Factors related to growth of sunflower sprout

Chapter 1: Recognition of and statement of the problem

Problem Statement:

Nowadays sunflower sprout become more popular in the market because there are many nutrition in this little sprout. And many farmers start to interested in growing sunflower sprout and focusing on increase its size in limited time to gain their profit. So, we construct this experiment to find the factors to increase the growth of sunflower sprout in a limit amount of time.

Objective:

1. To find out which main factor or interaction of factors are the most influential on the response of
interest. This phase is called “Factor screening and characteristic”.
2. To find the levels of important factors that result in desirable response values after the system
has been characterized.
3. To find the best recommendation to obtain the best requirement for plant sunflower sprout.

Note: we assess with statistical significance level (α) compare to 95%.

Chapter 2: Selection of the response variable

Response Variable	Unit	Measurement Precision / Accuracy	Relationship to Objective
Height of the sunflower sprout	mm. (millimeter)	Measured by using ruler.	The greater value of height, the more profit to the farmers.

Chapter 3: Choice of factors levels and range

Factors

Potential design factors classification

Design factors	Held-constant factors	Allowed-to-vary factors
Sunlight	Species of sunflower seed	-
Soil	Water quality and quantity	-
Fertilizer	Time to growth	-

Nuisance factors classification

Design factors	Uncontrollable factors	Noise factors
-	Temperature	-
-	Humidity	-

Factor levels and range

Due to our main objective is related to factor screening, we decide to take each factor in two levels (low level and high level) with broad range.

Factors	Level	
	Low (-)	High (+)
Sunlight	No light	Normal sunlight
Soil	Poly fiber	Gardening soil
Fertilizer	No fertilizer	Give fertilizer

Factor details

Control Variable

Control Variable	Measurement Precision / Accuracy	Predicted Effects
Sunlight	Control the environment by filter the sunlight to get illumination around 3,000 – 5,000 lux for positive factor and cover the sample with black plastic sheet to block the sunlight.	The sunlight should to increase the growth of sunflower sprout

Soil	For positive soil factor use the small particle soil mix with coconut fiber. While use polyfiber for negative factor.	The soil should to increase the growth of sunflower sprout
Fertilizer	Fertilizer is created by the ferment of fruits. Then combine the 5 cc of fertilizer with 300 cc or water in daily watering.	The fertilizer should to increase the growth of sunflower sprout

Held Constant Factors

Held Constant Factors	Measurement Precision /Accuracy	Settings	Predicted Effects
Species of sunflower seed	Use the same species of sunflower seed to measure all responses	N/A	None
Water quality and quantity	Use the same water to measure all responses	Use tap water	None
Time to growth	Limit the time to measure all responses	7 Days	None

Nuisance Factors

Nuisance Factors	Measurement Precision /Accuracy	Settings	Predicted Effects
Temperature	Unsuitable temperature affect the growth of sunflower sprout	N/A	Negligible
Humidity	Too much humidity, the sunflower sprout will be rotten	N/A	Negligible

Chapter 4: Experimental design

As we will study the effect of three factors and their interactions on a response and each of them has only two levels, two-level fractional design is appropriate for our experiment. Hence, we run full factorial experiment of two-level fractional design with 15 replications. We performed totally 120 runs with 8 different treatment combinations and 15 replications for each combination. The detail of the experiment are described in the following section.

Design the experiment

The factors tested in this experiment are as follows:

Variables	Factors	Level	
		Low (-)	High (+)
A	Sunlight	No light	Normal sunlight
B	Soil	Polyfiber	Gardening soil
C	Fertilizer	No fertilizer	Give fertilizer

The 2^3 fractional factorial design

Treatment combination	Factors		
	A	B	C
1	-	-	-
2	+	-	-
3	-	+	-
4	+	+	-
5	-	-	+
6	+	-	+
7	-	+	+
8	+	+	+

Equipment

Equipment	Quantity	
Sunflower seed	400	gram
Planting tray	4	unit
Soil	500	gram
Fertilizer	50	cc.
Tab water	3000	cc.
Coconut fiber	500	gram
Polyfiber	2	unit
Black plastic cover	1	unit
Ruler	1	unit
Measuring cup	1	cup

Chapter 5: Performing the experimental

Procedure

1. Environment preparation
    a. Planting media
        i. Soil – Mix small particle soil with coconut fiber as 1:1
        ii. Planting tray – divide each tray into two, fill one side with mixed soil and another half with half of polyfiber. Then tag labels on every side of all trays to identify the sample's treatment.
    b. Sun light control environment
        i. Find a place where have illumination about 3,000 – 5,000 lux which is proper for sprout to grow.

ii. Find a place where have no sun light, or cover the sample with black plastic to control the sun light.

c. Fertilizer – for the treatment that require fertilizer. 5 cc of fertilizer will be mixed with 300 cc of water on each time of watering.

2. Seed preparation – Put all 400 g of sunflower seed into water for 4 hours then wrap all seed together with fabric for 24 hours.

3. Seed planting – Plant sunflower seed in prepared planning tray. Each side of tray will contain 50 grams of sunflower seed. Every seed must lay individually, don't let any seed overlap each other.

4. Sprout growing

   a. Watering – Give 300 cc of water twice a day at 8.00 and 17.00 for treatment which require fertilizer mix 5 cc of fertilizer with water.

   b. Keep the environment for every treatment of six days.

5. Harvesting and Inspect the results

   a. Randomly pick 15 sprouts from each plating tray.

   b. Measure the length of each sprout from bottom to leaf top and record the result.

Experiment result

Factors			Result (replicate)														
A	B	C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-	-	-	8.4	7.5	8.8	10.6	7.3	6.9	7	8.9	6.6	7.1	6.7	8.1	10.1	7.6	9.1
+	-	-	6	4.8	5.5	4.5	5.7	5	3.6	5	4.7	5.4	5.2	5.1	4.4	4	5.1
-	+	-	12.6	10.5	10.6	15.7	16.2	14.6	17	11.9	13.7	10.1	13	12.8	10.8	13	12.6
+	+	-	10	9.1	10.3	11.1	10.5	11.2	11.9	8.9	10.3	12.4	11.8	12.2	12.8	11.8	11.2
-	-	+	7.8	6.8	7.2	8.4	8.5	5.9	7.1	8.1	6.7	6	6.9	8.6	5.6	5.9	7.6
+	-	+	7.5	7.9	8.3	8.1	5.8	8.1	8.5	7.7	7.2	6.6	7.1	6.9	6.2	7.1	5.7
-	+	+	17.2	14.3	14.3	12.4	18.5	14.1	14.9	17.9	15.7	16	17	14	16.2	19.5	15.8
+	+	+	9.2	9.6	9.9	9.1	8.9	11.4	10.4	10.4	10.1	9	12.1	9.2	10.2	9.9	12.2

Chapter 6: Statistical analysis and conclusion

After collecting data from the experiment, use Minitab software to calculate the model adequacy, analyze the data, and perform the residual analysis. Then, formulate the empirical model to describe the relationship between factors and response.

With full factorial of two-level fractional experiment. The results and the model gathered from Minitab shown below.

Full Factorial Design

Factors: 3 Base Design: 3, 8

Runs: 120 Replicates: 15

Blocks: 1 Center points (total): 0

All terms are free from aliasing.

Factorial Regression: Sprout Height versus A, B, C

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	7	1331.41	86.79%	1331.41	190.202	105.10	0.000
Linear	3	1196.99	78.03%	1196.99	398.997	220.47	0.000
A(Light)	1	215.74	14.06%	215.74	215.740	119.21	0.000
B(Soil)	1	960.50	62.61%	960.50	960.502	530.73	0.000
C(Fertilizer)	1	20.75	1.35%	20.75	20.750	11.47	0.001
2-Way Interactions	3	42.72	2.78%	42.72	14.241	7.87	0.000
A(Light)*B(Soil)	1	41.65	2.72%	41.65	41.654	23.02	0.000
A(Light)*C(Fertilizer)	1	0.57	0.04%	0.57	0.574	0.32	0.574
B(Soil)*C(Fertilizer)	1	0.49	0.03%	0.49	0.494	0.27	0.602
3-Way Interactions	1	91.70	5.98%	91.70	91.700	50.67	0.000
A(Light)*B(Soil)*C(Fertilizer)	1	91.70	5.98%	91.70	91.700	50.67	0.000
Error	112	202.69	13.21%	202.69	1.810		
Total	119	1534.11	100.00%				

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
1.34527	86.79%	85.96%	232.684	84.83%

Coded Coefficients

Term	Effect	Coef SE	Coef	95% CI	T-Value	P-Value	VIF
Constant		9.671	0.123	(9.428, 9.914)	78.75	0.000	
A(Light)	-2.682	-1.341	0.123	(-1.584, -1.098)	-10.92	0.000	1.00
B(Soil)	5.658	2.829	0.123	(2.586, 3.072)	23.04	0.000	1.00
C(Fertilizer)	0.832	0.416	0.123	(0.173, 0.659)	3.39	0.001	1.00
A(Light)*B(Soil)	-1.178	-0.589	0.123	(-0.832, -0.346)	-4.80	0.000	1.00
A(Light)*C(Fertilizer)	-0.138	-0.069	0.123	(-0.312, 0.174)	-0.56	0.574	1.00
B(Soil)*C(Fertilizer)	0.128	0.064	0.123	(-0.179, 0.307)	0.52	0.602	1.00
A(Light)*B(Soil)*C(Fertilizer)	-1.748	-0.874	0.123	(-1.117, -0.631)	-7.12	0.000	1.00

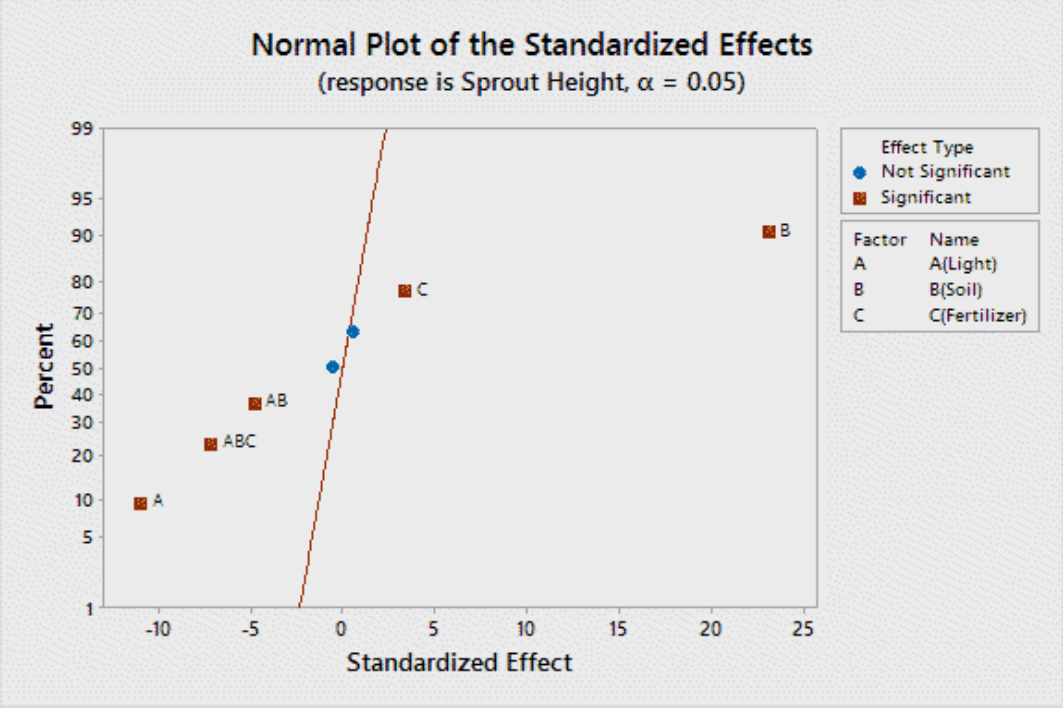
Regression Equation in Uncoded Units

Sprout Height = 9.671 - 1.341 A(Light) + 2.829 B(Soil) + 0.416 C(Fertilizer) - 0.589 A(Light)*B(Soil) - 0.069 A(Light)*C(Fertilizer)
+ 0.064 B(Soil)*C(Fertilizer) - 0.874 A(Light)*B(Soil)*C(Fertilizer)

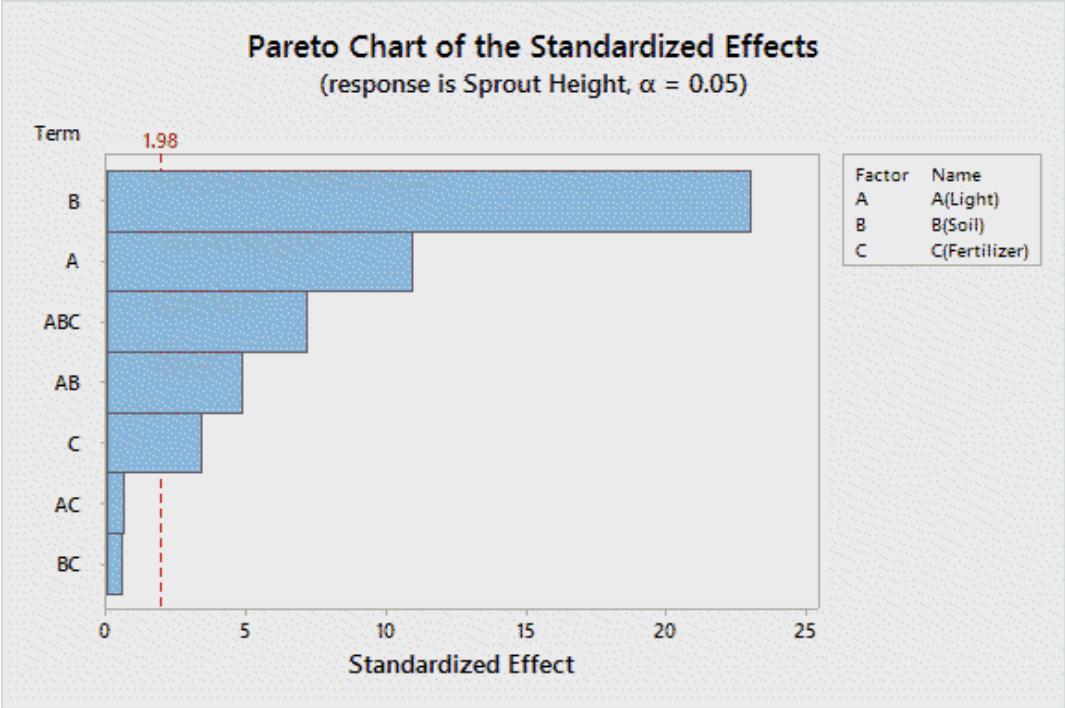
Fits and Diagnostics for Unusual Observations

Obs	Sprout Height	Fit	SE Fit	95% CI	Resid	Std Resid	Del Resid	HI
27	15.700	13.007	0.347	(12.318, 13.695)	2.693	2.07	2.10	0.0666667
31	12.400	15.853	0.347	(15.165, 16.542)	-3.453	-2.66	-2.73	0.0666667
35	16.200	13.007	0.347	(12.318, 13.695)	3.193	2.46	2.51	0.0666667
39	18.500	15.853	0.347	(15.165, 16.542)	2.647	2.04	2.07	0.0666667
51	17.000	13.007	0.347	(12.318, 13.695)	3.993	3.07	3.20	0.0666667
75	10.100	13.007	0.347	(12.318, 13.695)	-2.907	-2.24	-2.28	0.0666667
111	19.500	15.853	0.347	(15.165, 16.542)	3.647	2.81	2.90	0.0666667

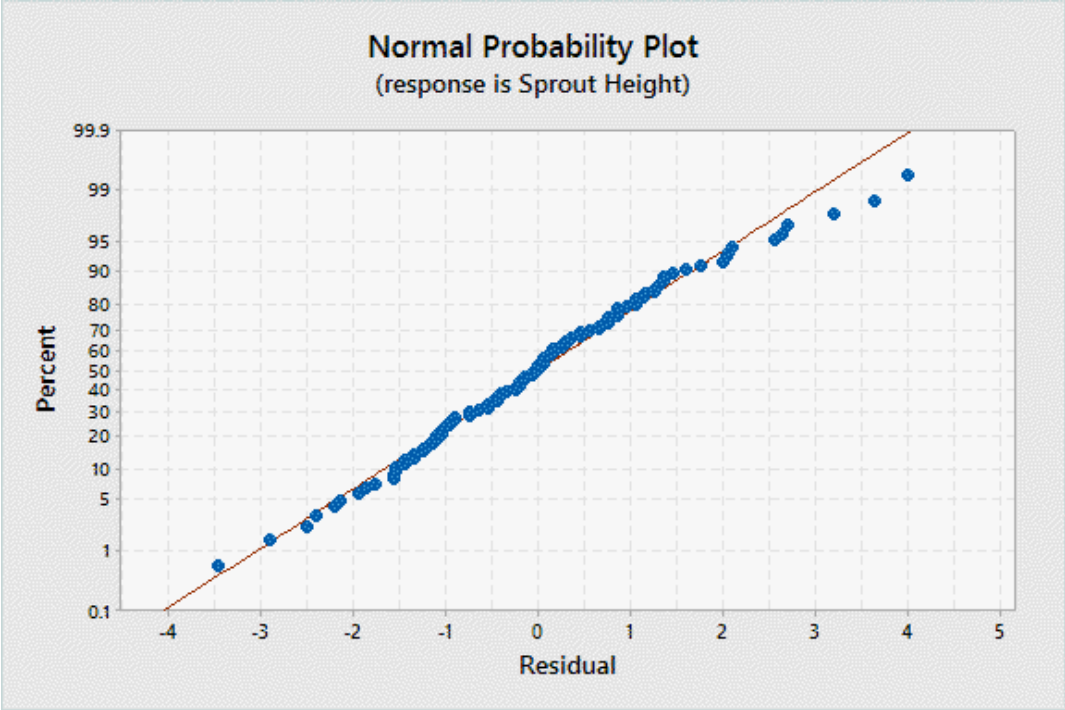
The normal plot of the standardize effects



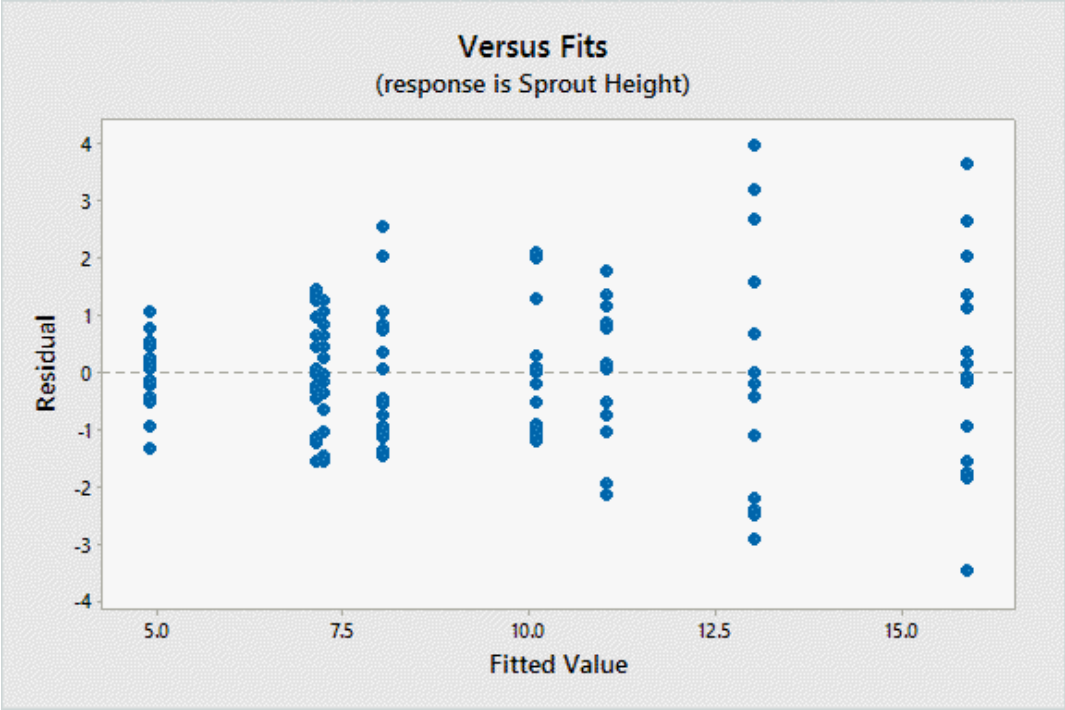
The Pareto chart of the standardize effects



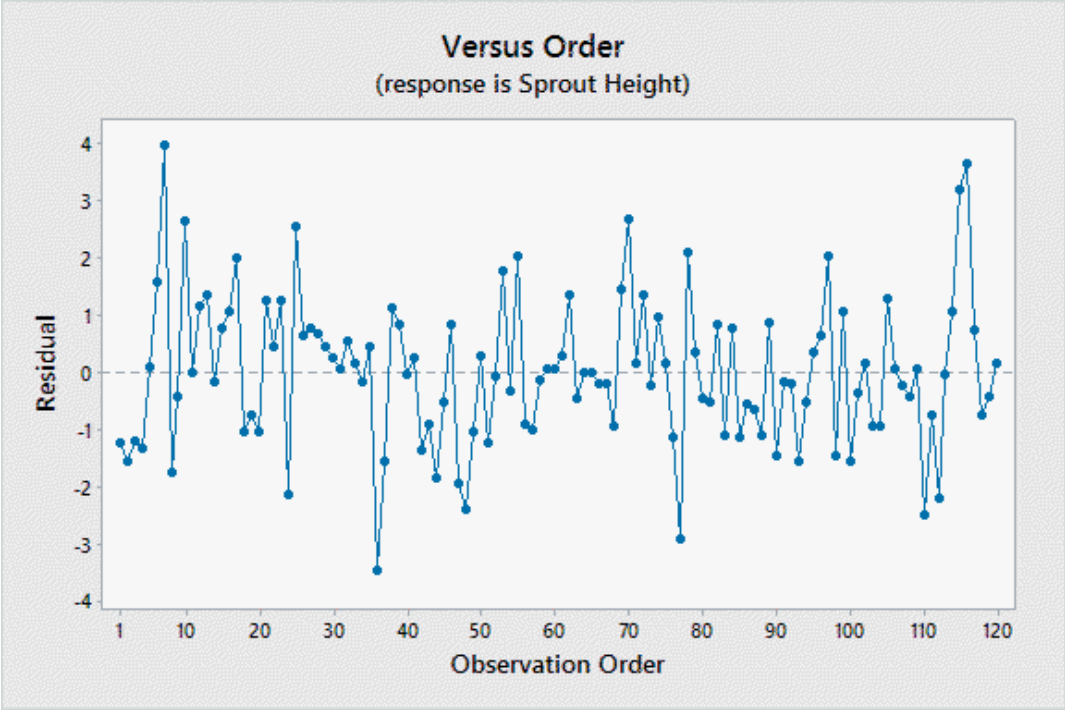
The normal probability plot of the residuals for Sprout Height



Residuals vs Fits for Sprout Height



Residuals vs Order for Sprout Height



Analysis of the result

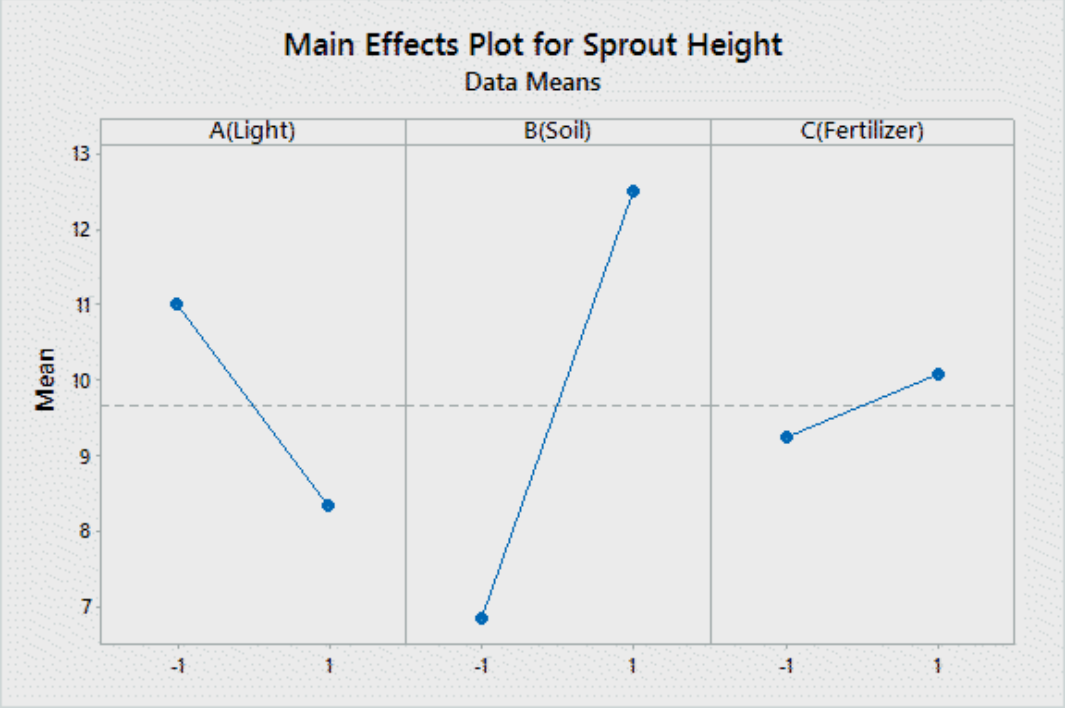
From the experiment analytical results (ANOVA, Pareto chart) shown the statistically significant factors at significant level = 0.05, which are all three main effect, one second-order, and the third-order interaction effect.

- Main effect B : Soil
- Main effect A : Sunlight
- Main effect C : Fertilizer
- Interaction effect AB : Sunlight * Soil
- Interaction effect ABC : All factors

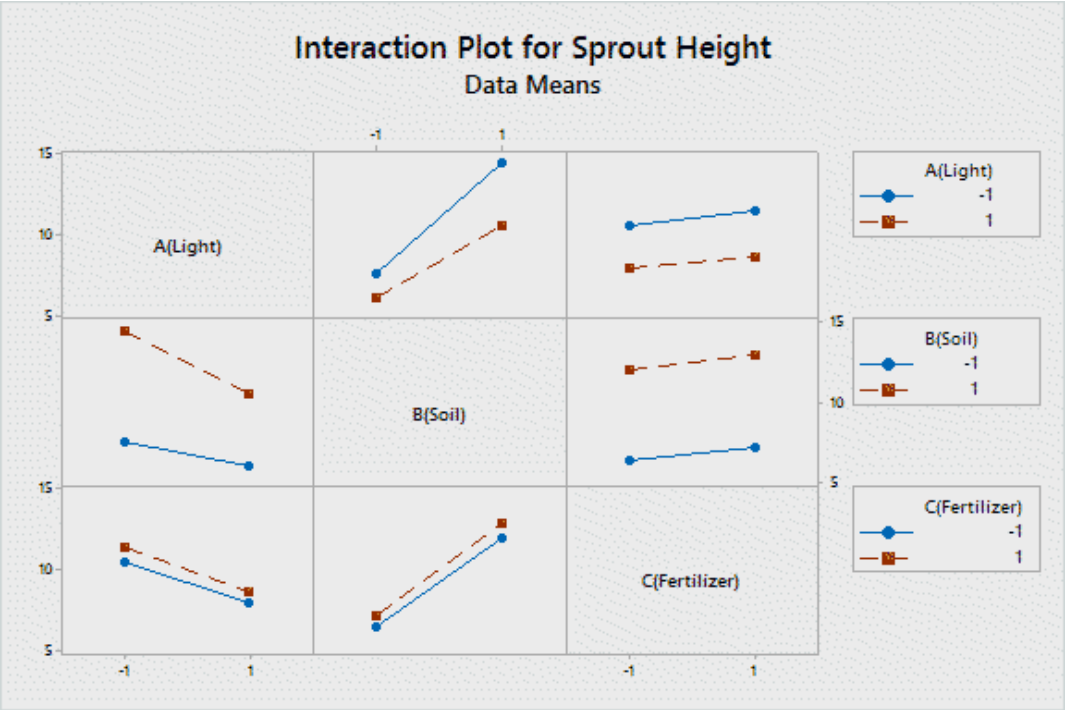
As well as the result shown in the normal plot shown the response that when factor A (sunlight) has an inverse variation relation with response will be high, while B (Soil) and C (Fertilizer) have direct variation relationship.

Another method which able to show the interaction between factors and the response are interaction plot which shown below.

Main effects plot for Sprout Height



Interaction plot for Sprout Height



The graph of main effect shown the match result with previous analysis. The main effect B (Soil) is the most significant main factor and has a direct variation relation with the response. While A (Light) has an inverse variation relation with the response. The interaction plot shown the effect of factors.

Analysis compare to hypothesis

Control Variable	Predicted Effects	Actual Effects
Sunlight	The sunlight should to increase the growth of sunflower sprout	The sunlight decrease the growth of sunflower sprout
Soil	The soil should to increase the growth of sunflower sprout	The soil increase the growth of sunflower sprout
Fertilizer	The fertilizer should to increase the growth of sunflower sprout	The fertilizer increase the growth of sunflower sprout

Chapter 7: Conclusion

In order to improve the benefits of sunflower sprout farm, from the experiment result show the most significant factor for sunflower sprout to grow is soil instead of using polyfiber. With the fertilizer, sunflower sprout can grow a bit longer than not using the fertilizer, then the farmer have to choose if the fertilizer cost is affordable or not. While the sunlight have an inverse variation relationship, which mean plant the sprout in the place that have no or few light is better for sunflower sprout to grow. By the treatment with the best response from this experiment shown below.

Sunlight	Soil	Fertilizer	Sprout height
-	+	+	**19.5**