The Effect of 10-34-00 Starter Fertilizer on *Glycine max* Yields, Protein and Oil Content

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Abstract

The objective was to compare the yield and protein and oil content of *Glycine max* planted with a 2x2 application of 10-34-00 starter fertilizer and without starter fertilizer, and to compare the quality of water discharge from field drainage tile before and after fertilizer application. The soil in each plot was tested for nutrients. Three replications were planted. Each contained a plot planted with 10-34-00 starter fertilizer and a control plot without fertilizer. A field drainage tile water discharge sample was taken before and after application of the fertilizer and was analyzed for orthophosphates and nitrates. A population count was conducted to determine percent of plant emergence. Plant specimens were collected randomly from each plot for pod and node count, DGCI, and plant tissue analysis. At maturity, the *Glycine max* were harvested. The plot length, weight, and moisture content of the *Glycine max* was recorded. A sample was collected from each plot for nutrient, protein, and oil content analysis. The fertilized plots averaged 146.75 kg/hectare more than the non-fertilized plots. This was not quite statistically significant. There was not a significant difference in the protein or oil content between the fertilized and non-fertilized plots. The water quality analysis did not show a significant increase in either nitrate or orthophosphate levels after the fertilizer was applied. The outcome may have been different if the soil was cooler and wetter at planting. Additional research is needed to determine if *Glycine max* can benefit from starter fertilizer applications.

Introduction

Glycine max, or the soybean, is a major crop that is produced around the world. *Glycine max* is grown mainly for its protein and oil content. The world population is growing rapidly and is projected to increase from 7.3 billion people in 2015 to 8.5 billion in 2030 and 9.7 billion in 2050 (World Population, 2015). Crop yields, including *Glycine max*, will have to be increased to feed the added population.

The agriculture industry is also under pressure to better protect the environment. In 2014, the City of Toledo, Ohio placed a ban on the city's drinking water because it was contaminated with a toxin produced by algae growing in Lake Erie. The algal blooms were caused by increased amounts of phosphorus and nitrates in the lake which have been attributed to agricultural runoff.

Fertilizer can be broadcast on the soil or it can be applied at planting. Fertilizer that is applied at planting is called starter fertilizer. By applying fertilizer close to the time the plant uses it, it is thought that runoff and leaching can be reduced because the nutrients are taken up by the plant before it can runoff or leach through the soil. It is also thought to benefit the plant by providing immediately available nutrients. Starter fertilizer is more commonly applied to *Zea mays* (corn) but there have been studies to evaluate its effectiveness on *Glycine max*. In 2015, Beck's Hybrids conducted a study with four types of starter fertilizers and found anywhere between a 0.8-4.9 bushel per acre yield advantage compare to the control (Practical Farm Research, 2015, pg. 54). Two of the fertilizers tested produced positive returns on investment.

The objective of this experiment is to compare the yield and protein and oil content of *Glycine max* planted with a 2x2 application of 10-34-00 starter fertilizer to *Glycine max* without a starter fertilizer applied and to compare the water quality of water flowing from field drainage tile before and after fertilizer application. *Glycine max* with 10-34-00 starter fertilizer applied at planting in a 2x2 band will have a higher yield than *Glycine max* without starter fertilizer applied because the starter fertilizer will make nutrients immediately available to the plant after emergence, increasing yield. *Glycine max* with 10-34-00 starter fertilizer applied at planting in a 2x2 band will have a higher protein and oil content because the starter fertilizer will provide essential nutrients for the production of protein and oil to the plants. Water from field drainage tile discharge after 10-34-00 starter fertilizer application will not have a higher orthophosphate or nitrate content than water from drainage tile before 10-34-00 application because the fertilizer will be incorporated in the soil.

Literature Review

Starter Fertilizer

Starter fertilizer is fertilizer that is applied to a crop at planting. The fertilizer may be placed in the row, most commonly 5cm (2in) below and 5cm to the side of the seed. It may also be placed directly in the seed furrow, which is known as pop-up fertilizer. By applying fertilizer close to the seed, the young plant can obtain nutrients for early and rapid growth (Hoeft, Aldrich, Nafziger, & Johnson, 2000). Starter can be more beneficial in cool and wet soil conditions which makes it ideal for early planting, northern climates, and no-till. Starter may be applied in either dry or liquid form, although liquid is more common because it is easier to handle. Starter fertilizer usually contains the macronutrients nitrogen and phosphorus, and sometimes potassium. Micronutrients such as sulfur, zinc, and boron may be added as well.

Nitrogen

Nitrogen is the most limiting nutrient to plants. Although most of earth's atmosphere is composed of nitrogen, it is not usable by plants because it is in the stable form of N_2. Nitrogen can be made into a usable form by *Bradyrhizobium* bacteria or by producing synthetic chemicals. *Bradyrhizobium* bacteria colonize nodules on the roots of plants in the legume family (including

Glycine max) and receive sugars from the plant. The bacteria fix nitrogen into a form that is usable by the plant, forming a symbiotic relationship. Bacteria in the soil also free nitrogen from decaying organic matter in a process called mineralization (Hoeft et al., 2000). Nitrogen from either organic matter or chemical fertilizers changes to the form of ammonium (NH_4^+) in the soil, which is further changed by microorganisms into nitrite (NO_2^-), and then nitrate (NO_3^-). This process is called nitrification (Hoeft et al., 2000). Nitrite is toxic to plants and animals; however, the conversion to nitrate under most conditions happens rapidly enough to prevent nitrite from accumulating in the soil. Nitrate is very mobile in water and can be carried deep into the soil by rainwater. Because of this, nitrate can leach into groundwater or enter field drainage tile. To prevent leaching, nitrogen should be applied when the plant needs it.

Phosphorus

The element phosphorus is essential to life because it is an essential component of DNA and RNA. It is also an essential component of several chemical reactions in plants. It is the second most limiting nutrient in the world, next to nitrogen (Hoeft et al., 2000). Phosphorus fertilizer is produced from phosphate rock. Phosphorus in rock is in the form of calcium fluorapatite ($3Ca_3(PO_4)_2CaF_2$) and hydroxyapatite ($3Ca_3(PO_4)_2Ca(OH)_2$) (Hoeft et al., 2000). Plants cannot use phosphorus in this form so it must be broken down into the orthophosphate form phosphoric acid (H_3PO_4) by either treating the rock with sulfuric acid or heating it in a furnace. Orthophosphate contains up to 68% phosphate (P_2O_5). When the phosphate content is raised to 83%, a water molecule is removed and the units link up, forming polyphosphate ($H_4P_2O_7$) (Hoeft et al., 2000). Polyphosphates are commonly used in liquid fertilizers because they don't settle out and allow for higher formulations (Hoeft et al., 2000). Polyphosphates can also be ammoniated to supply nitrogen to crops as well as phosphorus.

Phosphorus Pollution from Field Drainage Tile

Phosphorus can enter streams and ditches through surface runoff. Because phosphorus doesn't move much in the soil, it has been assumed that only surface runoff is a concern for phosphorus loss. However, a study published in the *Journal of Environmental Quality* found that water from drainage tile discharge can carry as much phosphorus as surface runoff (Fisher, 2014). The concentrations were generally below 1 part per million (ppm), but only 0.3 ppm is needed to contribute to algae growth (Fisher, 2014). The type of phosphorus that enters field tile is ortho or dissolved phosphate. Ortho phosphorus is much more potent than particulate phosphorus which is bound by soil particles or organic matter (Smith, 2016). One way that the phosphorus gets into the tile is through macropores in the soil. Macropore formation is encouraged by reduced tillage or no-till and provides beneficial aeration to the soil. However, they also form a direct path for water to carry phosphorus to tile systems. To prevent phosphorus from running into tile systems, fertilizer should be incorporated by either tillage or injection (Fisher, 2014). Farmers can also install movable gates to control tile outflow which can be opened in the spring to dry out fields for planting and closed later in the growing season to hold in water and prevent nutrients from leaching out.

Fertilizer and the Environment

Fertilizers can runoff from fields and into streams and ditches that run into larger bodies of water. Nitrates from fertilizers can also leach into groundwater. Nitrates are toxic at high levels, especially for young children (Muir, 2012). Excessive levels of nitrates and phosphorus in a body of water can cause large blooms of algae. The algae blooms form mats over the surface, blocking the sunlight needed for photosynthesis by plants in the water. The loss of these plants means less oxygen is produced. Oxygen is further reduced by bacteria that feed on the dead plant and algae matter which consume large amounts of oxygen. The decreased oxygen levels, known as hypoxia, cause fish that require large amounts of dissolved oxygen to die, disrupting the food chain. This process is known as eutrophication (Muir, 2012). Algae can also produce toxins that can make the water unsafe to drink.

Tri-State Fertilizer Recommendations

The Tri-State Fertilizer Recommendations are a set of recommendations on the amount of fertilizer that should be applied to soil. The recommendations were developed by Michigan State University, The Ohio State University, and Purdue University, for the states of Indiana, Michigan, and Ohio (Vitosh, Johnson, and Mengel, 1995). The recommendations are now over 20 years old and a reevaluation of these recommendations is currently being conducted to see if the standards need to be updated. Water quality issues in Lake Erie are creating a sense of urgency that nutrients need to be managed more efficiently and researchers are trying to determine how nutrient use can be reduced. They have recruited farmers to voluntarily try different rates of N, P, and K, and collect data to determine if additional fertilizer application results in a yield increase (Culman and Fulford, 2016). This data will help researchers determine if the Tri-State Fertilizer Recommendations should be changed.

Review of Literature Conclusion

Glycine max with 10-34-00 starter fertilizer applied at planting will have a higher yield than *Glycine max* without starter fertilizer applied because the starter fertilizer will make nutrients immediately available to the plant after emergence, increasing yield. *Glycine max* with 10-34-00 starter fertilizer applied at planting will have a higher protein and oil content because the starter fertilizer will provide essential nutrients for the production of protein and oil to the plants. 10-34-00 starter fertilizer will not increase the levels of orthophosphates and nitrates in field drainage tile discharge water because the fertilizer will be incorporated in the soil.

The agriculture industry must find ways to produce higher crop yields to feed the growing world population. Various methods are being researched to evaluate their effectiveness at increasing *Glycine max* yields, including starter fertilizer. The agriculture industry must also find ways to protect the environment. Phosphorus and nitrates from fertilizer contribute to algal blooms which cause eutrofication and harm aquatic ecosystems. Algal blooms can also produce toxins that make the water unsafe to drink. The Tri-State Fertilizer Recommendations are a commonly used set of recommendations for fertilizer application used in Indiana, Michigan, and Ohio. Research is currently being conducted to evaluate updating the Tri-State standards to balance the need for fertilizer to increase crop yields with the need to reduce fertilizer applications to protect the environment. The Agriculture industry has an enormous challenge, but these challenges can be solved if farmers and researchers work together to find solutions.

Materials and Methods

Hypotheses

Glycine max with 10-34-00 starter fertilizer applied at planting in a 2x2 band will have a higher yield than *Glycine max* without starter fertilizer applied because the starter fertilizer will make nutrients immediately available to the plant after emergence, increasing yield.

Glycine max with 10-34-00 starter fertilizer applied at planting in a 2x2 band will have a higher protein and oil content because the starter fertilizer will provide essential nutrients for the production of protein and oil to the plants.

Water from field drainage tile discharge after 10-34-00 starter fertilizer application will not have a higher orthophosphate or nitrate content than water from field drainage tile discharge before 10-34-00 application because the fertilizer will be incorporated in the soil.

Materials List

- Tractor
- 12 row 76.2cm (30in) row spacing planter
- Professional weather station
- Combine Harvester with 9.1m (30ft) grain head equipped with yield monitor
- *Glycine max* seed 3.2 maturity
- 3.53 hectares (8.72 acres) of farmland
- Chisel plow
- Soil Finisher
- Soil type map
- Soil Probe
- Sprayer
- 10-34-00 Starter Fertilizer
- Sulfentrazone and Chloransulum-methyl herbicide
- Trimethylbenzene herbicide
- Glyphosate herbicide
- Clethodim herbicide
- Thiophanate-methyl fungicide
- Manganese
- Sterile 0.45ppm filters and syringes.
- Dark Green Color Index (DGCI) measurer, color-board and app
- Grain cart with digital scales
- Potash

Steps of Procedure

1. Apply potash in accordance to soil tests.

2. Chisel plow soil.

3. Till soil with a soil finisher.

4. Collect a water sample from field drainage tile outlet.

5. Strain the tile water to remove debris and filter it through a 0.45ppm syringe filter. Refrigerate water until it can be delivered to the lab for testing of orthophosphate and nitrate levels.

6. Fill planter tank with 10-34-00 starter fertilizer.

7. Plant six plots in three replications as shown in figure 1. Apply 140.31 liter/hectare (15gal./ac.) of 10-34-00 in furrow using a 2x2 application to the phosphorus plots. Row width of 76.2 cm. Planting depth of 2.54cm and a population of 370,500 seeds per hectare (150,000 seeds per acre).

8. Collect fifteen soil cores in each plot in a "W" pattern as shown in figure 2.

9. Apply a pre-emerge of Sulfentrazone and Chloransulum-methyl and Trimethylbenzene herbicide to prevent weed growth.*

10. Collect water sample from drainage tile after significant rainfall.

11. Repeat step five.

12. Perform a population count at five weeks on Gf and La soil types by counting the number of plants in 3.05m divided by 10 and use figure 3 to determine population. Convert plants per acre to plants per hectare using the formula (plants per acre x 2.47 [acres/hectare] = plants per hectare).

13. Apply glyphosate as needed for weed control and a Clethodim herbicide if needed for volunteer *Zea mays* (corn) control.*

14. Collect ten uppermost fully developed trifoliates from each plot in a "W" pattern as shown in figure 2 at the R1 growth stage and send them to a lab to be analyzed for nutrient content.

15. Count number of plants in 0.91m (3ft), collect six specimens (three from Gf soil type and three from La soil type) at random from each plot and count the number of pods and nodes on a plant and observe the nodulation at 14 weeks. Calculate the number of pods in a 0.91m x 0.91m (3ft x 3ft) area by averaging the number of pods on three plants and multiplying it by the number of plants in 0.91m (3ft) of row. Take the total number of pods in the 0.91m (3ft) of row, multiply it by 91, and divide by the row spacing (76.2cm [30in]).

16. Measure nitrogen levels from each plot at three weeks and seven weeks using a Dark Green Color Index (DGCI) measurer, colorboard, and app. Observe the plots for any noticeable differences in height or color and take pictures.

17. Record the rainfall during the growing season using an on-site professional weather station.

18. Record the monthly average temperature during growing season from Fulton County, Ohio, Airport.

19. Harvest *Glycine max* when mature using a combine harvester equipped with a 9.1m (30ft) grain head and a yield monitor.

20. Unload *Glycine max* into grain cart equipped with electronic scales at the end of each plot and record weight from electronic scales.

21. Record the length of plot, acreage, and moisture for each plot from yield monitor.

22. Calculate average yield correcting to 13% moisture using data recorded from steps 14 and 15 and the formula 43,560 x harvested wt (in lb) x (100-harvest moisture %)/(harvest length(ft) x harvest width (ft) x 60(lb/bu) x 87)[87 is 100-standard moisture (13%)]. Convert bu/acre to kg/ha using formula bu/acre x 60(lb/bu) x 2.47(acres/ha)/2.205(lb/kg).

23. Send Glycine max samples from each of the plots to a lab to have the nutrient and protein and oil contents measured.

***NOTE:** All chemicals were applied by supervising adult/licensed pesticide applicator. All regulations pertaining to chemicals were adhered to and all label recommendations followed with regard to amounts applied and re-entry requirements.

Figure 1

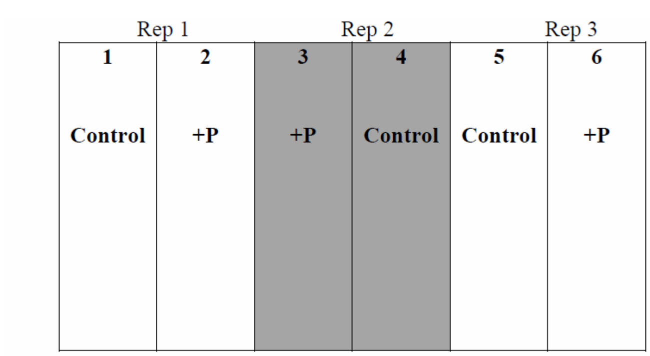

Figure 2

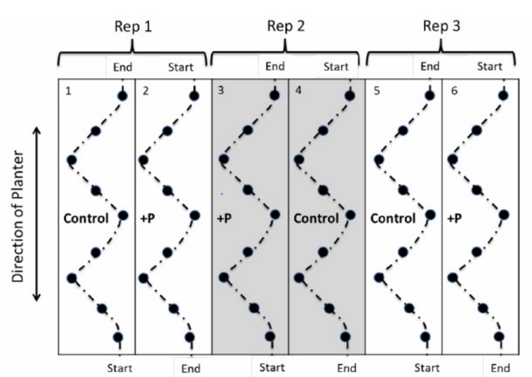

Figure 3

Soybean Plants Per 3.05m of Row	Row Width 76.2cm
5.5	95,832
6.0	104,544
6.5	113,256
7.0	121,968
7.5	130,680
8.0	139,392
8.5	148,104
9.0	156,816
9.5	165,528

Results

Yield

Table 1.

Average bushels/acre and kilograms/hectare of no starter fertilizer and starter fertilizer plots.

Plot #	Length of Plot (ft.)	(m)	Scale Weight (lbs.)	(kg)	Bu/ Acre*	kg/ Hectare*
			No Starter Fertilizer			
1	2,118	645.57	5,080	2,304.25	66.72	4,484.31
4	2,108	642.52	5,040	2,286.11	66.51	4,470.20
5	2,106	641.91	5,180	2,349.61	68.42	4,598.57
Avg.					**67.22**	**4,517.69**
			Starter Fertilizer			
2	2,112	643.74	5,220	2,367.75	68.75	4,620.75
3	2,110	643.13	5,200	2,358.68	68.55	4,607.31
6	2,103	640.99	5,360	2,431.26	70.90	4,765.25
Avg.					**69.40**	**4,664.44**

*Bu/acre and kg/hectare have been corrected to 13% moisture (industry standard)

Notes. Bu = Bushels. kg = kilograms. m = meters.

140.31 liters/hectare (15 gals./acre) of starter fertilizer was applied in furrow using a 2x2 application at planting on the starter fertilizer plots.

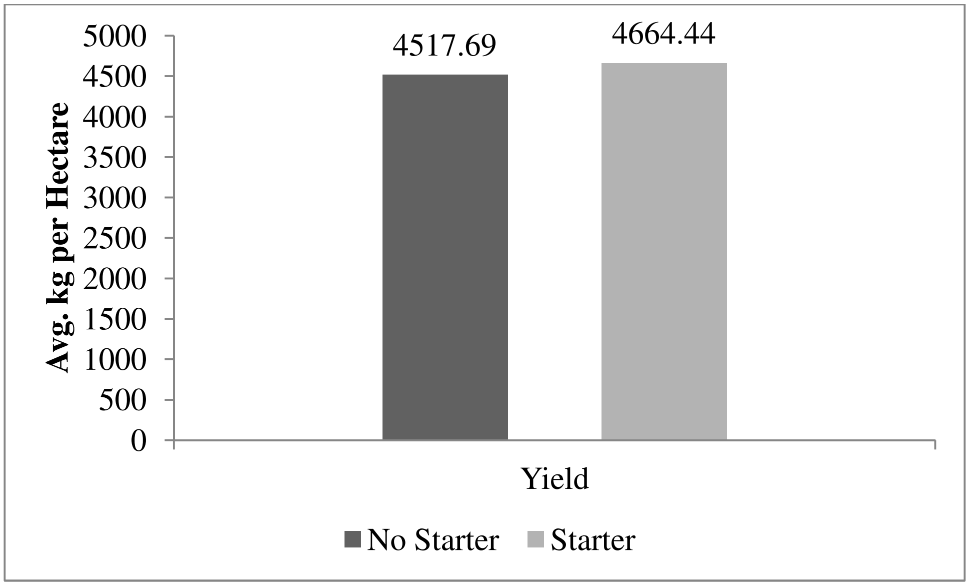

Figure 4. Average kg/hectare of *Glycine max*. This figure represents the average kg per hectare of the *Glycine max* no starter fertilizer and starter fertilizer plots.

T-test: Two tailed p value =0.09. The difference is considered to be not quite statistically significant.

Oil and Protein

Table 2.

Percentage of protein and oil content of Glycine max grain from no starter fertilizer and starter fertilizer plots.

Plot #	Protein %*	Oil %*
	No Starter Fertilizer	
1	33.92	20.60
4	33.66	20.48
5	33.73	20.98
Avg.	**33.77**	**20.67**
	Starter Fertilizer	
2	34.10	20.35
3	34.30	20.29
6	33.86	19.89
Avg.	**34.09**	**20.18**

*Protein and oil content percentages are based on *Glycine max* moisture of 13%.

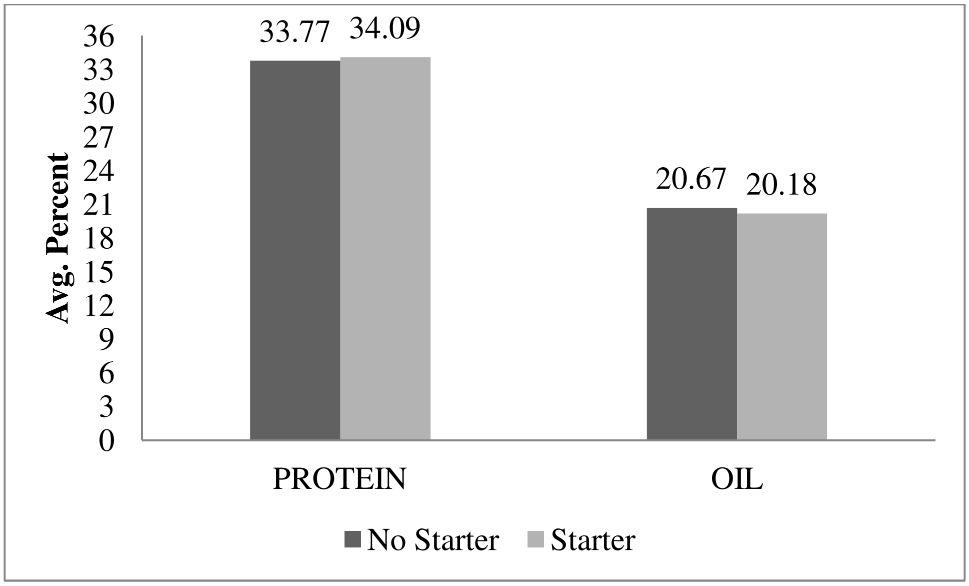

Figure 5. Average percent of protein and oil content. This figure represents the average protein and oil content of the *Glycine max* grain at 13% moisture from the no starter fertilizer and starter fertilizer plots.

T-test: Protein two tailed p value =0.10; Oil two tailed p value=0.07. The difference is considered to be not statistically significant.

Water Samples

Table 3.

Average parts per million (ppm) of orthophosphates and nitrates in field tile water discharge prior to applying starter fertilizer and after applying starter fertilizer to soil.

Date	Sample #	Orthophosphates Avg. ppm	Nitrates Avg. ppm
5/30/16	1	0.0023	14.8077
5/30/16	2	0.0021	15.1958
5/30/16	3	0.0056	15.9386
Avg.		**0.0033**	**15.3140**
6/07/16	1	0.0005	14.7891
6/07/16	2	0.0007	14.5719
6/07/16	3	0.0020	14.1470
Avg.		**0.0011**	**14.5027**

Note: 1 ppm = 1 mg/liter

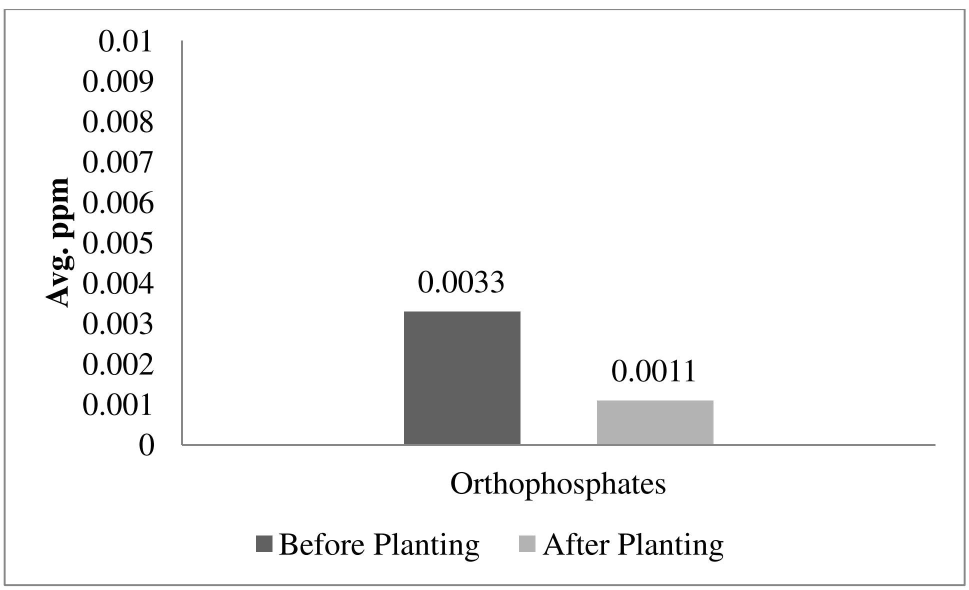

Figure 6. Average parts per million (ppm) of orthophosphates in field tile water discharge prior to and after applying starter fertilizer to soil. This figure represents the average ppm of orthophosphates in the field tile before and after applying starter fertilizer to soil.

T-test: Two tailed p value =0.14. The difference is considered to be not statistically significant.

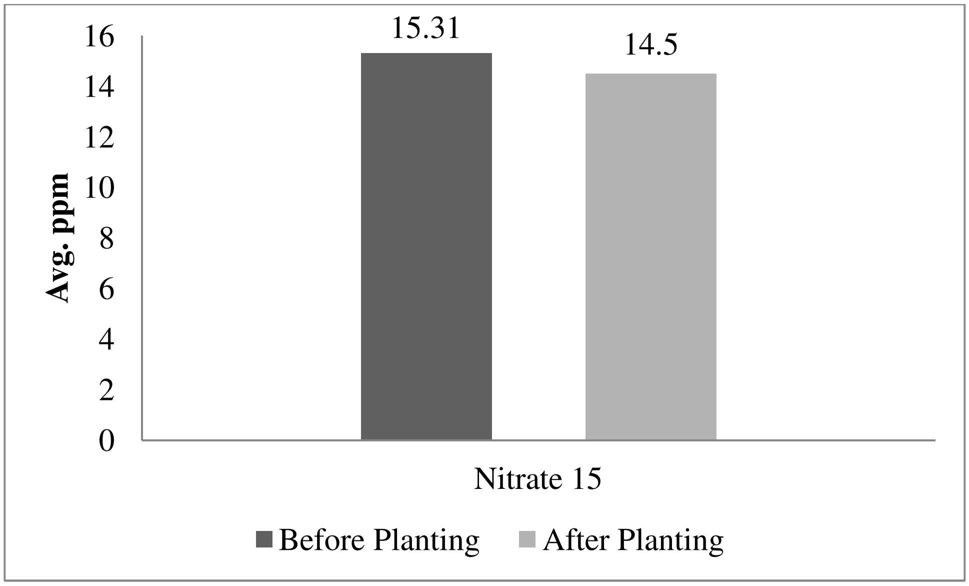

Figure 7. Average parts per million (ppm) of nitrates in field tile water discharge prior to and after applying starter fertilizer to soil. This figure represents the average ppm of nitrates in the field tile before and after applying starter fertilizer to soil.

T-test: Two tailed p value =0.10. The difference is considered to be not statistically significant.

Soil Test

Table 4.

Soil test prior to planting.

Plot #	Soil pH	Organic Matter %	Phosphorus ppm
1	6.2	0.7	201
2	6.2	1.6	177
3	6.4	1.0	175
4	6.3	1.2	182
5	6.2	1.0	198
6	6.3	0.9	202

Note: Optimum soil pH for soybeans is 6.7 to 6.9.
Tri-State Fertilizer Recommendations indicates phosphorus levels are "high" indicating no additional phosphorus is needed to grow *Glycine max.*

Emergence

Table 5.

Estimated plants per hectare and percent of emergence by soil type at 4 weeks.

Soil Type	Plot #	No. of Plants in 3.05m row	Estimated Plants per/hectare
		No Starter Fertilizer	
Gf	1	71	301,261
Gf	4	77	344,298
Gf	5	74	322,780
Average - Gf			**322,780**
Percent Emerged - GF			**87%**
La	1	73	322,780
La	4	79	344,298
La	5	52	236,705
Average – La			**301,261**
Percent Emerged – La			**81%**
Average – all plots			**312,020**
Percent Emerged – all plots			**84%**
		Starter Fertilizer	
Gf	2	67	301,261
Gf	3	71	301,261
Gf	6	70	301,261
Average – Gf			**301,261**
Percent Emerged – Gf			**81%**
La	2	74	322,780
La	3	75	322,780
La	6	73	322,780
Average – La			**322,780**
Percent Emerged – La			**87%**
Average – all plots			**312,021**
Percent Emerged – all plots			**84%**

Notes. Gf = Gilford fine sandy loam. La=Lamson fine sandy loam

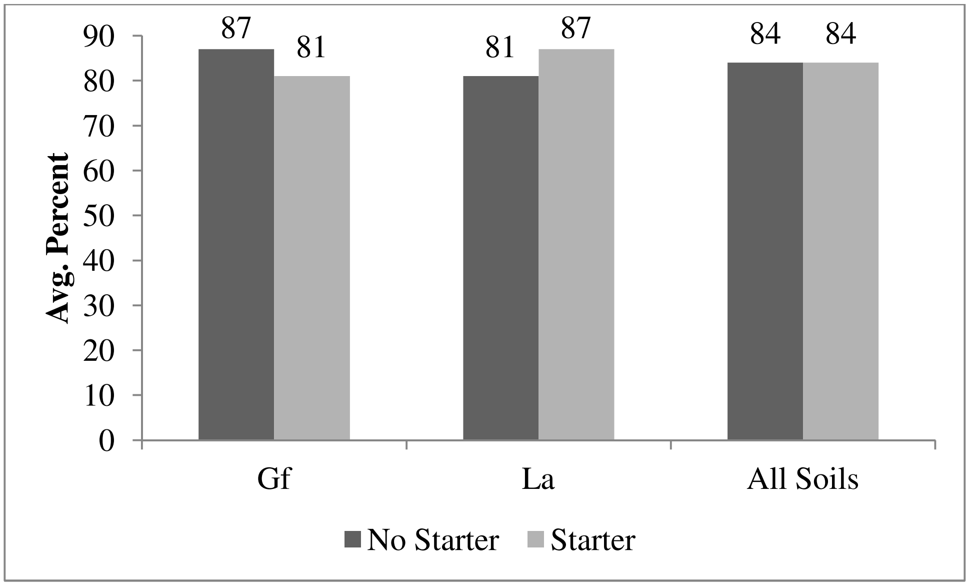

Figure 8. Average percent of emergence of plants in Gf soil, La soil, and all soil types. This figure represents the average plant emergence in the Gf soil, La soil and all soil types of the no starter fertilizer and starter fertilizer plots at 4 weeks.

T-test: Two tailed p value =0.51 - La; 0.09 - Gf. This difference is considered to be not statistically significant.

Plant Tissue Analysis

Table 6.

Percent of nitrogen, phosphorus, and potassium in leaves of Glycine max from no starter fertilizer and starter fertilizer plots at beginning R1 growth stage.

Plot #	Nitrogen% Leaves	Phosphorus% Leaves	Potassium% Leaves
		No Starter Fertilizer	
1	5.60	0.51	1.96
4	5.85	0.53	1.84
5	6.06	0.50	1.95
Avg.	**5.84**	**0.51**	**1.92**
		Starter Fertilizer	
2	5.37	0.49	1.63
3	5.27	0.48	1.90
6	5.88	0.52	1.72
Avg.	**5.51**	**0.50**	**1.75**

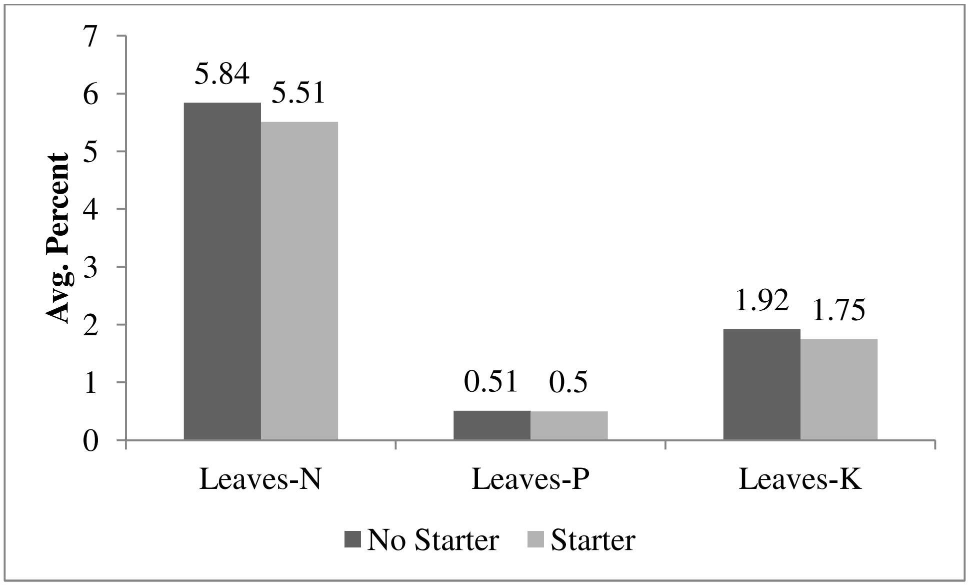

Figure 9. Average percent of nitrogen, phosphorous and potassium in *Glycine max* leaves. This figure represents the average percent of nitrogen, phosphorous and potassium in *Glycine max* leaves from the no starter fertilizer and starter fertilizer plots at beginning R1 growth stage.

T-test: Two tailed p value N=0.23; K=0.13. The difference is considered to be not statistically significant.

DGCI

Table 7.

Average dark green color index (DGCI) of Glycine max leaves of no starter fertilizer and starter fertilizer plots at 3 and 7 weeks.*

Date	Plot #1	Plot #4	Plot #5	Avg.
		No Starter Fertilizer		
6/24/16	0.429	0.617	0.561	0.536
7/17/16	0.576	0.618	0.546	0.580
		Starter Fertilizer		
6/24/16	0.499	0.601	0.552	0.551
7/17/16	0.579	0.556	0.546	0.560

* DGCI is a number between 0 and 1 that is influenced by the leaf's chlorophyll content.

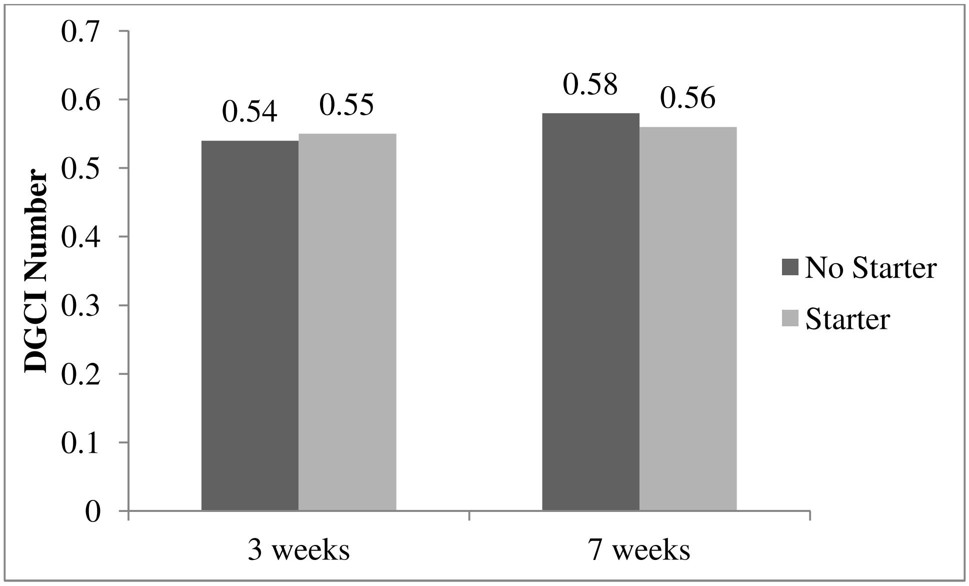

Figure 10. Average DGCI (dark green color index) of *Glycine max* plants. This figure represents the DGCI at 3 weeks and 7 weeks of the *Glycine max* plants with starter fertilizer applied and without starter fertilizer applied at planting. DGCI is a number between 0 and 1 that is influenced by the leaf's chlorophyll content.

T-test: Two tailed p value =0.94. This difference is considered to be not statistically significant.

Pod Count

Table 8.

Average number of pods in a .83m² area from no starter fertilizer and starter fertilizer plots at 14 weeks.

Sample #	No. of Plants in .91m	1 pod	2 pod	3 pod	4 pod	Total	No. of Pods in .83m² Area
			No Starter Fertilizer				
1	20	6	25	42	0	73	1,476
2	23	6	36	59	1	102	2,372
3	23	5	24	38	1	68	1,581
4	23	5	23	28	1	57	1,326
Avg.						**75**	**1,689**
			Starter Fertilizer				
1	21	9	24	54	1	88	1,869
2	26	2	19	67	2	90	2,366
3	27	4	15	25	2	46	1,256
4	24	7	32	56	4	99	2,402
Avg.						**81**	**1,973**

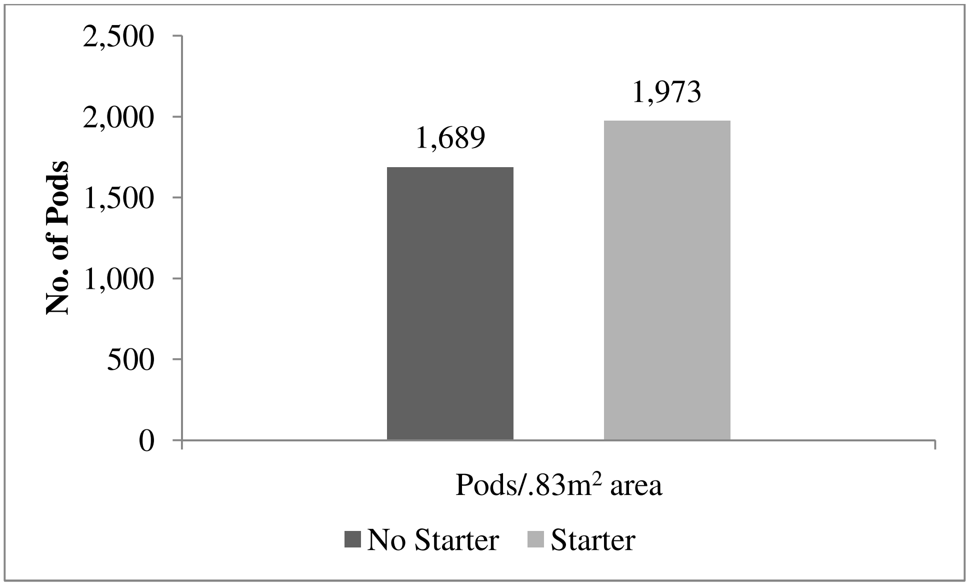

Figure 11. Average pods per .83m^2 area. This figure represents the average pods per .83m^2 area of the no starter fertilizer and starter fertilizer plots at 14 weeks.

T-test: Two tailed p value =0.45. This difference is considered to be not statistically significant.

Node Count

Table 9.

Average number of nodes on 3 plants from no starter fertilizer and starter fertilizer plots at 14 weeks.

Sample #	No. of Nodes on Plant 1	No. of Nodes on Plant 2	No. of Nodes on Plant 3	Avg. No. of Nodes
		No Starter Fertilizer		
1	12	12	9	11
2	13	11	10	11
3	13	12	11	12
4	11	12	12	12
Avg.				**11**
		Starter Fertilizer		
1	9	9	10	9
2	13	12	15	13
3	12	11	14	12
4	11	9	15	12
Avg.				**11**

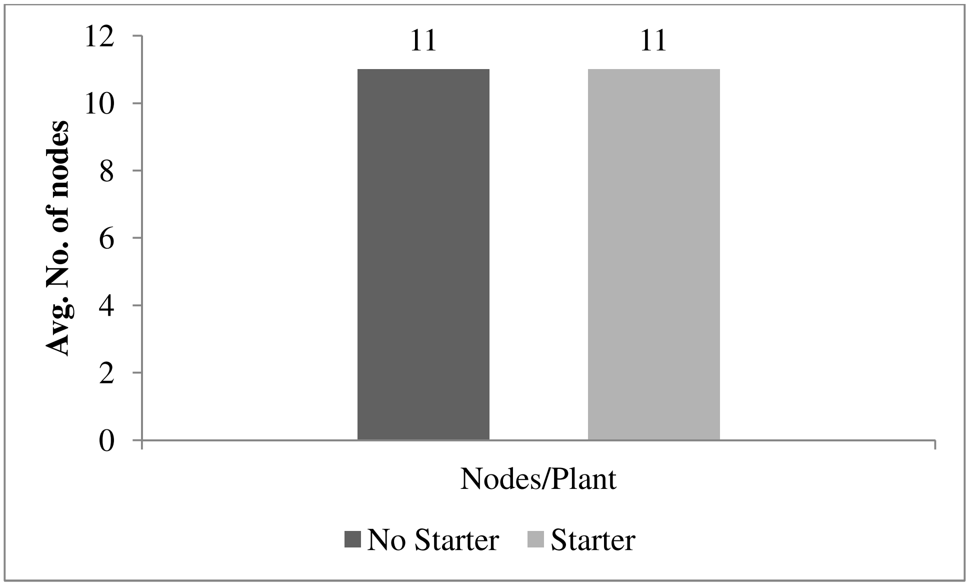

Figure 12. Average nodes per plant. This figure represents the average nodes per plant of the no starter fertilizer and starter fertilizer plots at 14 weeks.

Grain Analysis

Table 10.

Percentage of nitrogen, phosphorus and potassium of Glycine max grain from no starter fertilizer and starter fertilizer plots.

Plot #	Nitrogen % Grain	Phosphorus % Grain	Potassium % Grain
		No Starter Fertilizer	
1	5.86	0.63	1.57
4	5.32	0.68	1.65
5	6.16	0.59	1.51
Avg.	**5.78**	**0.63**	**1.58**
		Starter Fertilizer	
2	5.47	0.64	1.62
3	5.69	0.62	1.55
6	5.65	0.62	1.60
Avg.	**5.60**	**0.63**	**1.59**

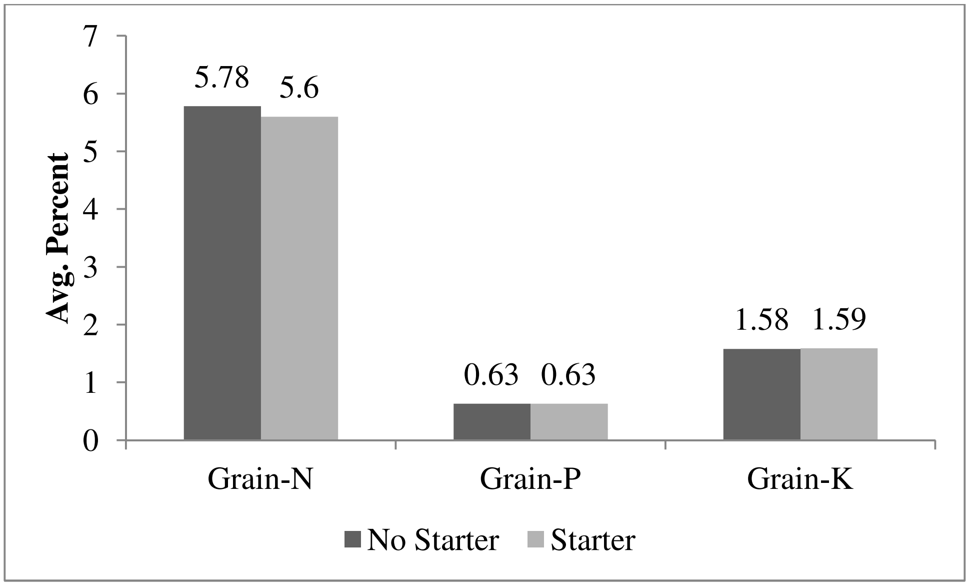

Figure 13. Average percent of nitrogen, phosphorous and potassium in *Glycine max* grain. This figure represents the average percent of nitrogen, phosphorous and potassium in *Glycine max* grain from the no starter fertilizer and starter fertilizer plots.

T-test: Two tailed p value =0.53-N; 0.78-K. This difference is considered to be not statistically significant.

Cost Analysis

Table 11.

Cost analysis of no starter fertilizer and starter fertilizer plots.

Treatment	Avg. kg/ Hectare*	kg/hectare Difference	Net** Return Per Hectare	ROI*** Per Hectare
No Starter	4517.69	--	$1,536.01	--
Starter	4664.44	146.75	$1,464.39	-$49.90

*Kg/hectare has been corrected to 13% moisture (industry standard).
**Net return is gross income (kg/hectare x $.340/kg) on the no starter and kg/hectare x $.340/kg) minus cost of starter fertilizer ($121.52/ha) on the starter.
***ROI is kg/hectare difference x $.340/kg minus cost of starter fertilizer ($121.52/ha).
Notes. ROI = return on investment. 140.31 liters/hectare of starter fertilizer was applied at planting on the starter fertilizer plots using a 2x2 in row application.

Rainfall

Table 12.

Rainfall during growing season from onsite professional weather station.

Date	**Rainfall (cm)**	**Monthly Total (cm)**
6/04/16	6.35	
6/06/16	0.40	
6/15/16	0.15	
6/22/16	3.43	
6/22/16	0.79	
TOTAL JUNE		11.12
7/07/16	2.62	
7/12/16	0.13	
7/13/16	0.43	
7/18/16	1.60	
7/21/16	0.20	
7/24/16	6.17	
7/29/16	0.51	
TOTAL JULY		11.66
8/11/16	0.43	
8/12/16	1.50	
8/15/16	1.55	
8/17/16	1.37	
8/20/16	0.25	
8/24/16	0.20	
8/27/16	2.62	
8/30/16	0.41	
TOTAL AUGUST		8.33
9/10/16	4.32	
9/17/16	1.85	
9/26/16	0.36	
9/28/16	4.98	
TOTAL SEPT.		11.51
TOTAL		**42.62**

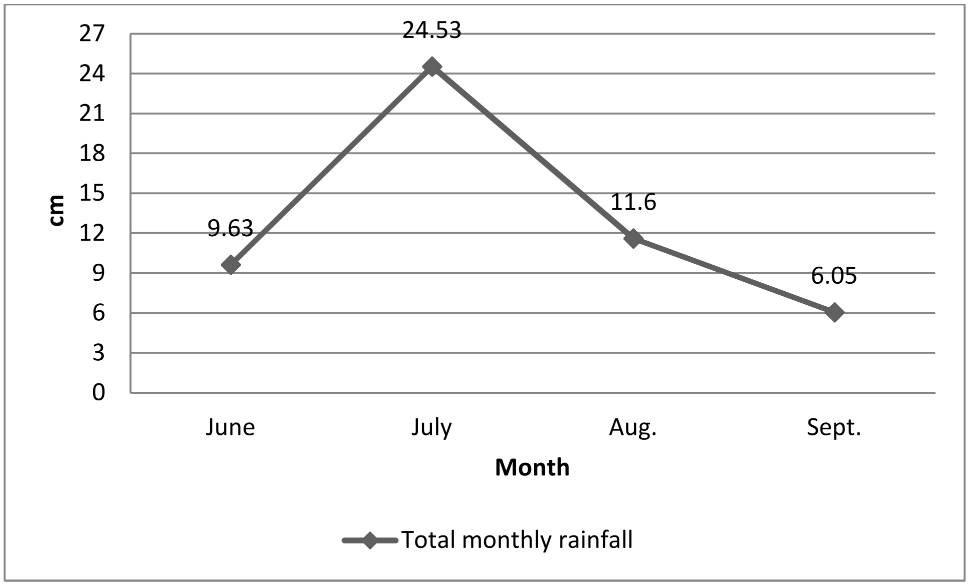

Figure 14. Monthly rainfall during growing season. This figure represents the total monthly rainfall as measured by an onsite professional weather station.

Temperature

Table 13.

Monthly average highs and lows during growing season.

Month	**Avg. High Degrees Celsius***	**Avg. Low Degrees Celsius***
June	27	16
July	29	18
August	29	18
September	26	14

*Data retrieved from the Fulton County, Ohio airport.

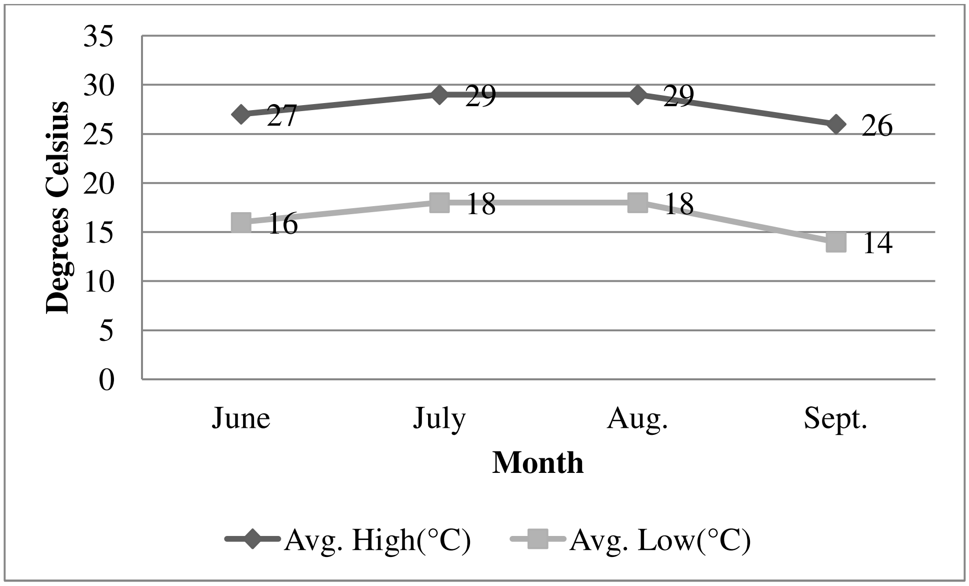

Figure 15. Monthly average high and low temperature. This figure represents the average high and low temperature during the growing season at the Fulton County, Ohio Airport.

Discussion and Conclusions

The objective was to compare the yield and protein and oil content of *Glycine max* planted with a 2x2 application of 10-34-00 starter fertilizer to *Glycine max* without a starter fertilizer applied and to compare the water quality of water flowing from field drainage tile before and after fertilizer application. The first hypothesis was that *Glycine max* with 10-34-00 starter fertilizer applied at planting in a 2x2 band would have a higher yield than *Glycine max* without starter fertilizer applied because the starter fertilizer would make nutrients immediately available to the plant after emergence, increasing yield. The second hypothesis was that *Glycine max* with 10-34-00 starter fertilizer applied at planting in a 2x2 band would have a higher protein and oil content than *Glycine max* without starter fertilizer applied because the starter fertilizer would provide essential nutrients for the production of protein and oil to the plants. The third hypothesis was that water from field drainage tile discharge after 10-34-00 starter fertilizer application would not have a higher orthophosphate or nitrate content than water from field drainage tile discharge before 10-34-00 application because the fertilizer would be incorporated in the soil.

The soil test (Table 4) showed adequate nutrients in the soil prior to planting.

The water quality analysis (Figures 6 and 7) did not show a significant difference in nitrate ($p=0.10$) or orthophosphate ($p=0.14$) levels present in drainage tile discharge after the application of the 10-34-00 compared to before the application. Orthophosphate levels were not enough to contribute to significant algae growth and nitrate levels were at a level that would be expected at the time and conditions of the test location.

The population count (Figure 8) showed that the plots with 10-34-00 applied had a higher rate of emergence on Lamson fine sandy loam (87%) than on Gilford fine sandy loam (81%), while the non fertilized plots had a higher rate of emergence on Lamson (87%) than on Gilford

(81%). Both the fertilized and non fertilized plots had an average rate of emergence of 84%. The differences were not significant. Lamson - (p=0.51); Gilford - (p=0.09).

The Dark Green Color Index (DGCI) measurements (Figure 10) showed that the plots with 10-34-00 applied had a slightly higher DGCI than the non-fertilized plots in the first measurement, but the non-fertilized plots had a slightly higher DGCI in the second measurement. However, these differences were not statistically significant (p=0.94).

The plant tissue analysis (Figure 9) showed that the non-fertilized plots contained an average of 5.84% nitrogen compared to 5.51% in the fertilized plots. This data was not statistically significant (p=0.23). The non-fertilized plots contained 0.51% phosphorus, compared to 0.50% in the fertilized plots. The non-fertilized replications contained 1.92% potassium, compared to 1.75% in the fertilized plots which was not statistically significant (p=0.13).

The pod count data (Figure 11) indicates that the fertilized plots had 284 more pods in a $0.83m^2$ ($9ft^2$) area than the non fertilized plots. However, this was not statistically significant (p=0.45). Both replications had an equal average of nodes per plant (Figure 12).

The rainfall data (Figure 14) shows that June, July, and September received around 11cm of rainfall, except August which received around 8cm. The rainfall received was adequate for *Glycine max*. The monthly average temperatures (Figure 15) remained stable throughout the growing season, and were not extremely hot or cool for the season.

The yield data (Figure 4) showed that the fertilized plots slightly out yielded the non-fertilized plots by 146.75kg/hectare. This difference was not quite statistically significant (p=0.09). A cost analysis (Table 11) showed a negative return on investment of -$49.90/hectare.

The oil and protein analysis (Figure 5) indicates no statistically significant difference between the protein and oil content of *Glycine max* planted with 10-34-00 compared to *Glycine* *max* without fertilizer applied. Protein content unpaired t-test (p=0.10); Oil content unpaired t-test (p=0.07).

The grain analysis (Figure 13) indicates no statistically significant difference between the nitrogen, phosphorus, or potassium content of the fertilized plots compared to the non-fertilized plots. Nitrogen content unpaired t-test (p=0.53); Potassium content (p=0.78).

Neither the first or second hypotheses was supported. The third hypothesis was supported. One variable that may have affected the outcome was that the *Glycine max* was planted at the end of May when the soil is warmer. Starter fertilizer may be more beneficial to *Glycine max* if the seed is planted earlier in the growing season in cooler soils or in less favorable soil and weather conditions. Further research is needed to determine if starter fertilizer is beneficial to *Glycine max*.

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