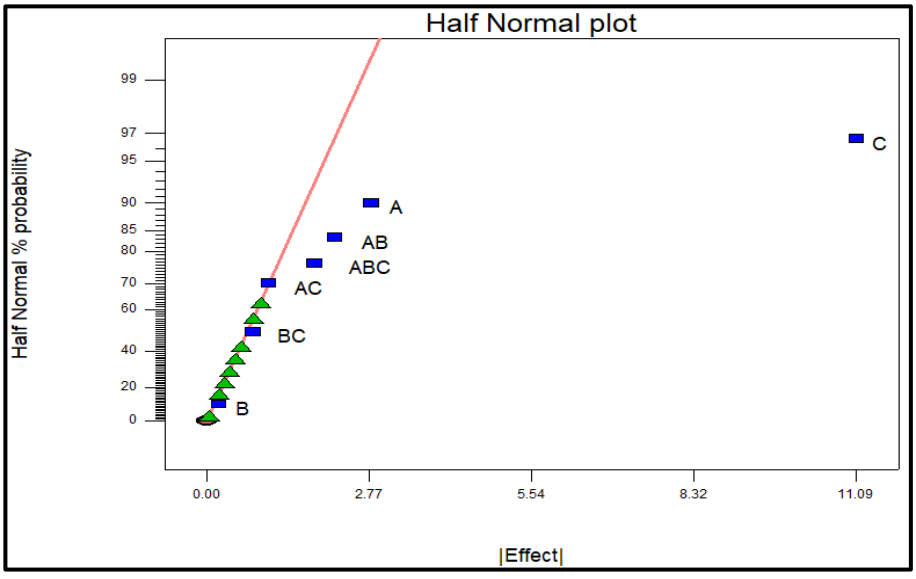

Figure 4: Half Normal Plot (All Factors)

Based on the half normal plot and when all factors were selected, as shown in Figure 4, single factor C was the farthest from the red "error" line which probably implies having the highest effect on the response variable. It is followed by single factor A, 2FI AB and 3FI ABC. However, interactions AC, BC and B belong to the factors with smallest effects.

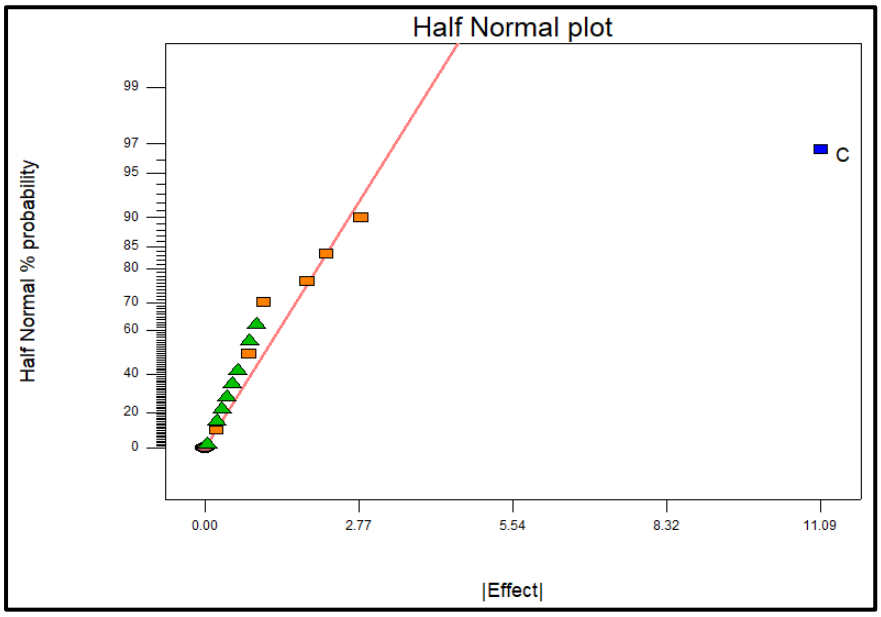

Figure 5: Half Normal Plot (Modified)

Upon manually deselecting all factors that fell/was closer to the red line (Figure 5), only factor C happened to be the farthest which can be conclusive of being the only significant factor affecting the growth of the sprout in terms of length. Thus, the rest of the single factors (A and B) and all kinds of interactions: 2FIs (AB, AC and BC) and 3FI (ABC) were insignificant to the response variable. The impact of single factor C to the length of sprout were then generalized.

5.2 Analysis of Variance

Table 3: Analysis of Variance (All Factors)

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	563.19	7	80.46	19.18	0.00	
A	31.64	1	31.64	7.54	0.03	sig.
B	0.18	1	0.18	0.04	0.84	
C	491.73	1	491.73	117.24	0.00	sig.
AB	19.14	1	19.14	4.56	0.07	
AC	4.52	1	4.52	1.08	0.33	
BC	2.48	1	2.48	0.59	0.46	
ABC	13.51	1	13.51	3.22	0.11	
Pure Error	33.56	8	4.19			

Cor Total	596.75	15				

To further validate the results of Half Normal Plot, Analysis of Variance report was further explored (Table 3). It happened that single factors A and C were significant.

Table 4: Analysis of Variance (Modified)

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	523.37	2	261.69	46.36	0.00	
A	31.64	1	31.64	5.61	0.03	sig.
C	491.73	1	491.73	87.12	0.00	sig.
Residual	73.38	13	5.64			
Lack of Fit	39.82	5	7.96	1.90	0.20	in.
Pure Error	33.56	8	4.19			
Cor Total	596.75	15				

Based on the final ANOVA table (Table 4) wherein the researcher excluded the insignificant factors (P Value > 0.05) in the analysis according to highest order hierarchy, it indicated that two single factors (A and C) were affecting the growth of mung bean sprout in terms of its length significantly.

Both significant factors had a linear relationship and a negative effect on the response variable implying that an increase to the amount of these factors will decrease the value of the response variable. Based on *Figure 7*, it shows that light exposure had the greatest effect on the growth of sprout having a steeper decreasing line compared to the graph of soaking time (Figure 6). Rightfully, from Table 5, factor C attained the chunk of the effects contribution (82.40%) among the factors followed by factor A (5.30%).

Table 5: Model: Effects List

Require	Term Intercept	Standardized Effect	Sum Square	% Contribution
Model	**A**	**-2.81**	**31.64**	**5.30**
Error	B	0.21	0.18	0.03
Model	**C**	**-11.09**	**491.73**	**82.40**
Error	AB	-2.19	19.14	3.21
Error	AC	1.06	4.52	0.76
Error	BC	0.79	2.48	0.42
Error	ABC	1.84	13.51	2.26
Error	Lack Of Fit		0.00	0.00
Error	Pure Error		33.56	5.62
	Lenth's ME	3.04		
	Lenth's SME	4.56		

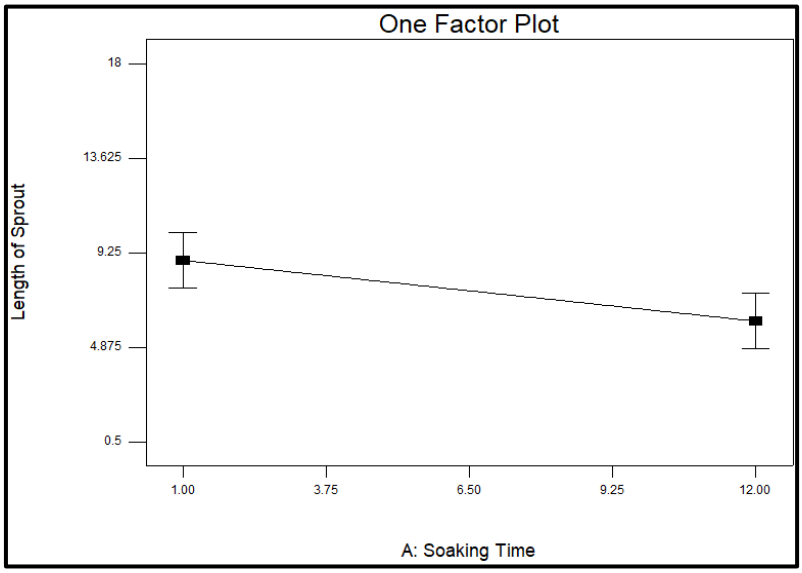

Figure 6. One Factor-Plot Soaking Time (A)

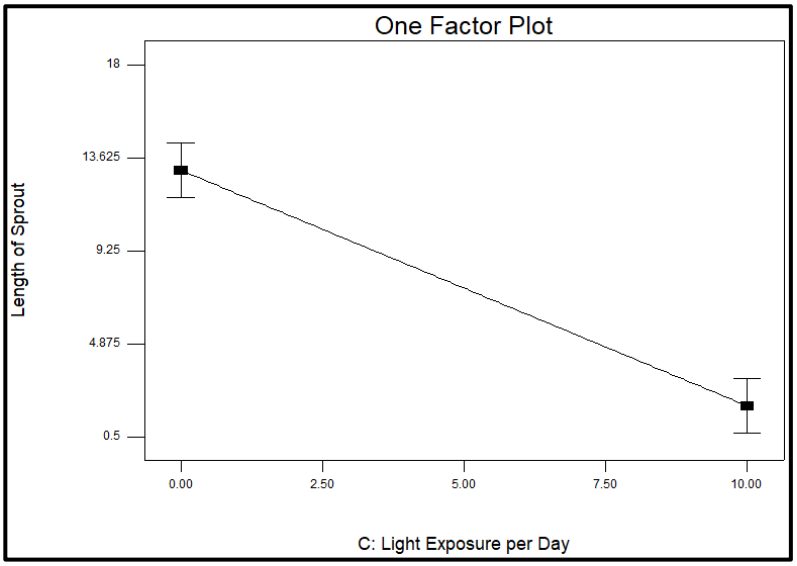

Figure 7: One Factor Plot – Light Exposure (C)

5.3 Model Validation

Based on the ANOVA report (*Table 4*), it shows that the model is significant.

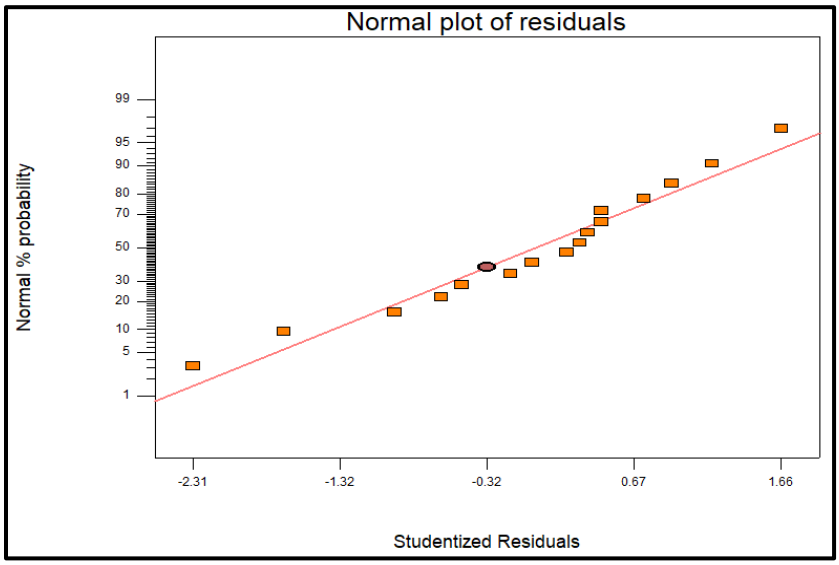

Figure 8: Normal Probability Plot – Residuals

The Normal Probability Plot (Figure 8) displayed above shows that residuals fall in a straight line (red line), implying that ANOVA is not violated.

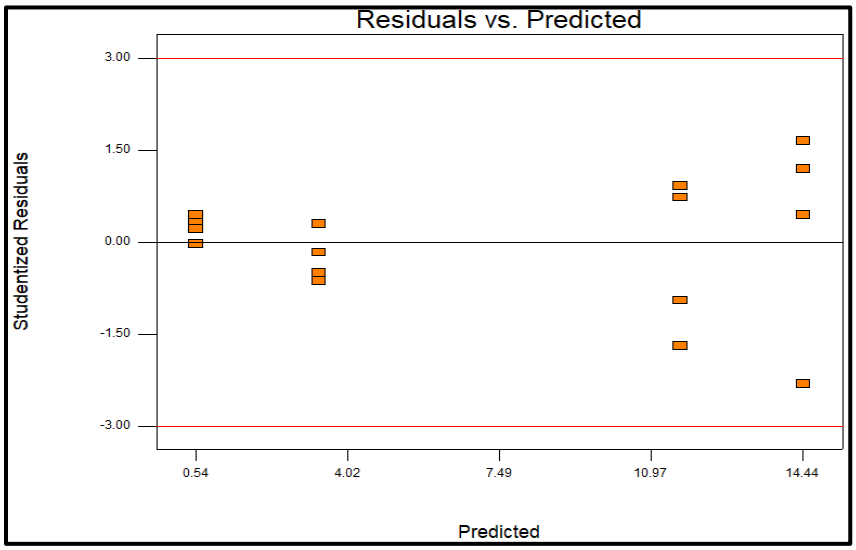

Figure 9: Residuals vs. Predicted Plot

The Residuals and Predicted Values Plot *(*Figure 9*)* above shows that residuals have no pattern and are unconnected to any other factors.

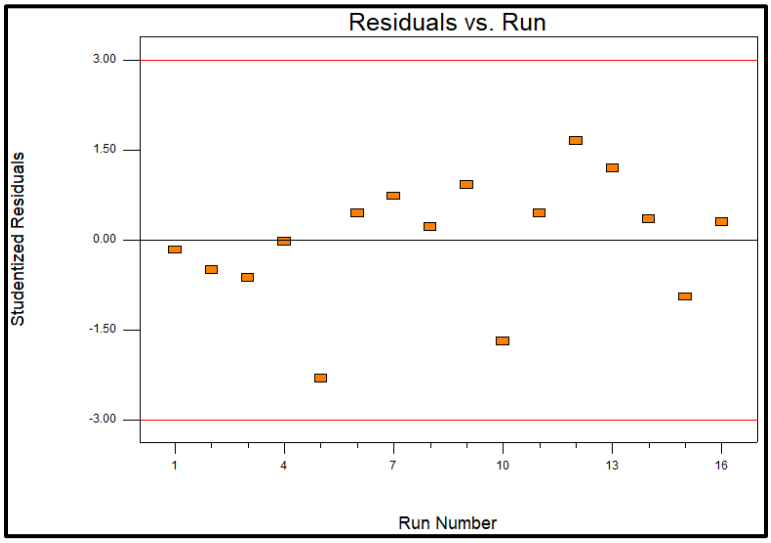

Figure 10: Residuals vs. Run Plot

Based on the graph of Residuals vs. Run Plot *(*Figure 10), the model is independent since residuals are dispersed and pattern less. There were no outliers found. As a result, no violations occur in the model adequacy test.

5.4 Regression Model

Through Analysis of Variance, final equation is defined by the following model:

$$Y = 14.69 - 0.26 * A - 1.11 * C \quad \text{[Actual]}$$

$$Y = 7.49 - 1.41 * A - 5.54 * C \quad \text{[Coded]}$$

where:

$$Y = Length\ of\ Sprout\ (cm)$$
$$A = Soaking\ Time\ (Hours)$$
$$C = Light\ Exposure\ per\ Day\ (Hours)$$

The coefficients indicates that high levels of A (soaking time in hours) and C (light exposure per day in hours) will yield to a shorter sprout of mung beans.

6. Conclusion

The study concluded that light exposure (Factor C) is a significant factor and gravely affects the growth of mung beans. It also concluded that soaking duration (Factor A) is also significant to yield a longer and quality sprouts. Furthermore, the study also showed that the relationship of these factors to the response variable (length of sprout) is inversely proportional in a sense of having a negative coefficient in the model. Thus, this implies that when a consumer plans to do a home-based set-up (non-soil) of production of mung bean sprout, high levels of soaking time and light exposure should be critically controlled because increasing the amount or duration of these factors will result to a shorter mung bean sprout.

The study also found that rinse interval will not affect the growth, and interaction among the three factors did not prevail. Furthermore, no 2FI and 3FI were considered significant thus the impact of single factor A and C to response Y is generalized and treated individually.
In terms of the analysis, the researcher came to an end that by merely observing the Half Normal Plot, it will not quantifiably justify the determination of significant factors. It is best to analyze the ANOVA report since there might be a masking effect which makes the significant factor close to being insignificant.

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Biography

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