Do Soil Elements Affect Nodulation On Soybean Plants?

Student Researcher: Josie Jennings

Chapter: Global Impact STEM Academy

Category: Plant Systems

Division: 1

Abstract

This project studied the effects of Phosphorus, Potassium, and Nitrogen on the nodule growth on the root system of a soybean plant. The objective was to compare the nodule population on the roots. This was done while also testing the soil in each field plot to determine what fertilizations could be added. Nodulation growth was determined by rating of the count of nodules on the lateral root. A poor population was a count of nodules of zero to eight, a populated lateral root was determined by eight to ten nodules, and very populated roots contained a nodule count of ten or more. Soil was tested using a LaMotte NPK soil test kit and five trials were conducted of each sample regarding each element. The most effective soil element was found to be nitrogen and similar results are verified in numerous scholarly articles. These studies show that soybeans have a high demand for nitrogen and the other tested elements, Phosphorus and Potassium also had a subtle but positive proven effect on the soybean plants. The more nitrogen fixation in the soil, the healthier, more active nodules and the higher population on the lateral root. Less nitrogen-rich soils result in higher nodule counts while low amounts of nitrogen fixation resulted in poor populations of nodules. Prior research affirms the results of this study. This study adds to the confidence of farming practices that rely on scientific research. It also allows for other studies to build upon the results found in this study and more to come.

Importance

This study adds to the confidence of farming practices that rely on scientific research. The research gives examples of soil elements and fertilization practices that suit the nutrients crucial for the quality production of soybeans. In addition to that, this study can be built upon by other researchers and can act as base research for other studies. Research shows that the higher amount of nodules on a soybean root system causes higher yield during harvest. If soil elements have a direct relationship with nodule count, then these elements should result in higher yields, which is valuable for crop production.

Knowledge of soil qualities that have a direct effect in the formation of more nodules would allow producers to make better nutrient decisions for their operations, ultimately resulting in higher yields

and revenues. Better operation decisions cause a higher quality and quantity of production, which affects the industry in a positive way.

Other's Work

Summary

In "Soybean interactions with soil microbes, agronomical and molecular aspects" from HAL archives-ouvertes, D. Rodríguez-Navarro et al states that "Soybean, Glycine max (L.) Merrill, is one of the most important food crops in the world." Therefore, keeping the yields high for production is beneficial to our world and makes the year's crop profitable for producers. It is found that Nitrogen can be an inexpensive and valuable resource to increase grain yield and quality. This element is best infused to promote nodule growth and stimulate the use of nitrogen within the soybean plant itself. Although shown advantageous in the United States and other high producing soybean countries, it was found that for inoculation, the size of natural soil rhizobial can affect the successful outcome. This can block nodule growth, which would lead into the stunting of the soybean plant. The article ultimately states that N fertilization can have an impact in the nodule growth on the soybean's root system.

Evaluation

The article, "Soybean interactions with soil microbes, agronomical and molecular aspects" by D. Rodríguez-Navarro et al is a credible source published in 2011. This article clearly shows evidence of a detailed procedure and results. The information and evidence can be confirmed in numerous additional scholarly articles and is proven to be accurate. The credentials of the authors can be verified in further research and in the document as well. The authors presented themselves knowledgeable on the subject while citing and referring to other known scientists and authors in the text to confirm their evidence and theories. The overall intentions of this article are credible for the purpose to share research made on the growth of soybean nodules corresponding with the use of Nitrogen.

Rodríguez-Navarro, D., Oliver, M., Contreras, A., & Ruiz-Sainz, J. (2011, January 31). Soybean interactions with soil microbes, agronomical and molecular aspects. *Agronomy for Sustainable Development*, *31*, 173-190. doi:10.1051/agro/2010023

Summary

In "Unprecedented bacterial community richness in soybean nodules vary with cultivar and water status" from BMC, Hazem Sharaf states that, "Diazotrophs inhabiting root nodules provide soybean with nitrogen required for growth.". Therefore, it is important to use nitrogen fertilizers to ensure healthy and quality growth for the soybean crop. Is it explained that despite the understanding of Bradyrhizobium, less is known about bacteriome diversity within nodules. The bacteriome variability could have a large influence on scientific views and knowledge upon the plant-bacteriome's interaction. In addition to that, water availability can also have a substantial impact not only on the soybean plant itself, but also the water-deficit sensitive nodule diazotrophs. When this was tested on the nodule bacteriomes, they were not only "dominated by rhizobia, but also described by high variability and partly dependent on cultivar and water status."(Hazem Sharaf et af 2019). As a result, the nodule function had changed due to cultivar and water limitations.

Evaluation

The article, "Unprecedented bacterial community richness in soybean nodules vary with cultivar and water status" by Hazem Sharaf et al is a credible source published in 2019. This article intends to share and inform information about the research taken on the nodule system of a soybean plant. Multiple authors contributed to the testing and writing of this piece, which was shared on a credible research platform: BMC, research in progress. Further research on the authors can verify their credentials and academic degrees. An abundance of evidence was presented to support the hypothesis, and conclusion. The evidence listed can be confirmed in several other professional journals. In addition to that, the author also cites and refers to other credible sources that are proven to be accurate. With that being said, the

article is dependable to gain knowledge on the function of the bacteriome, nodule system, and how those interact and affect each other.

Sharaf, H., Ridrigues, R. R., Moon, J., Zhang, B., Mills, K., & Williams, M. A. (2019, April 16). Unprecedented bacterial community richness in soybean nodules vary with cultivar and water status. *Microbiome*, *7*(63), 1-18. doi:https://doi.org/10.1186/s40168-019-0676-8

Summary

In "Effects of Phosphorus and Potassium on Soybean Nodules and Seed Yield" from Agronomy Journal G. D. Jones states that, "The purpose of this investigation was to determine under field conditions the effects of P and K fertilization..." Usually experiments such as these have been conducted under a greenhouse or in laboratory conditions, but it is important to do procedures such as these in these conditions to relate it to what producers experience. Either Potassium or Phosphorus applied alone increases the number of nodules per plant. Applied Potassium most effectively increased the number of nodules, while also increasing the total and individual weight of nodules, and the number of pods per plant. On the other hand, Phosphorus also increased these dependents,(while not including yield) but applying Phosphorus without Potassium predominantly increased the Phosphorus concentration. The results showed that the application of both Potassium and Phosphorus was when the maximum result occurred, of dependents being increased tremendously.

Evaluation

The article, "Effects of Phosphorus and Potassium on Soybean Nodules and Seed Yield" by G. D. Jones et al is a credible source published in 1977. This article's intentions are to inform the audience about nodule growth and how Potassium and Phosphorus can affect these characteristics on soybean plants. Various additional authors contributed to the writing of this article, and are listed at the top of the document. In addition to that, the organizations that also contributed to the project are listed. Their credentials can be confirmed in further research about the topic and on themselves. Although this piece may seem old, the information is accurate and still modern. The authors present a factual report filled with

a clear conclusion and evidence. There is evidence of a research trial with a detailed procedure and this can be verified in numerous other sources.

Jones, G. D., Lutz, J. A., & Smith, T. J. (1977, November 1). Effects of Phosphorus and Potassium on Soybean Nodules and Seed Yield. *Agronomy*, *69*(6), 1003-1006. doi:https://doi.org/10.2134/agronj1977.00021962006900060024x

Summary

In "Effects of nitrogen concentrations on nodulation and nitrogenase activity in dual root systems of soybean plants" from Soil Science and Plant Nutrition, the author, Xuan Xia et al states that "...these results indicated that high nitrogen concentration exerts a contact-dependent localized inhibitory effect on the formation (number of nodules) and growth of root nodules (weight of nodules)." In other words, the high nitrogen intake stimulated nodule growth. The procedure of this experiment included the grafting of soybeans to create two root systems per plant. They tested each root system on each individual plant (there were two tests per plant since each contained two roots systems) to decide the speed in which nodules grow depending on the nitrogen concentrate. The research exhibited that with the addition of nitrogen applied to the root the nodulation growth peaked and then deceased with gaining the Nitrogen concentration. In contrast, with the N- side, all aspects increased at a constant rate. Based upon the results of the test, the scientists found that reflecting on their hypothesis, the nodule growth sped up in effect to the interactions between the nitrogen measure aboveground and underground.

Evaluation

The article, "Effects of nitrogen concentrations on nodulation and nitrogenase activity in dual root systems of soybean plants" by Xuan Xia et al is a credible source published in 2017. Although this article focuses on the amount of nitrogen or the concentration characteristics, the same is to be shown alike to the articles above. There are four listed authors of this article and their contact information is linked at the top of the page. The credentials of the authors can be found and confirmed in further research, contacts with the authors themselves, and lastly in the site. The article includes evidence of a detailed procedure and

also includes photos to support the explanation. The theories and conclusions can be verified in similar articles not only like the ones evaluated above, but further in additional informative journals. The general intent of this article was displayed throughout as it informed the audience and reader of the benefits of nitrogen in the quality production of the soybean crop.

Xia, X., Ma, C., Dong, S., Xu, Y., & Gong, Z. (2017, August 30). Effects of nitrogen concentrations on nodulation and nitrogenase activity in dual root systems of soybean plants. *Soil Science and Plant Nutrition*, *63*(5), 470-482. doi:https://doi.org/10.1080/00380768.2017.1370960

Summary

In "Impact of Soybean Nodulation Phenotypes and Nitrogen Fertilizer Levels on the Rhizosphere Bacterial Community" from Frontiers in Microbiology, Hao Wang et al states "...both the soybean nodulation phenotypes and the N levels affected the rhizosphere bacteria community…." The nodulation contributed more to this increase, although the diversity was decreased in the rhizosphere when only the super-nodulation was used. The more nitrogen fixation in the soil, the higher nodule count and heavier weight in regard to the soil effect on the soybean nodules. These results can be displayed as a cycle, the soil affects the nodule formation and the nodule formation affects the rhizosphere microbiome. The nodule numbers, nodule mass, and other dependents tested in the experiment were shown to be significantly higher with additional Nitrogen supplements. The data collected by Hao Wang ultimately presents that nodule growth slimates best in a high nitrogen fixed soil.

Evaluation

The article, "Impact of Soybean Nodulation Phenotypes and Nitrogen Fertilizer Levels on the Rhizosphere Bacterial Community" by Hao Wang et al is a credible source published in 2017. Numerous authors contributed to the construction of this article and procedure and their credentials can be verified in further research and in the links to contact each one in the article. The source contains information of its DOI, which evaluates the sources level. The accuracy of the facts and results shown in the text can be confirmed in several other similar articles about alike topics. There authors support their conclusions and

theories with evidence of a detailed procedure, research trail and tested results. The intentions of this article were met in information shown, which informed the audience about the formation of soybean nodules and the effect the rhizosphere microbiome, and soil elements have on the formation.

Wang, H., Gu, C., Liu, X., Yang, C., Li, W., & Wang, S. (2020, May 12). Impact of Soybean Nodulation Phenotypes and Nitrogen Fertilizer Levels on the Rhizosphere Bacterial Community. *Frontiers in Microbiology*, *11*(750). doi:10.3389/fmicb.2020.00750

Hypothesis/Anticipated Results

- The higher nitrogen levels, the higher population of nodules on a soybean root system.

Materials

- Five soil samples extracted from each of five field plots
- Three pulled soybean plants from each of the five field plots
- LaMotte NPK soil test kit
- 400 mL of distilled water
- Timer
- Vortex mixer
- Plastic teaspoon

Methods:

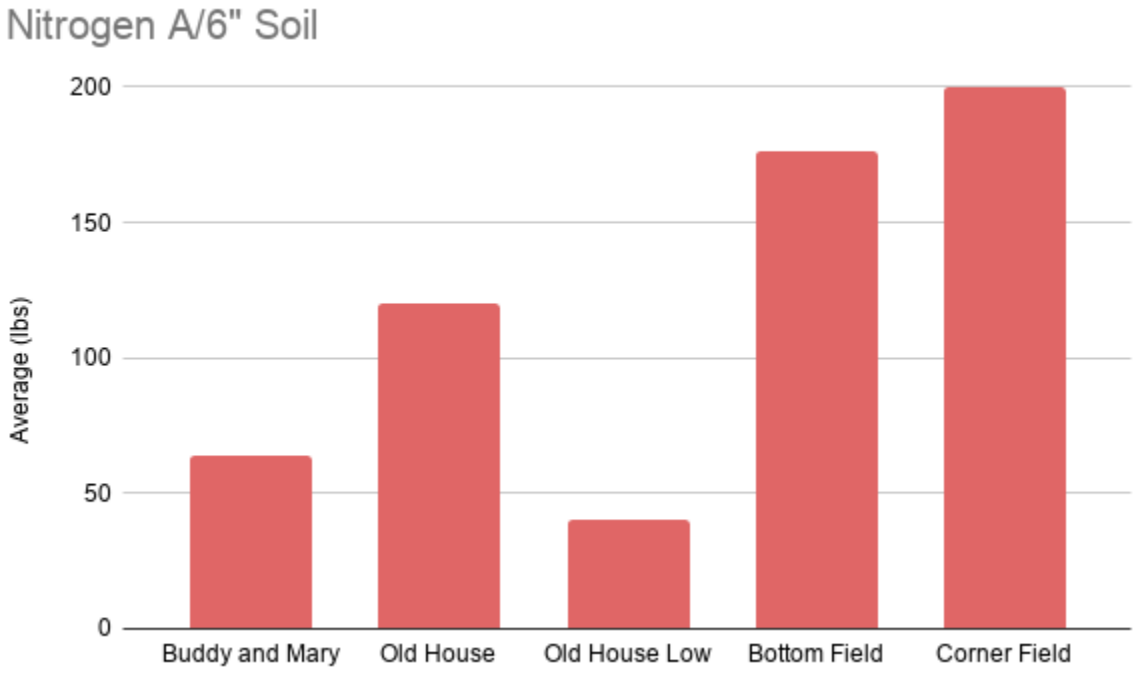
I collected the one cup of soil samples using a clean utensil to loosen the soil from 5 different locations around our fields. To conduct the LaMotte soil tests for nitrogen, phosphorus and potassium a soil extraction solution was prepared by filling the five round extraction tubes to the 30 mL line with distilled water, then added two Flox-Ex tablets and mixed in the vortexer for 10 seconds. Then I removed the cap and added 6 grams to each test tube of the same soil samples, then capped and mixed on vortexer for 1 minute. Then the tubes set still until the soil settles out. The clear solution filtrate above was used for the N, P, K testing.

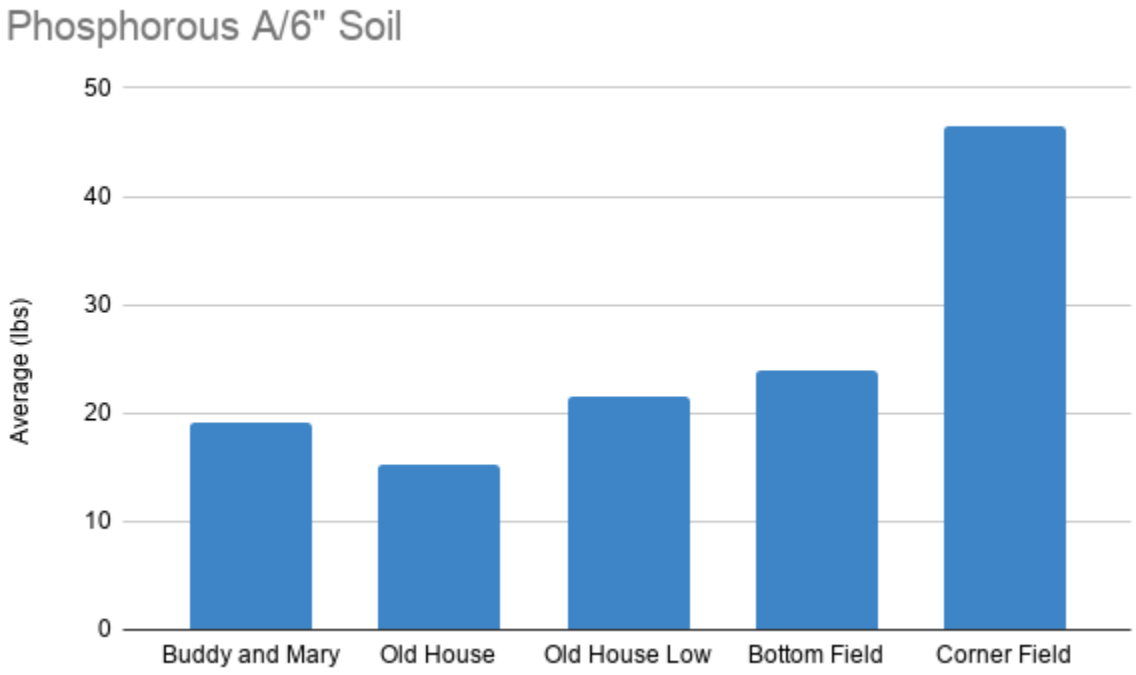
For the phosphorus (P) test, I used a pipet to transfer 25 drops of the clear solution to each of the 5 square test tubes, then filled the remaining space to the shoulder in each square test tube with distilled water. Next I added one phosphorous tablet to each square test tube, capped and mixed on vortex mixer for 1 minute. Finally, I waited 5 minutes for the color to appear and then read the results compared to the color chart. All of the following steps were repeated for each soil sample.

For the potassium (K) test, I used a pipet to transfer the clear solution above the soil to a square test tube until it is filled to the shoulder. Then I added 1 potassium tablet, capped and mixed on vortex mixer for 1 minute. Then I compared the cloudiness of each solution using the color chart. All of the following steps were repeated for each soil sample.

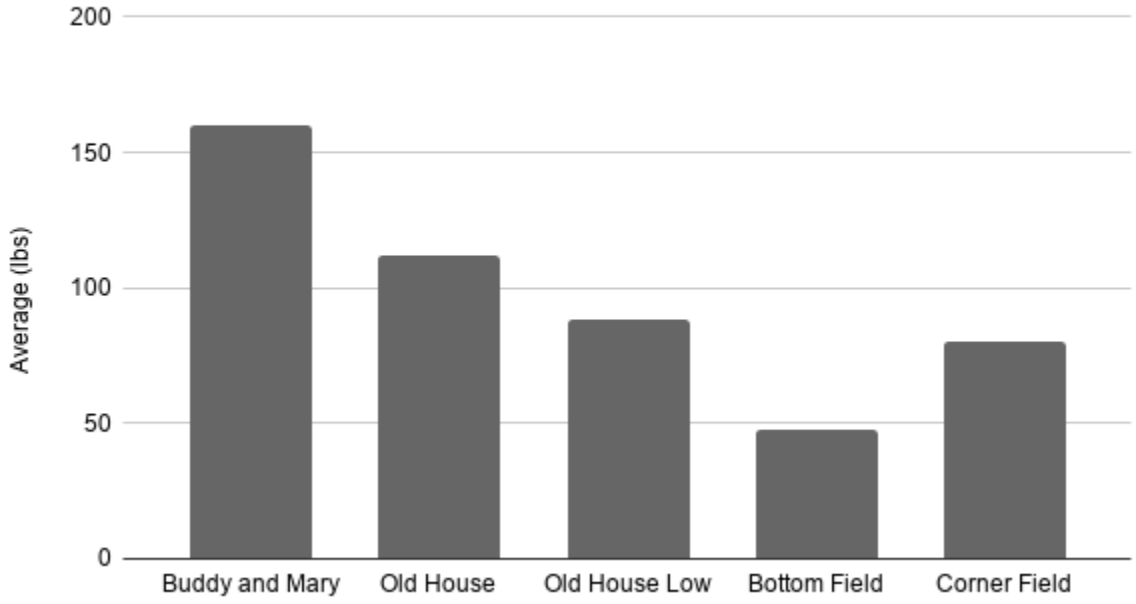
For the nitrogen (N) test, I used the pipet to transfer the clear solution above the soil to a square test tube until it is filled to the shoulder and added 1 Nitrate WR CTA Tablet. Then I immediately slid the tube into the protective sleeve and waited 5 minutes for the color to develop. I removed the protective sleeve and compared the pink color of the solution to the color chart. All of the following steps were repeated for each soil sample.

Results

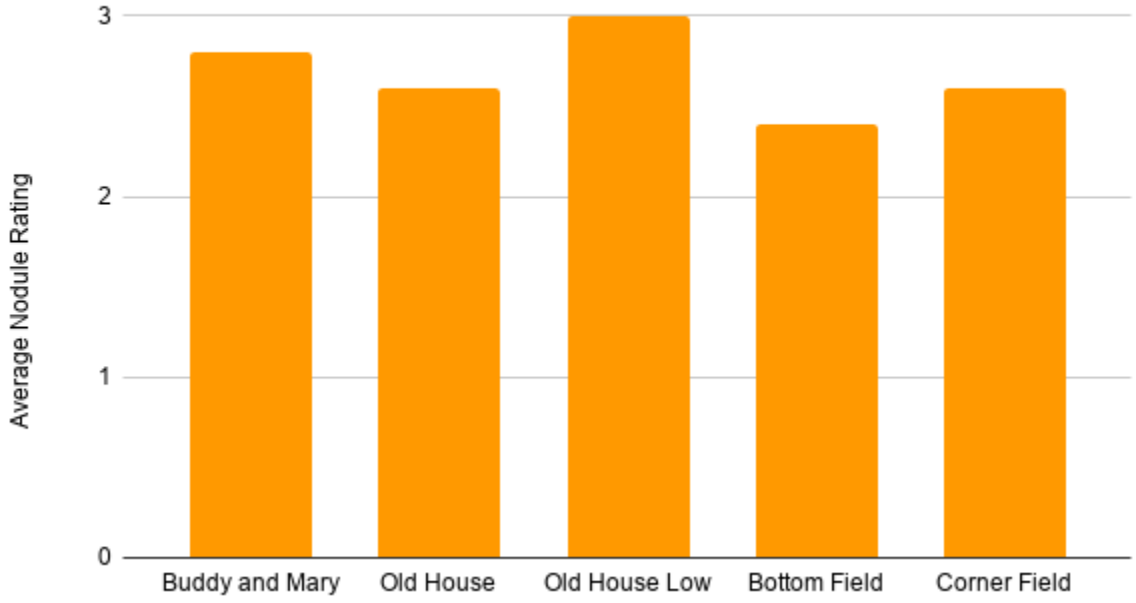

Nitrogen A/6" Soil
Average (lbs)
200
150
100
50
0
Buddy and Mary
Old House
Old House Low
Bottom Field
Corner Field


Phosphorous A/6" Soil
Average (lbs)
50
40
30
20
10
0
Buddy and Mary
Old House
Old House Low
Bottom Field
Corner Field

Potassium A/6" Soil



Soybean Plant Nodule Count



Nitrogen

FIELD TRIAL	1	2	3	4	5	Average
Buddy and Mary	40	160	40	40	40	64
Old House	320	160	40	40	40	120
Old House Low	40	40	40	40	40	40
Bottom Field	320	320	160	40	40	176
Corner Field	320	320	160	160	40	200

Phosphorous

FIELD TRIAL	1	2	3	4	5	Average
Buddy and Mary	64	8	8	8	8	19.2
Old House	20	8	20	8	20	15.2
Old House Low	64	8	8	8	20	21.6
Bottom Field	64	20	20	8	8	24
Corner Field	64	64	20	64	20	46.4

Potassium

FIELD TRIAL	1	2	3	4	5	Average
Buddy and Mary	160	160	160	160	160	160
Old House	160	80	160	80	80	112
Old House Low	80	160	80	40	80	88
Bottom Field	40	40	40	40	80	48
Corner Field	40	160	40	80	80	80

Nodule Count

FIELD TRIAL	1	2	3	4	5
Buddy and Mary	3	3	2	3	3
Old House	3	3	3	1	3
Old House Low	3	3	3	3	3
Bottom Field	2	3	3	2	2
Corner Field	3	3	3	2	2

1: poorly populated- 0-8

2: populated- 8-10

3: highly populated- 10 and above

- Nodule count visually rated and turned into a number for recording
- Elements were visually recorded by chart color

Discussion

These results scientifically show that soybean nodule population and nitrogen have a clear relationship. Although expected that the relationship would mean both observations would be high recordings, nitrogen levels were found to be low. As these pulled crops matured and passed the end of development, this shows that the nodule formation count was higher because of the high amount of nitrogen intake. The data tables and graphs exhibit that the same trials that had low nitrogen levels, were the ones that held the highest population of soybean nodule growth. Although there was an outlying trial, error is very possible since the color comparison observations to determine the levels for each nutrient in the soil tests were qualitative. These results verify the research found on this study which support the distinct relationship between nodule growth and nitrogen fixation.

Conclusions

The predominant relationship shown in the data is between nitrogen amount and the population of nodule growth. In regards to the data tables and graphs, this means that the higher the nitrogen intake, the higher nodule growth on the soybean roots. Because these were mature plants past the end of development, the elements that were found in samples were supplemental to what the plant had already consumed. This data matched the hypothesis, but lacked the anticipated relationship of the Phosphorus and Potassium having a higher effect on the nodule counts. Next steps to follow through with this procedure would be to conduct a second procedure including immature soybean plants, close to six weeks old. This could present clearer results, but unlike the data shown above, display the consumption of the elements. As the data was qualitative, the results could likely include errors. An additional procedure should be conducted with quantitative data to ensure accuracy. A nodule's main source of nourishment is nitrogen fixation; therefore, if error exists in this procedure, then the weaker relationships may not as visibly show.

Acknowledgements

- Thank you to Ms. Rachel Sanders and Dr. Monna Hess for the guidance in conducting the procedure for this experiment and Mr. Bart Neer and Mr. Eric Neer for providing personal experiences and examples relating this experiment to assist in connecting the root of this project back to the sole purpose of providing the agriculture industry with more information on how to supply the world with quality crops.