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An Analysis of the Allelopathic Relationship Between Basil (Ocimum basilicum) and Tomatoes (Solanum lycopersicum) as an Alternative to Fertilizer

Keondra Jenkins
Rappahannock Community College

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Chesapeake Bay Governor's School

Jim Beam, Instructor

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Abstract

Allelopathy is a trait within certain organisms that allows them to produce and secrete certain biochemical that have various effects on other organism's growth, survival, and reproduction processes. This study compared the growth results of the allelopathic relationship between basil and tomatoes against fertilized tomatoes and untreated tomatoes. With the information from this study and conclusions can be made about whether or not allelopathic or "companion planting" can serve as a viable alternative for fertilizer.

After nearly 5 months of growth, the allelopathic properties of basil were found to be equal, if not more, beneficial to the growth of the tomato plants as fertilizer. Basil being planted along the tomato plants resulted in more tomatoes produced, faster germination time, and more massive roots. In those cases, the findings were all significant and the null hypothesis was rejected. There was no significant difference in the effects of basil or fertilizer final plant height, final plant biomass, and root length and growth rate. In those cases, the null hypothesis fails to be rejected.

This study seemed to indicate that the allelopathic relationship seems to greatly benefit the root growth of tomato plants. With more massive, dense roots, the plants maintain greater water retentions which is likely the cause of its greater tomato production. Considering this may mean the companion planting is in fact a suitable alternative to fertilizer, thus lessening the effects of its harmful chemicals.

Introduction

Allelopathy is a trait within certain organisms that allows them to produce and secrete certain biochemical that have various effects on other organism's growth, survival, and reproduction processes. The creation of these chemicals can result in negative or positive interactions plants (Qasem, 2010). The greatest priority for organisms is survival and reproducing. There are various relationships between organisms to ensure that plants can achieve these goals (Watson et. al, 2000). Mutualism is a relationship defined as the symbiosis between two different species that is beneficial to both and help them improve their chances of survival (Qasem, 2010).

While basically any part of the plant can house these chemicals, most store the chemicals in their leaves and roots. When their leaves fall and decompose, the toxins that are released affect nearby organisms (Phipps, 2011). Other plants are able to release chemicals though the roots in order for it to be absorbed by other plants in the area. A prime example allelopathic chemicals being released through soil is basil. Sweet basil releases its allelopathic oils into the soil in the surrounding areas (Phipps, 2011). Basil's essential oils are linalool, citronellol, terpineol, and eucalyptol. All of these oils serve as pest repellents and insecticides for both basil and the plants around it (Simon, et. al, 1999).

Runoff is one of the biggest dangers for the Chesapeake Bay. The buildup of nitrogen and phosphorus is the leading factor in the depletion of the Bay's water quality of the Chesapeake Bay. In terms of fertilizer, often too much is used so the excess makes its way to the nearest body of water causing hypoxia and threatening Bay life (Dewar, et al, 2011). Increasing restrictions on fertilizer use, banning phosphorus from fertilizers used on turf grass, and limiting the amount of nitrogen in fertilizers are goals to lessen the overall use of fertilizer, but these measures have not been enacted yet (Dewar, et. al, 2011).

Growing "companion" plants in close proximity to each other can improve the growth and overall health of the plants. When planted near a companion, plants will experience increased growth and improved heath factors such as germination, biomass and fruit size (Kuse, et. al, 2000). Also, the plants were less likely to be eaten by bugs, harmed by weeds. Certain plants can be used to fight off weeds and other harmful infestations by using the chemicals they produce through allelopathy (Kuse, et. al, 2000). Previous studies have also looked at allelopathic relationships have looked at the possibility of taking advantage of allelopathy to use it as a pest and weed repellent, creating more sustainable crop production, and increasing crop growth (Hage-Ahmed, et. al, 2013).

Tomato and basil is a common pair that is intercropped (Bomford, 2009). Previous research has observed basil's ability to attract the positive bacteria, Arbuscular mycorrhizal fungi (AMF) (Hage-Ahmed, et. al, 2013). AMF helps prevent diseases in tomatoes and increases the biomass of tomatoes (Hage-Ahmed, et. al, 2013). This study will focus on basil's positive effect on tomatoes based on the positive nitrogen fixing bacteria it attracts. Allelopathic plants can become an alternative for fertilizers, herbicides, and pesticides. In turn, this can decrease the pollution that the chemicals in these products cause because there was a decreased reliance on them (Kruse, 2000).

The observations of this study could lead to establishing efficient ways to grow crops in order to decrease the need for fertilizers, herbicides, and pesticides. This was done by observing how a positive allelopathic relationship compares to the use of fertilizer. If the importance of allelopathy on farming is acknowledged the production of foods will greatly improve by taking advantage of these relationships. Taking advantage of companion relationships can lead to the use of fewer fertilizers and mixed planting, grouping plants to *improve them* has been shown to increase the efficiency of land use (Bomford, 2009). Decreasing how much fertilizer is used on farm land can be very beneficial to the bay (Dewar, et. al, 2011).

Hypotheses

Previous research has shown that allelopathy is a useful tool for farming. Allelopathic plants are sometimes used as cover crops. This study determined if allelopathic plants can be a useful alternative to fertilizers. The following are the hypotheses that were tested in this study in reference to the three groups that were tested.

$$H_o: G_A = G_F = G_C$$

$$H_a: G_A > G_F > G_C$$

Where:

A represents the allelopathic group

F represents the fertilizer group

C represents the control group

The null hypothesis states that there would be no difference in the growth rate **(G)** of tomatoes planted in close proximity to basil, the plants given fertilizer, and the control group that grew alone.

The alternative hypothesis states the growth rate **(G)** of tomatoes grown near basil would have significantly higher growth than the group given fertilizer and the fertilizer will have a higher growth rate **(G)** than the control group.

$$H_o: N_A = N_F = N_C$$

$$\mathbf{H_a: N_A > N_F > N_C}$$

The second null hypothesis states that there would be no difference in the number **(N)** of tomatoes produced by the three plant groups.

The alternative hypothesis states tomatoes produced by the plants planted grown near basil would have a greater number **(N)** of tomatoes than the group that was given fertilizer and the fertilizer would have a higher number **(N)** tomatoes than the control group.

$$\mathbf{H_o: H_A = H_F = H_C}$$

$$\mathbf{H_a: H_A > H_F > H_C}$$

The third null hypothesis states that there would be no difference in the final height **(H)** of tomatoes planted in close proximity to basil, the plants given fertilizer, and the control group of tomatoes that grew alone.

The alternative hypothesis states tomatoes planted grown near basil would have a higher final height **(H)** than the group given fertilizer and the fertilizer will have a higher final height **(H)** than the control group.

$$\mathbf{H_o: E_A = E_F = E_C}$$

$$\mathbf{H_a: E_A < E_F < E_C}$$

The fourth null hypothesis states that there would be no difference in the time of emergence/germination **(E)** of any of the tomato groups.

The alternative hypothesis states the tomatoes grown near basil would have an earlier germination than group given fertilizer and the fertilizer group would germinate earlier than the control group that wasn’t planted in close proximity to basil

$$\mathbf{H_o: B_A = B_F = B_C}$$

$$\mathbf{H_a: B_A > B_F > B_C}$$

The fifth null hypothesis states that there would be no difference in the root biomass **(B)** of the tomato groups.

The alternative hypothesis states the tomatoes grown near basil would have a high root biomass **(B)** than the fertilizer group, and the fertilizer group will have a heavier root biomass **(B)** than the control group that wasn't planted in close proximity to basil.

$$\mathbf{H_o: R_A = R_F = R_C}$$

$$\mathbf{H_a: R_A > R_F > R_C}$$

The sixth null hypothesis states that there would be no difference in the final root length **(R)** of the three tomato groups.

The alternative hypothesis states plants grown near basil would have a longer final root length **(R)**than the fertilizer group, and the fertilizer group would have a longer root length **(R)** than the control group that wasn't planted in close proximity to plant basil.

Materials and Methods

This study compared tomatoes affected by the allelopathic properties of basil, tomatoes given nitrogen fertilizer, and tomato plants grown by themselves with no treatments. The testing was conducted at a residence in Lancaster, Virginia. The time range of this experiment was from June 2015 until the end of October 2015.

To begin this study the tomato seeds were separated into their respective independent variable group; the treatment of the soil, and planted in organic seed starters. These independent variable groups are tomatoes with basil planted in the surrounding soil, tomatoes that had nitrogen fertilizer periodically added to its soil, and tomatoes that received no treatments to its soil.

Tomato seeds were planted in compostable seed starters. There were fifteen seed starters for each variable group thus, 45 initial seeds were planted. One group were planted close proximity to basil which will allow it to benefit from its allelopathic properties. A separate group of tomatoes was given a two tablespoon dosage of fertilizer every two weeks. There was a control group of tomatoes that was not planted near basil and was not given fertilizer. As these groups of tomatoes grew, several variables were measured.

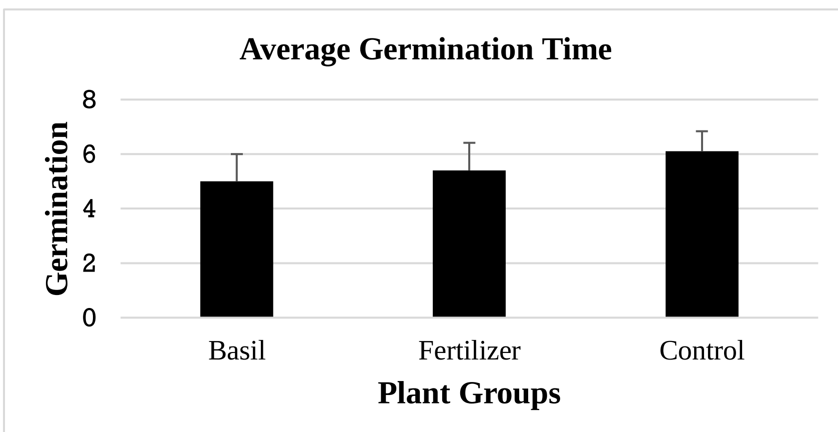
For each group of plants the following dependent variables were measured: growth rate, final height, final root biomass, final root length, emergence/germination, the number of tomatoes produced, and the mass of those tomatoes. After the tomato plants emerge they were measured once a week in order to calculate its growth rate.

All of the groups were given the same type and amount of water were planted in the same type and amount of organic, non-treated soil, and the group given fertilizer received the same type and amount.

After the data for this observation was collected data analysis was taken. For each dependent variable that was measured for the three treatment groups, a One-Way Anova were conducted in order to determine if there is a significant difference between the results of the three groups. If there isn't a significant difference between the groups then the null hypothesis will fail to be rejected. If there was a significant difference between the groups then further statistical analysis was taken. A Multiple Comparisons test (Bonferroni) was conducted in order to determine if there is a significant difference between specific groups (ie: the allelopathic, fertilizer, and control groups).

Results

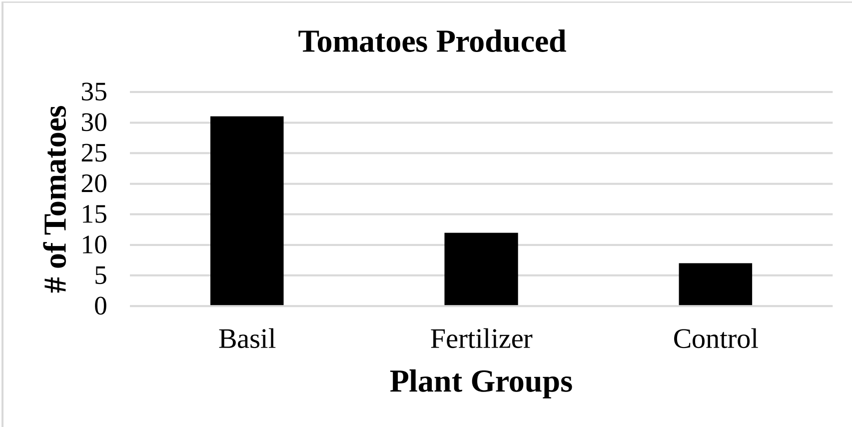
This study compared the development of tomato plants affected by the allelopathic properties of basil, tomatoes given nitrogen fertilizer, and tomato plants were grown by themselves with no treatments. The following are the recorded results of this study.



Graph 1: This graph shows the average time it took the plants in each treatment group to germinate once planted.

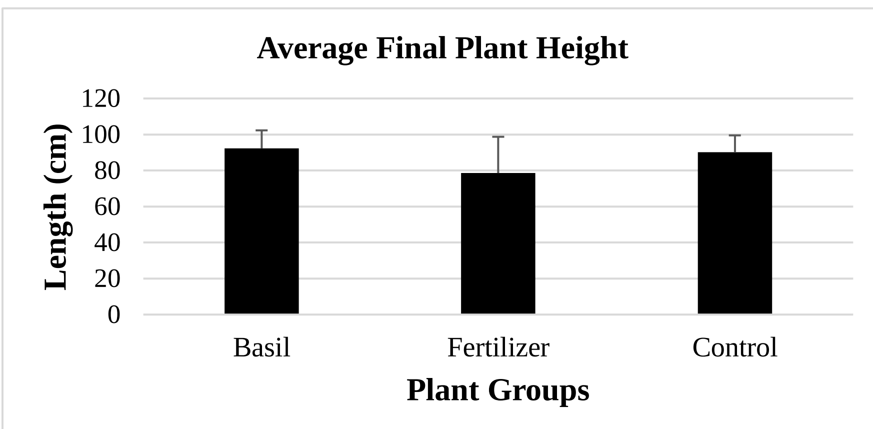
On average, it took the plants in the basil group 5 days to germinate, the fertilizer group took an average of 5.4 days, and control group took an average of 6.1 days (Graph 1). An ANOVA test comparing the values within the three groups resulted in a p-value of 0.047248 (Appendix Table 1). A post-HOC test found that there was a significant difference between the germination times of the basil and control groups (Appendix Table 3).

Plant growth throughout the study was measured (Appendix Graph A and B). The graphs show that the ongoing growth of the tomato plants.



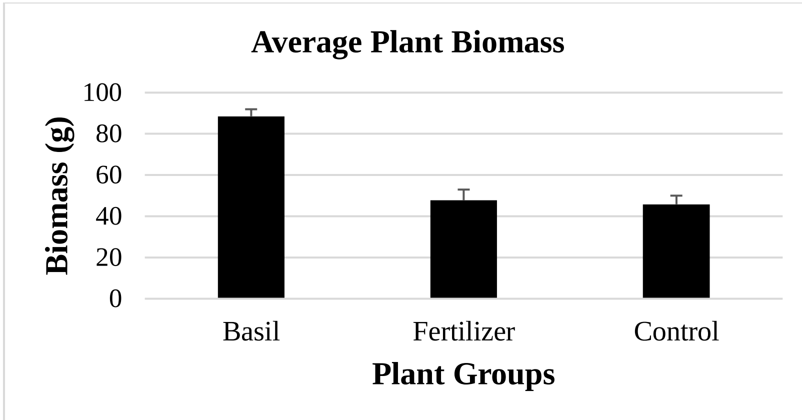
Graph 2: This graph shows the total number of tomatoes produced by each of the treatment groups.

The group of tomatoes grown with basil produced the most amounts of tomatoes, 31. The fertilizer group of plants produced 12 tomatoes and the control group produced 7 tomatoes.



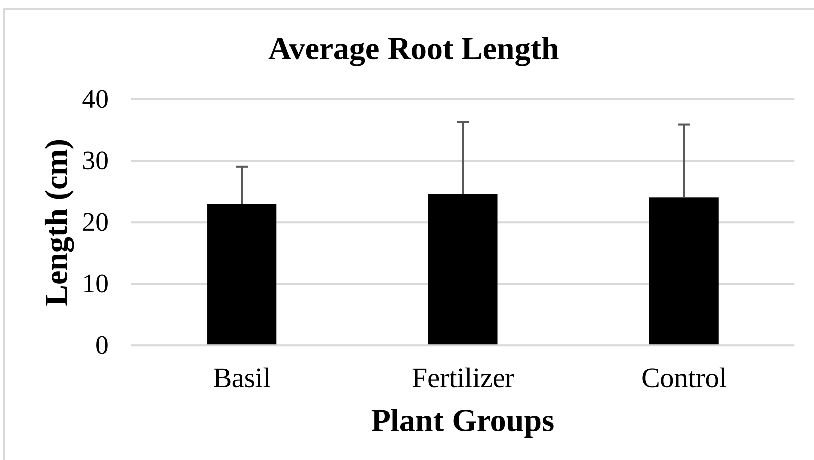
Graph 3: This graph shows the average final plant heights of the three plant groups. There are also error bars that represent the standard error of each data set.

The group of tomatoes grown with the basil had the highest average final height, 92.24 inches, and the group grown with fertilizer had the lowest average height, 78.56 inches, at the end of the study (Graph 3). An ANOVA test comparing the final plant height was run and resulted in a p-value of 0.345992 (Appendix Table 6).



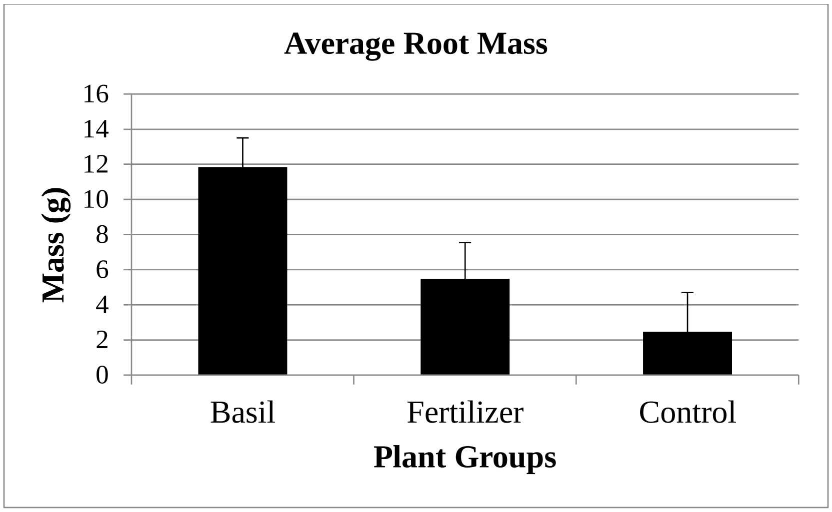
Graph 4: This graph shows the average plant biomasses (in grams) of the plants in each treatment group. The error bars represent the

The average plant biomass of the basil group was 88.515 cm, the fertilizer group's was 47.7108 cm, and the control group's was 45.814 cm. An ANOVA test comparing the average plant biomass was ran and resulted in a p-value of 0.146077 (Appendix Table 7).



Graph 5: This graph shows the average root lengths of plants after they were fully grown.

The average root length of the tomato plants in the basil group was 23 cm. The average for the fertilizer group was 24.6 cm, an average for the control group was 24.04 cm. An ANOVA test was ran on the three groups resulting in a p-value of 0.967129 (Appendix Table 9).



Graph 6: This graph shows the average root masses of the tomatoes in each treatment group. The error bars show the standard deviation of each data set.

The average root mass of the plants in the basil group was 11.8374 grams, the fertilizer group was 5.4756 grams, and the control group had an average root mass of 2.467667 grams. An ANOVA was run on the root masses which resulted in a p-value of 0.000131. Because of the significance of that p-value A Multiple Compassion Bonferroni test was run which resulted in p-values of 0.000337102 between basil and fertilizer and 0.000237 between basil and the control (Appendix Table 10).

Conclusion

After analyzing the test results of this study, the allelopathic properties of basil was found to be equal, in not more, beneficial to the growth of tomato plants as fertilizer. Basil resulted in more tomatoes produced (Graph 2), faster germination time (Graph 1), and more massive roots (Graph 6). In those cases, the null hypothesis is rejected. There was no significant difference in the effects of basil or fertilizer final plant height, final plant biomass, and root length and growth rate.

While some of the measurements weren't statically significant that does not to the findings aren't significant. When looking at the big picture of this study and the issues that fertilizers cause, no significant difference means that while taking advantage of allelopathic relationships might not be better in all factors of plant growth, it is equal. This means that allelopathic relationships can be a viable alternative because, at the least, they are equal plant productivity. If people were to become aware of the benefits allelopathic relation can provide to their plants, maybe they would be more interested in using it as a replacement for harmful fertilizer. Further research related to this study could include observations on the benefits of allelopathic relationships on a larger scale. A larger number and variety of plants species could help further the range of this study.

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Appendix

Appendix Table 1: Germination Time

Germination					
Control	Days	Fertilizer	Days	Basil	Days
	5		4		3
	5		4		4
	6		5		5
	6		5		5
	6		6		5
	6		6		5
	6		6		6
	7		6		6
	7		7		6
	7				

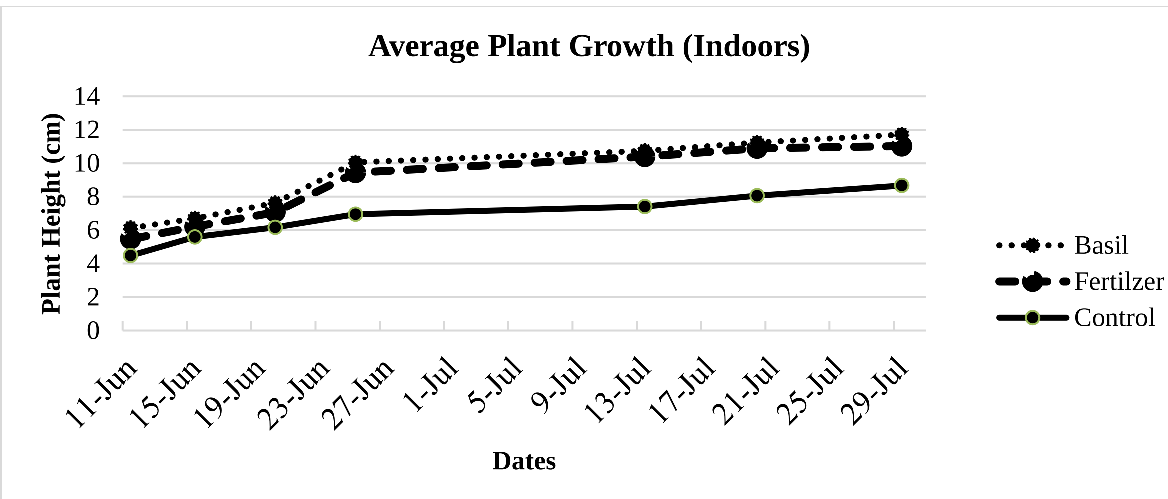
Appendix Table 2: Anova Single Factor of Germination

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Control	10	61	6.1	0.544444		
Fertilizer	9	49	5.444444	1.027778		
Basil	9	45	5	1		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.842063	2	2.921032	3.457297	**0.047248**	3.38519
Within Groups	21.12222	25	0.844889			
Total	26.96429	27				

Appendix Table 3: Germination Bonferroni P-Values

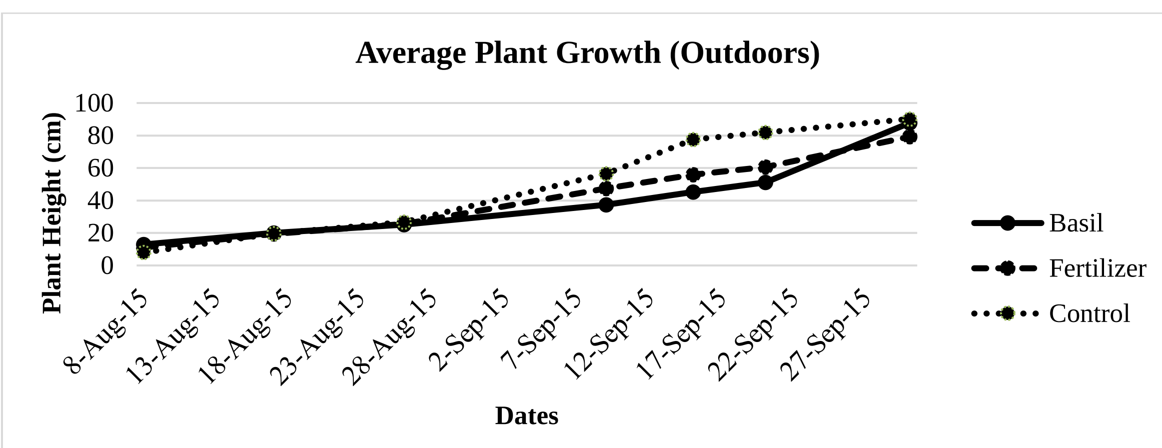
α= 0.01	Basil	Fertilizer	Control
Basil		0.181511227	**0.008172**
Fertilizer	0.181511227		0.065630169
Control	**0.008172**	0.065630169	

Appendix Graph A: Average Plant Growth June-July



Graph 8: Shows the average plant growth of all the treatment groups when they were indoors from June to July

Appendix Graph B: Average Plant Growth August-September



Graph 9: This graph shows the growth of the treatment groups will they were outside from August until September.

Appendix Table 4: Recorded Plant Heights from June-July

Height(cm)	11-Jun	15-Jun	20-Jun	25-Jun	13-Jul	20-Jul	29-Jul
Basil	4.4	6.6	7.2	9.5	10	10.5	11.1
	7.9	8.6	10.1	13	13.4	13.8	14.5
	7	7	7.9	11.1	11.5	12	12
	6.9	6.6	8	10.5	11.9	11.9	11.9
	5.7	7.6	7.9	11	11.6	11.8	12.5
	6.7	7.1	7.5	9.5	10.2	10.8	11.5
	6	6	6.6	9	9.7	10.5	11
	5.5	5.9	7	9.9	10.7	10.9	10.9
	5	5	6.4	7	7.6	9	10
Fertilizer	9	10	11	13.1	15.1	15.7	15.8
	7.1	7.1	7.9	10	11.2	11.5	11.5
	6	7	9.1	13.9	14.5	15.5	15.5
	6.1	6.9	8	10	11.5	12.5	12.5
	5.5	5.9	7	8.2	8.5	9.2	9.5
	5.6	6.9	6.9	10.9	11	12	12.5
	5.1	6	7.2	8	9	9	9.2
	3.8	4.9	5.5	9	9.9	9.9	10
	4.5	4.9	5	5.5	7.5	7.5	7.5
Control	4	6	6.1	7	7	8.9	9.5
	4	5.1	6	7.5	8.2	8.9	10.9
	5.9	6.1	6.5	7.1	8.1	9	9.2
	5.5	6.2	6.6	8.3	8.8	9.2	9.5
	5	5.9	7.5	8.1	8.1	8.5	9
	4.1	5.9	5.9	6.5	6.5	7.5	8
	6.2	6.5	6.7	7	8.5	9.9	11
	3	4.9	5.5	6.5	6.5	6.5	6.5
	2.5	3.9	5	5	5.5	5.9	6
	4.1	5.9	5.9	6.5	6.5	7.2	7.9

Appendix Table 5: Recorded Plant Heights from August-September

Height(cm)	Aug-8	17-Aug	26-Aug	9-Sep	15-Sept	20-Sept	30-Sept
Basil	17.5	25	39	49	62.5	75.2	109.8
	12	17.8	20.8	46	58.2	66.5	87.7
	11.7	20	22.2	39.5	42.7	56	89.4
	12.5	22.4	30.9	33	39.9	40	84.4
	11	20	26.7	31	39.9	42	89.9

Fertilizer	12	19.7	24.6	60	79.8	85	107
	11.5	17.8	25	49	51.3	60	79.1
	12	20.1	30.5	30.9	36.6	39	63.1
	10	22.1	27.9	41	53.3	59.4	87.4
	9.9	17.8	19.5	56	58.9	60	59.8
Control	8.2	21.5	28.5	62.5	70.3	77	81
	6.5	22	28	60	75.4	79	99.6
	8	12.9	18.2	38	86.9	89.9	90
	9	22	32.5	65.1			

Appendix Table 6: Anova Single Factor of Final Plant Heights

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Basil	5	461.2	92.24	100.993		
Fertilizer	5	392.8	78.56	406.563		
Control	3	270.6	90.2	86.52		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	521.0252	2	260.5126	1.182394	**0.345992**	4.102821
Within Groups	2203.264	10	220.3264			
Total	2724.289	12				

Appendix Table 7: Anova Single Factor of Final Plant Biomass

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Basil	5	442.575	88.515	399.3022		
Fertilizer	5	238.554	47.7108	421.5132		
Control	3	137.442	45.814	4016.754		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	5309.936	2	2654.968	2.346047	**0.146077**	4.102821
Within Groups	11316.77	10	1131.677			
Total	16626.71	12				

Appendix Table 8: Anova Single Factor of Final Root Masses

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Basil	5	59.187	11.8374	2.768622		
Fertilizer	5	27.378	5.4756	4.263828		
Control	3	7.403	2.467667	4.977174		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	189.5697	2	94.78484	24.88827	**0.000131**	4.102821
Within Groups	38.08415	10	3.808415			
Total	227.6538	12				

Appendix Table 9: Anova Single Factor of Final Root Lengths

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Basil	5	115	23	36.5		
Fertilizer	5	123	24.6	136.8		
Control	3	72.12	24.04	140.4237		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.532923	2	3.266462	0.033535	**0.967129**	4.102821
Within Groups	974.0474	10	97.40474			
Total	980.5803	12				

Appendix Table 10: Root Masses Bonferroni Table

α= 0.01	Basil	Fertilizer	Control
Basil		**0.000337102**	**0.000237**
Fertilizer	**0.000337102**		0.050133
Control	**0.000237**	0.050133	