The Effect of Fulvic Acid and Urea on *Raphanus Sativus:*A Two Factor Design of Experiment

Table 1

Factors used in Experiment

|  |  |
| --- | --- |
| Fulvic Acid (g per 100 ml) | Urea (g per 100 ml) |
| (-) | Standard | (+) | (-) | Standard | (+) |
| 5 | 10 | 15 | 5 | 10 | 15 |

 Table 1 shows that factors were chosen to see how they affected the growth of the *Raphanus Sativus*. The amount of Fulvic Acid and Urea (measured in grams) put into 100 ml of distilled water were used as the two factors. The tables show the lows, highs, and standards for each factor. The values for Fulvic Acid (grams per 100 ml) are as follows: 5 grams (low), 10 grams (standard), 15 grams (high). The values for Urea (grams per 100 ml) are as follow: 5 grams (low), 10 grams (standard), and 15 grams (high).

Table 2

Data for Three Runs

|  |  |  |
| --- | --- | --- |
| First Run | Second Run | Third Run |
| Order  | Trial | Result(amount germinated) | Order  | Trial | Result (amount germinated) | Order | Trial | Result (amount germinated) |
| 1 | Standard | 2 | 1 | Standard | 2 | 1 | Standard | 1 |
| 5 | (+,+) | 0 | 5 | (+,+) | 1 | 6 | (+,+) | 1 |
| 6 | (-,-) | 3 | 6 | (-,-) | 3 | 2 | (-,-) | 3 |
| 4 | Standard | 2 | 4 | Standard | 1 | 4 | Standard | 1 |
| 3 | (+,-) | 3 | 2 | (+,-) | 4 | 3 | (+,-) | 3 |
| 2 | (-,+) | 0 | 3 | (-,+) | 0 | 5 | (-,+) | 0 |
| 7 | Standard | 2 | 7 | Standard | 2 | 7 | Standard | 2 |

 Table 2 shows the results for the germination of all the seeds. There were 4 seeds for each test, and the amount germinated was tested. The range was from 0 seeds germinated to 3 seeds germinated, giving a range of 3 seeds.

Table 3

Data of Standards

|  |
| --- |
| Standard (seeds germinated) |
| 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 2 |

 Table 3 shows how many seeds grew under the standards for both Urea (5 grams per 100 ml) and Fulvic Acid (5 grams per 100 ml). The range of standards is 1 seed and 2 seeds, making a range of 1 seed.

Figure 1. Standards Plot

Graph 1 shows how many seeds germinated when given the standard dose of the factors. The results were as low as one seed germinated and as high as two seeds germinated. Doubling the range of standards would yield two seeds.

Table 4

Average Number of Seeds Germinated Data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| trials | FirstRun | Second Run | Third Run | Averages |
| Urea | Fulvic Acid |
| (+) | (+) | 0 | 1 | 1 | 0.66 |
| (-) | (-) | 3 | 3 | 3 | 3.00 |
| (+) | (-) | 3 | 4 | 3 | 3.33 |
| (-) | (+) | 0 | 0 | 0 | 0.00 |

 Table 4 shows the results for amount of seeds germinated of each combination and each DOE. It also shows the average of each combination with the factors. The grand average is all four averages added together and divided by four. In this case, the grand average is 1.75 seeds germinated.

Table 5

Effect of Urea

|  |
| --- |
| Urea  |
| - | + |
| 3.00 | 0.66 |
| 0.00 | 3.33 |
| Avg. 1.50 | Avg. 2.00 |

Table 5 shows how many seeds on average germinated when Urea was applied. It gives both high and both low amounts, as well as an average for both. When the high amount of urea was applied, an average of 2 seeds germinated. When the low amount of urea was applied, and average of 1.5 seeds germinated.

Figure 2. Effect of Urea

 Figure 2 shows the effect of the Urea. The effect of the Urea is found from subtracting the low value, 1.5, from the high value, 2. The effect of the Urea on the germination of the seeds is 0.5. This means that as the urea increases, the germination rate of the seeds increases by 0.5 seeds.

Table 6

Effect of Fulvic Acid

|  |
| --- |
| Fulvic Acid |
| - | + |
| 3.00 | 0.00 |
| 3.33 | 0.66 |
| Avg. 3.17 | Avg. 0.33 |

 Table 6 shows the average high amounts and low amounts. It also shows both of these values averaged. When the high amount of Fulvic acid was applied to the plants, an average of 0.33 seeds germinated. When the low amounts of Fulvic acid were applied to the plants, an average of 3.17 seeds germinated.

Figure 3. Effect of Fulvic Acid

 Figure 3 shows the effect of Fulvic Acid. The effect of the Fulvic Acid is found from subtracting the low value (3.17) from the high value (0.33). The effect of the Fulvic Acid is -2.84. This means that as the amount of Fulvic Acid increases, the germination rate of the seeds decreases by 2.84 seeds.

Table 7

Interaction Effect.

|  |  |
| --- | --- |
|   | Fulvic Acid(g) |
| (-) | (+) |
|
| Urea(g) | Solid Segment | (+) | 3.33 | 0.66 |
|
| Dotted Segment | (-) | 3 | 0 |
|

 Table 7 is a table comparing the total averages between the Urea and Fulvic Acid when interacting with one another.

Figure 4. Interaction of Fulvic Acid and Urea

 Figure 4 shows the interaction effect between Urea and Fulvic Acid. The solid segment represents the high amount for Urea and the dotted segment represents the low amount for Urea. The slope of the sold segment is -1.33. The slope of the dotted segment is -1.5. Knowing these values, the interaction effect can be found. The interaction effect of these factors is 0.17. This is found by subtracting the slope of the dashed (low) segment from the slope of the solid (high) segment.

 It should be noted that when Urea is held high, on its own (see figure 2), 2 seeds were expected to germinate on average. Look at the solid segment above which also represents Urea held high with the interaction of Fulvic Acid. Notice that when Fulvic Acid is low, the high amount of Urea yields 3.33 seeds on average, which is much larger than the 2 seeds that were expected. However, when Fulvic Acid is high only 0.66 of a seed germinates on average. This is well below the expected amount of two seeds.

 Further, When Urea is held low, on its own (see figure 2), 1.5 seeds were expected to germinate on average. Look at the dotted segment above which also represents Urea held low with the interaction of Fulvic Acid. Notice that when Fulvic Acid is low, the low amount of Urea yields 3 seeds on average, which is much larger than the 1.5 seeds that were expected. However, when Fulvic Acid is high no seeds germinate on average. In both cases, adding more Fulvic Acid seems to significantly decrease the yield of seed germination. Further, decreasing the amount Fulvic Acid seems to increase the number of seeds germinated.

Figure 5. Dot Plot of Effects.

 Figure 5 shows the effects of the Urea (U), Fulvic Acid (F), and their interaction(FU). When thinking about significant factors that affect an experiment, a dot plot of effects can be drawn. These effect values can be compared to twice the range of standards to see if there are any significant factors based on the data. The dotted lines represent the range of standards doubled, which in this case has an absolute value of 2. If the effects are outside the dotted lines, they are deemed statistically significant. If not, then they are not. This is because the effect exceeds the standard even when it is doubled, making it significant. It can be seen that the Fulvic Acid is the significant factor in this case. This supports the data from the interaction effect.

Figure 6. Prediction Equation

 Figure 6 shows the prediction equation. This can be used to predict variables of future experiments. The prediction equation is the grand average totaled with half of each of the effects. Noise is an unquantifiable variable that allows for inaccuracies due to experimental design and follow through issues. The variables can be used to make predictions. The accuracy of the mathematics can be checked using this equation.

Figure 7. Checked Prediction Equation

 Figure 7 is the prediction equation but checked. The high-high (+, +) experiment was used. Recall that +1 used when referring to any high value on a graph. Because of this, +1 is plugged in for the both of the effect variables in the equation. The equation equals 0.66, which was the average of the high-high(+, +) experiment, meaning that the math conducted in the experiment is correct.

Figure 8. Parsimonious Prediction Equation

 Figure 8 shows the parsimonious prediction equation. The difference between this and the prediction equation is that only the significant effects are used. Only the Fulvic Acid is significant, so that is the only effect included.

Figure 9. Parsimonious Prediction

Figure 9 shows a prediction of 2.46 seeds. Notice that (-0.5) was inserting into the equation for the Fulvic Acid variable. This means that if this experiment were done again, and if Fulvic Acid is used at 7.5 grams per 100 milliliters, which is half way between the low (-1) and the standard (0) values, that one could expect 2.46 seeds to germinate on average.