THE EFFECTS OF VARYING RATES OF P AND K FERTILIZER ON SANDY SOIL AND PEANUT PRODUCTION

By

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ABSTRACT

Over 4 million metric tons of peanuts are produced annually in the US, with the majority in the southeast. The economic value of peanut production in Florida was $124 million in 2014. Both phosphorus (P) and potassium (K) are key macronutrients for proper growth of peanut plants. However, sandy soils in Florida can potentially result in leaching of these nutrients. A field demonstration was set up on a 400-acre Spanish-runner peanut farm in Suwannee County to determine the optimum P and K requirements of peanuts for optimum yields while minimizing nutrient leaching. In addition to four replications of a control plot, four rates of P and K combinations were applied to the plots and replicated four times. Soil samples were collected in depths of 15cm ranges from the soil surface to 90cm in depth from each plot at 30, 60, 90, and 120 days following planting as well as at harvest. Tissue samples were also taken at these dates. Soil and tissue samples were analyzed for P and K concentrations. Results showed there was no statistical difference between treatments in tissue samples for P or K. It was determined there was no statistical difference between treatments in terms of P in the soil. Analysis using ANOVA and tukey testing revealed statistical difference with K between the treatments only in the upper levels of the soil profile. Yield data determined the treatments that received P and K amendments to be higher on average than the control group, although analysis determined the data differences to be non-significant. This information can be beneficial to farmers by ensuring the best fertilizer application rate is applied for maximum yield and reducing the environmental impact of excess nutrients entering the soil. Similar replicated field studies will be continued in the region to further understand the nutrient applications, plant uptake and efficiencies.

INTRODUCTION

Peanuts are an important agricultural crop in the United States and the world. Peanuts are predominately used in peanut butter, candies, oil, flour, biodiesel, and a host of other home products used on a daily basis (Marzolo, 2017). The U.S. is the third largest producer of peanuts in the world behind only China and India. Although only three percent of the world peanut acreage is located in the U.S., the U.S. produces ten percent of world's supply of peanuts (Peanut Country U.S.A, 2017). The amount of peanuts produced in the U.S. has been somewhat varied over the past couple decades with a national average of 1.6 million metric tonnes per year. In 2014, the estimated total revenue generated by Florida peanuts was $124 million (Bailey, 2015).

Peanuts being legumes have the capability of fixing their own nitrogen (N). Therefore, farmers do not need to apply N to the soil except in a small starter dose of inorganic N added at planting to help during the pre-nodulation period. (Wright et al., 2009). Phosphorus (P) and potassium (K) are critical macronutrients for proper plant growth. In many parts of the world, P and K are limiting growth factors for food production. Phosphorus is located in every living cell in a plant and aids in photosynthesis, energy transfer, sugar transformation, and many other important functions. Phosphorus is applied to crops in the form of phosphate (IPNI, 1999). Potassium on the other hand, aids in photosynthesis, adenosine triphosphate (ATP) production, regulates carbon dioxide uptake, and assists in protein synthesis (McKenzie et al., 2013). While the application of additional P and K is often necessary for optimum plant growth, depending on the nutrient requirements of crops, too much of the nutrients being added to the soil can cost the farmer unnecessary expenditures and harm the environment.

Florida soils are commonly sandy. Some are located on a karst landscape where with time, acid and leaching rains can dissolve the carbonate rocks below and form solution channels resulting in natural fresh water springs. Such phenomena can also allow sinkholes to be formed resulting in unstable ground. The porousness of the rock and coarseness of the soil means there is little material to stop contaminants or excess nutrients from reaching the underlying aquifer (Wynn et al., 2014). A common result of excessive application of nutrients such as N and K is leaching and eutrophication. With the exception of very sandy soils, P typically does not move in through the soil profile as it quickly binds to other soil-bound chemicals forming relatively insoluble compounds. Potassium is very prone to leaching in sandy soils due to its ionic charge. This can be a problem for farmers by costing unnecessary money if too much K is being applied (Sela, 2016). Excessive nutrients can leach into groundwater or runoff into nearby water bodies and promote extensive algae growth. While alive, the alga prevents sunlight from penetrating the waters surface and depriving plants of an essential life source. When this growth dies off, the decomposition process depletes the oxygen in the water, causing larger organisms suffocate and die and result in a “dead zone” deprived of life (Smith et al., 1998).

Soil testing can determine soil pH and the extractable P, K, magnesium (Mg) and calcium (Ca), along with micronutrients, interpret the results for crop nutrient requirement and can enable determination of proper application rates based on the crop being produced. The University of Florida/IFAS Analytical Services Laboratories (ANSERV Labs) provides soil testing for homeowners, consultants, farming operations, and local and state agencies. The Florida Department of Agriculture and Consumer Services requires that standardized IFAS nutrient recommendations be used for implementing Agricultural BMPs in the state. Therefore, it is important to ensure IFAS recommendations for the various nutrients and crops are up to date and accurate to help growers optimize the production and minimize negative environmental impact (Silviera, 2014). This project aims to determine the accuracy of IFAS recommendations from Mehlich-3 testing for P and K amendments to the soil for peanut production and determine the application rate that will optimize peanut yields.

OBJECTIVES

- To determine the validity of the current soil test interpretation based on Mehlich-3 extraction method
- To determine the requirements of P and K in peanuts produced on north FL sandy soils for optimal yields
- To field validate current IFAS P and K recommendations based on Mehlich-3 soil test interpretation for peanuts

REVIEW OF LITERATURE

One of the most crucial nutrients for plant growth is P. The phosphate rock in which P fertilizers are derived is a finite resource, making proper application imperative (Vance et al., 2003). Phosphorus is necessary for healthy plant growth due to its role in converting sunlight into useful compounds within the plant. Phosphorus is also a component of RNA, which aids in the development of compounds related to maintaining plant structure and vigor. Other roles include improved seed yield, disease resistance, and root development. The P already existing in soil is often not enough to support the production of row crops, including peanuts, without the addition of P amendments (Richardson et al., 2009). Many plants have created certain modifications when dealing with limiting conditions preventing the uptake of P. Such modifications include root architecture, improved metabolism of carbon and membrane structure, and the enhanced expression of genes associated with the adaptation of low-P conditions (Vance et al., 2003). In order for P to be taken up by plant roots, P must be dissolved in a soil solution (Figure 1). A soil solution is formed when the nutrient is dissolved by water located in the soil. The form of P that is in soil solution and available to plants is referred to as orthophosphate ($H_2PO_4^-$ or HPO_4^{2-}). Orthophosphates are rapidly depleted in the plant root zone (Richardson et al., 2009). In natural settings, plants obtain P from the decomposition of organic materials or weathering of P-containing minerals. However, in an agricultural setting, crops are harvested and a large portion of organic material is removed from the system, meaning plants must receive P from fertilizers. Examples of P fertilizer are superphosphate (OSP), concentrated superphosphate (CSP), triple superphosphate (TSP), monoammonium phosphate (MAP), diammonium phosphate (DAP), and phosphate rock. Phosphorus has tendencies to bind with cations (positive ionic charge) such as clays, iron (Fe), and aluminum (Al), due to P being an anion (negative ionic charge). Such binding of nutrients is referred to as adsorption (Smith et al., 1998).

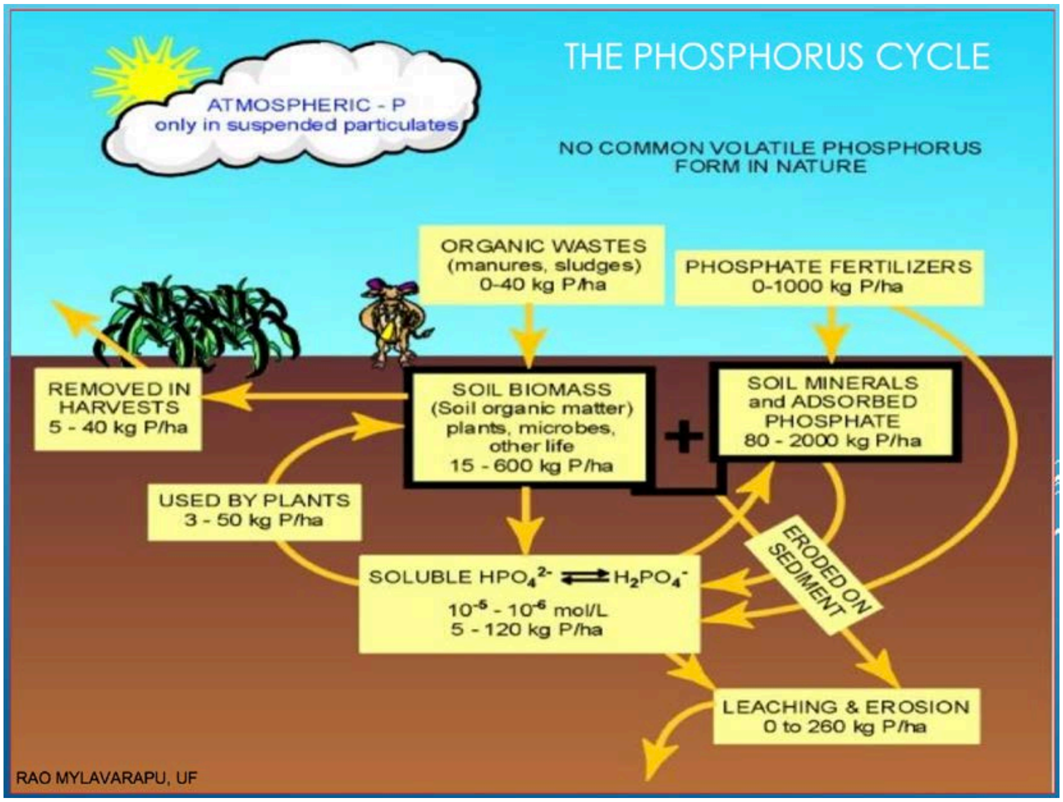

Figure 1. The phosphorus cycle in an agricultural setting

Potassium is the third most commonly added nutrient to crop behind nitrogen and phosphorus respectively (Cakmak, 2005). Potassium aids in the activation of enzymes involved with starch, protein, and ATP production. The ATP in plants is responsible for the regulation of photosynthesis in plants. In addition, K also influences the opening and closing of stomata, improves root growth and drought resistance, and helps with maintaining plant turgor (Kaiser, et al. 2016). In an agricultural setting, especially in sandy soils, there is not enough available K for crops to reach maximum yields. Potassium deficiencies manifest itself in the form of chlorosis around the edges and veins of leaves (Kaiser et al., 2016). An Egyptian study found that 48 kg K_2O significantly increased peanut oil and seed yields by up to 40 percent (Darwish et al., 2002). Common K fertilizers used by farmers include potassium chloride, potassium sulfate, potassium nitrate, and potassium-magnesium sulfate (Sul-Po-Mag) (Schulte et al., 2008). The properties of

K keep the nutrient from leaching in soils with excessive clay and organic matter. Organic matter by itself does not hold K well as its attraction with K ions is somewhat weak (Sparks, 2002).

In terms of fertilizer application, there are few major factors that farmers and agriculturists need to consider. Two of those factors include the fertilizer application of the correct rate and at the right time (Hochmuth et al., 2014). A balance of these factors is necessary in for protecting the environment and ensuring effective crop production. Soil samples should be collected and testing performed by UF/IFAS or a similar facility to reveal the recommended rate of fertilizer for that particular crop. A soil testing lab takes into account the available nutrients in the soil and combines this with the nutrient use efficiency of the crop being produced in order to provide an accurate fertilizer recommendation. Phosphorus and potassium are essential macronutrients for peanuts. Additionally, small amounts of boron (B), magnesium (Mg), and copper (Cu) are important micronutrients for all plant growth and play a key role in peanuts (Hochmuth et al., 2014). Fertilizer must be also applied at the right time. This practice takes into consideration the nutrients and growth pattern of a crop and the natural changes in nutrient demand as the season progresses. Nitrogen, phosphorus and potassium are typically applied to peanut fields shortly before planting (Wright et al., 2009). With many crops, including peanuts, K will often need to be added to soil in smaller amount over more than one application due to increased risk of leaching. Scheduling fertilizations directly before rainfall or irrigations can result in the leaching and runoff of nutrients and preventing plants from obtaining the nutrients (McKenzie et al., 2013).

The primary extracting reagent used for soil testing by UF IFAS/ANSERV was Mehlich-1 until 2013. Mehlich-3 has since been used to perform the majority of soil testing. Dr. Adolf Mehlich developed both reagents. Extracting solutions contain a variety of chemicals that react with and release soil P and K, among other nutrients, into solution. Mehlich-1 is a double-acid extractant that is accurate in determining plant available P in acidic soil with pH<6.5, low cation exchange capacity and organic matter lower than 5%. It was determined that Mehlich-1 testing was often inaccurate in determining plant-available P in soils with high pH, high CEC, and containing large accumulations of Fe and Al. Mehlich-3 was developed by replacing the dilute acids of Mehlich-1 with 0.2M CH_3COOH, 0.015M NH4F, 0.013M $HN0_3$, 0.001M EDTA, and 0.25M NH_4N0_3. The added fluoride extraction allows for better assessment of phosphates in soils while the ethylenediaminetetraacetic acid (EDTA) allowed for better extraction of micronutrients (Mylavarapu, 2015).

MATERIALS & METHODS

Tests plots were located within a 42-acre peanut field owned by Harold Land II in southern Suwannee County at 30°12’25.53”N, 83° 4’0.40”W (Figure 2). The soil map unit for the test area was Blanton-Lynchburg-Bonneau Complex 0 to 5 percent slope. Blanton soils are classified as loamy, siliceous, semiactive, thermic Grossarenic Paleudults. Lynchburg soil classification is a fine-loamy, siliceous, semiactive, thermic Aeric Paleaquults. Bonneau classification is a loamy, siliceous, subactive, thermic Arenic Paleudults. This farm was chosen because its size and sandy soil morphology was representative of typical north Florida peanut operations and for Mr. Land’s willingness to allow the study to be conducted. This field was chosen because it tested medium for P levels (35ppm), and medium for K levels (39ppm). The farm grows approximately 400 acres of the Spanish-runners peanut variety.

Figure 2. The plot area located within the 42-acre peanut field.

The IFAS recommended nutrient rates were 44.8kg/ha P_2O_5 and 89.7kg/ha K_2O for this study site based on pre-treatment soil test results. The study was laid out in a randomized block design with four different combinations of P_2O_5 and K_2O and a control replicated four times (Table 1). The test plots were placed in an area 36.6m long by 14.6m wide that tested Low for K and Medium for P. A 1.5m buffer was allowed between each plot in order to prevent unintended cross-fertilization between plots. Peanuts were planted on May 6, 2016 with a twin row planter. Each plot consisted of six twin peanut rows. The peanut plots were fertilized at the time of planting with the total amounts of P_2O_5 (triple superphosphate 0-46-0) and 1/3rd of the recommended K_2O (muriate of potash 0-0-60) at the time of planting, with the remaining K_2O applied in equal doses at 3 weeks and 5 weeks after planting. The remainder of the field not used for testing received blended 3-7-28 (N-P-K) fertilizer at a rate of 516 kg/ha prior to planting.

Treatment	Kg/Ha P_2O_5	Kg/Ha K_2O
1-Control	0	0
2-P1K1	44.8	89.7
3-P1K2	67.3	89.7
4-P2K1	44.8	112.1
5-P2K2	67.3	112.1

Table 1. Fertilizer rates by treatment

All nutrients other than P and K, along with standard pesticides were applied throughout the field. Similarly, the entire field received consistently uniform amount of water through center pivot irrigation system during the entire crop growth period. Soil samples were collected using a Dutch mud auger to a depth of 90cm, in 15cm increments. Both soil and leaf samples were taken at 30, 60, 90 and 120 days after planting (DAP) as well as at harvest (131 days after planting) (Figure 3). At harvest, peanuts from 1.5m of each peanut row within the plot were taken in order to determine the total yield of each treatment. Tissue and soil samples were tested at the UF/IFAS Extension Soil Testing Lab using Mehlich-3 testing in order to determine macronutrient and micronutrient levels.

Figure 43. Soil samples were taken within the plot and submitted to IFAS Extension-Soil Testing Lab for analysis.

Upon completion of soil analysis, three soil samples from random plots of the at-harvest subset samples were used for texture analysis. Two samples were from plots that appeared to be sandy throughout, and one sample was from a plot that appeared to contain a silicate clay layer that started at approximately the 55 cm depth. Texture analysis was conducted on the soil samples using the hydrometer method (Beretta et al. 2014).

Soil and tissue samples and the yield results were analyzed using R statistical software. Using this software, an analysis of variance (ANOVA) was performed on the data results. ANOVA determines if the variability between the treatments is relatively large compared to the variability within the treatments. For this analysis, the confidence interval was established at 95% or higher in order for the data to be deemed significantly different. Once determined if there was significant difference between data, a tukey analysis must be run in order to determine which data set was significantly different. A designation of “a” refers to no significant difference between the means being found, while designations of “ab” and “b” represent significant differences found between treatments labeled “a,” with “b” being the greatest amount of variability.

RESULTS AND DISCUSSION

The background P and K concentrations in soil within the test plot area were medium for P levels (35 ppm) and medium for K levels (39ppm). This was the basis for determining the rates of fertilizer application (Figure 3). Soil samples were collected at depths of 0-15cm, 15-30cm, 30-45cm, 45-60cm, 60-75cm, and 75-90cm, at 30, 60, 90, and 120 DAP and at harvest. Tissue samples were also collected at these dates. Tissue sample data revealed a decrease in P and K content over time, but no significant difference between the treatments for either nutrient was found (Figures a.1 & a.2).

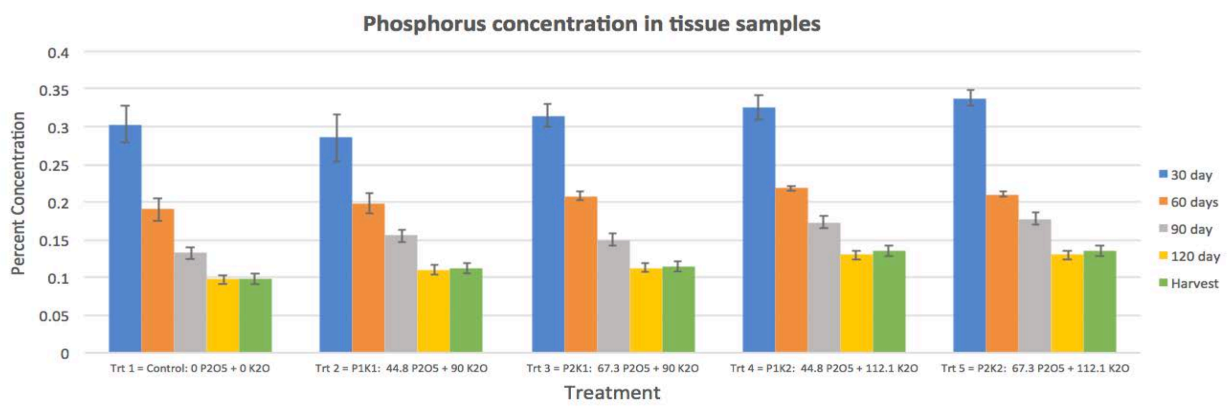

Figure a.1: Phosphorus in tissue samples with standard error

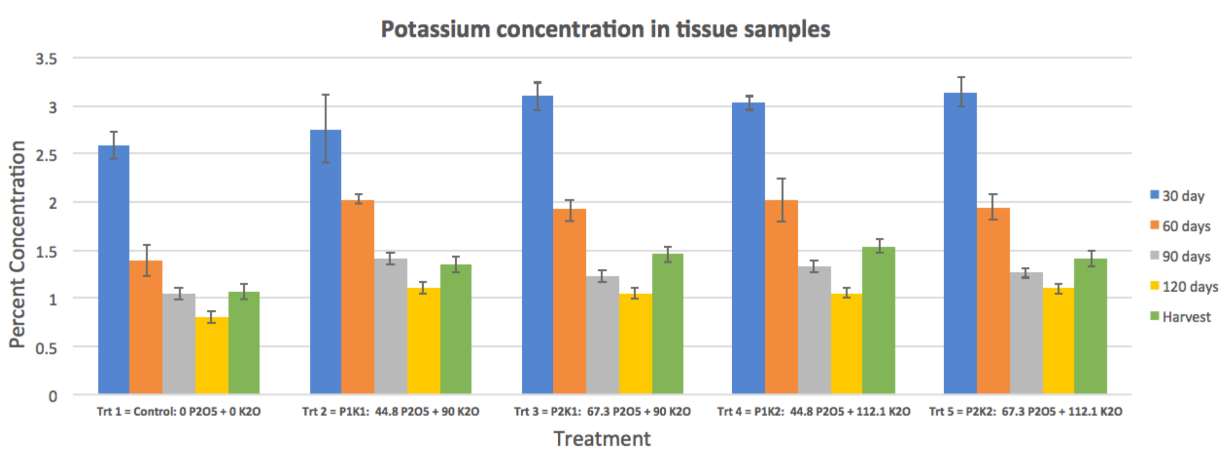

Figure a.2 Potassium in tissue samples with standard error.

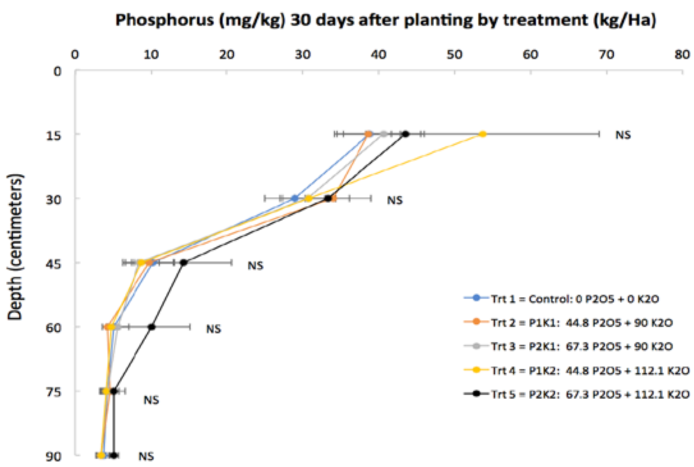

Figure b.1: Phosphorus at 30 DAP through soil profile[1]

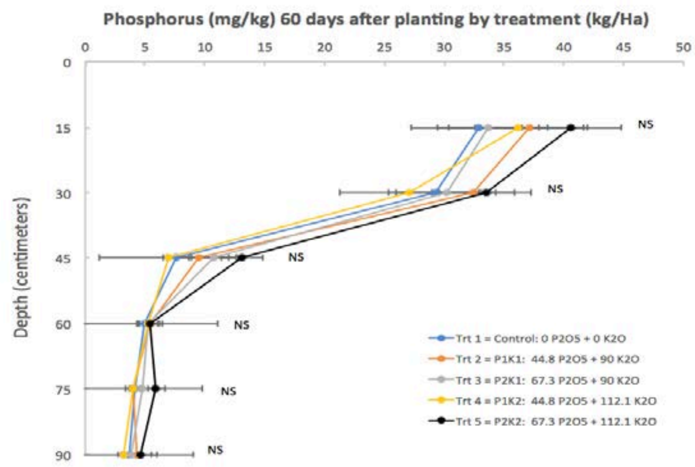

Figure b.2: Phosphorus at 60 DAP through soil profile

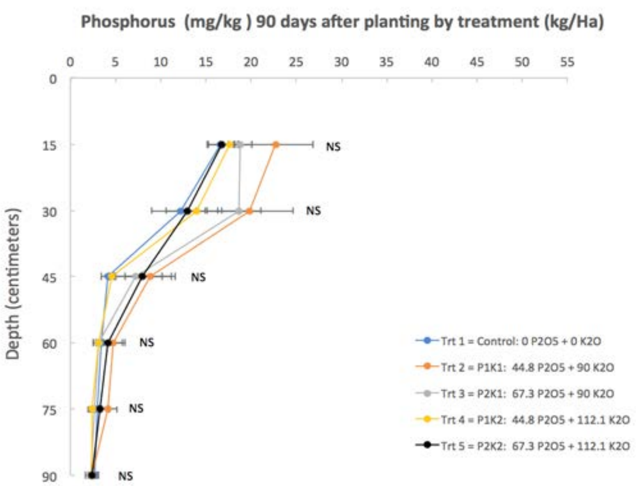

Figure b.3: Phosphorus at 90 DAP through soil profile

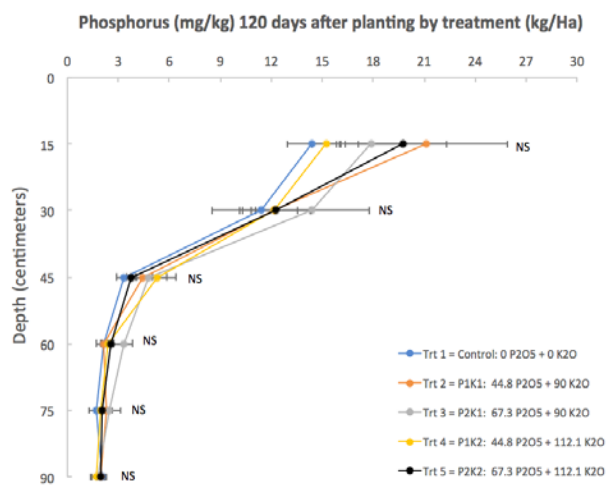

Figure b.4: Phosphorus at 120 DAP through soil profile

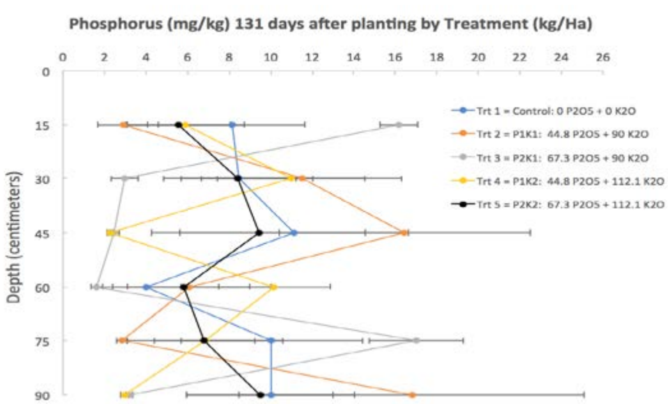

Figure b.5: Phosphorus at harvest through soil profile

[1] [1] Data designated with a "NS" is non-significant and data designated a "*" was determined to be significantly different

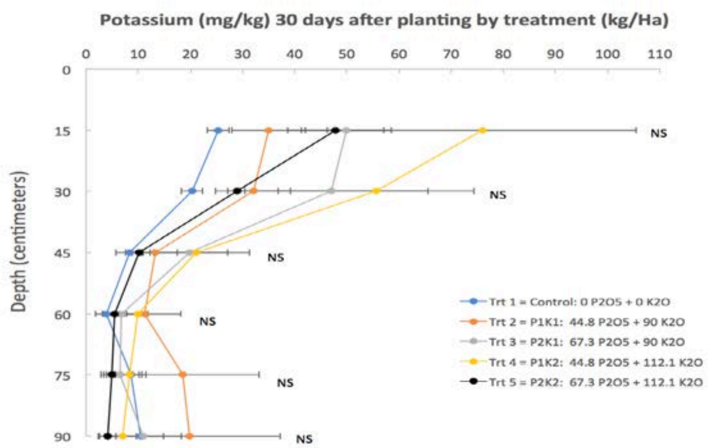

Figure c.1: Potassium at 30 DAP through soil profile

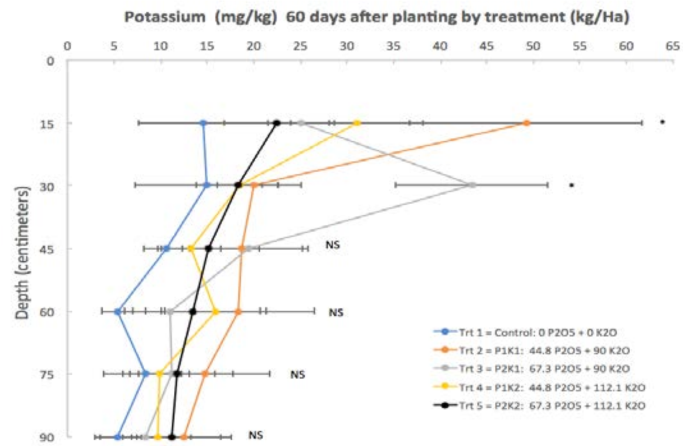

Figure c.2: Potassium at 60 DAP through soil profile

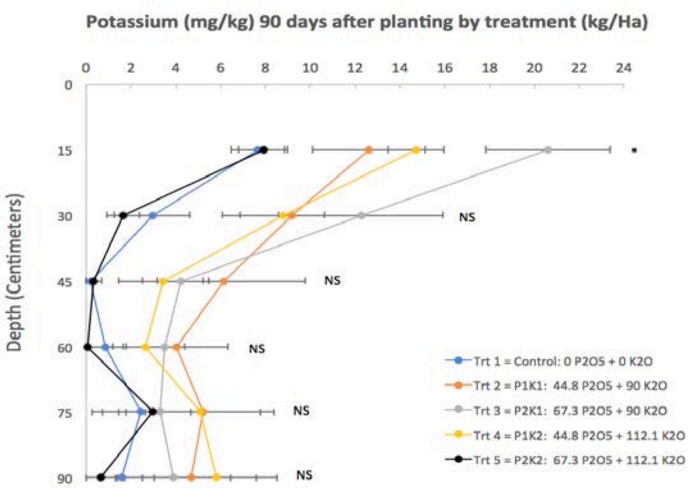

Figure c.3 Potassium at 90 DAP through soil profile

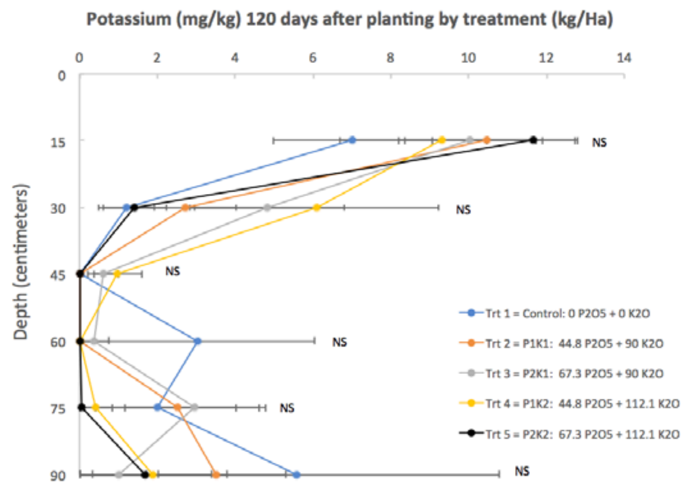

Figure c.4: Potassium at 120 DAP through soil profile

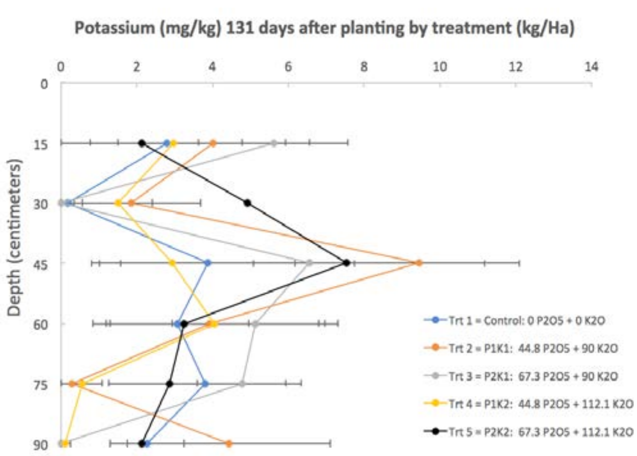

Figure c.5: Potassium at harvest through soil profile

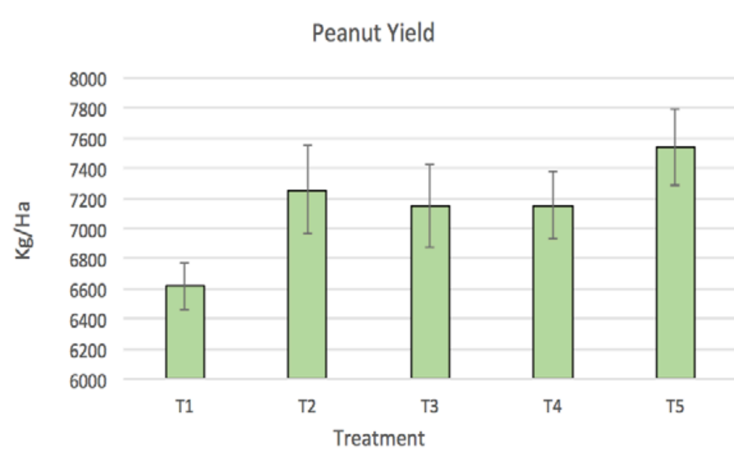

Figure d.1: Average yield by treatment in kg/Ha

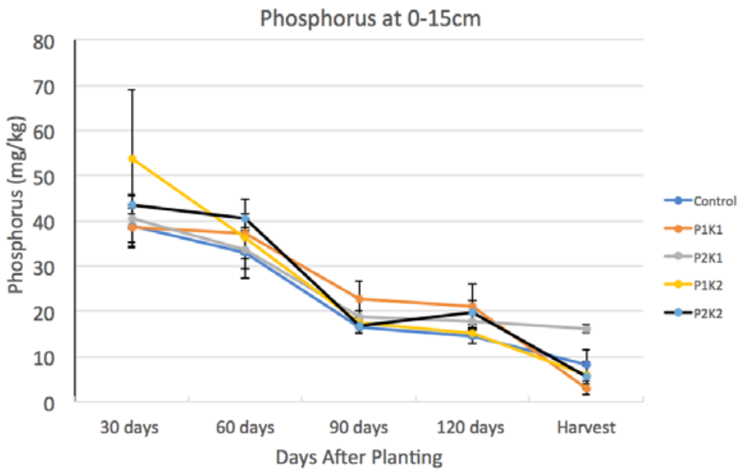

Figure e.1: Phosphorus at 0-15cm from planting to harvest

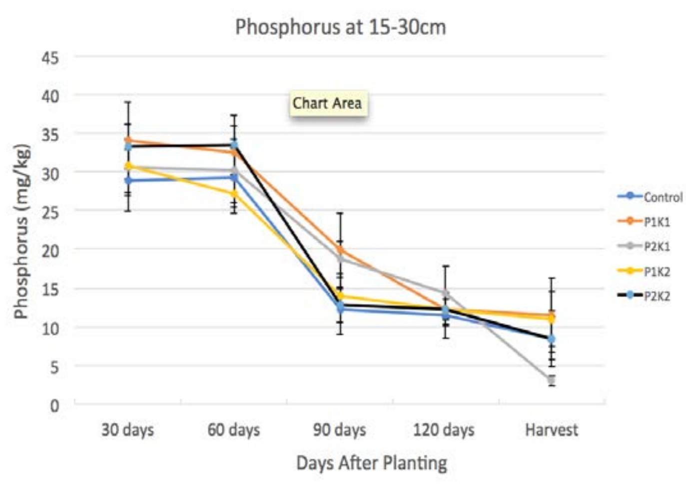

Figure e.2: Phosphorus at 15-30cm from planting to harvest

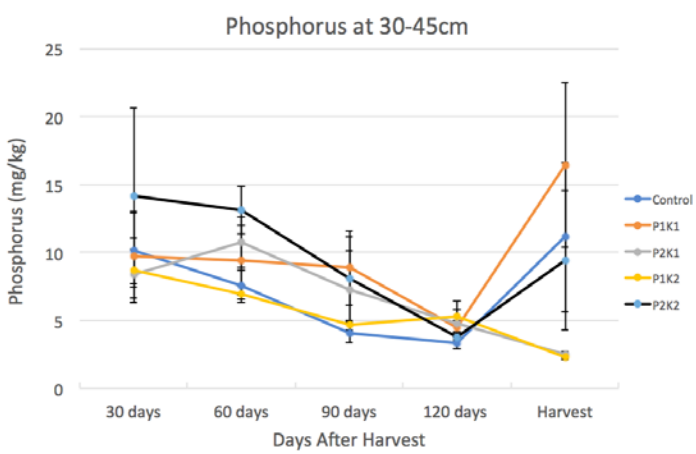

Figure e.3: Phosphorus at 30-45cm from planting to harvest

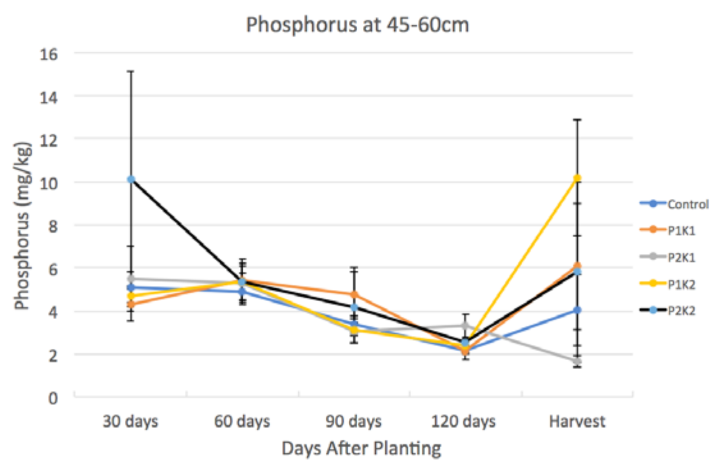

Figure e.4: Phosphorus at 45-60cm from planting to harvest

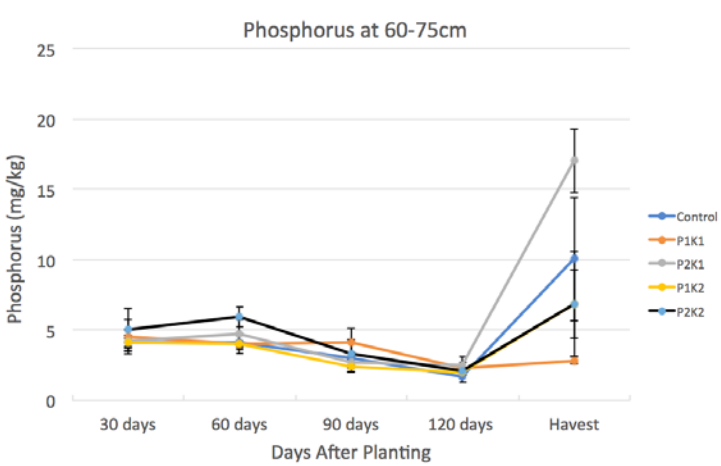

Figure e.5: Phosphorus at 60-75cm from planting to harvest

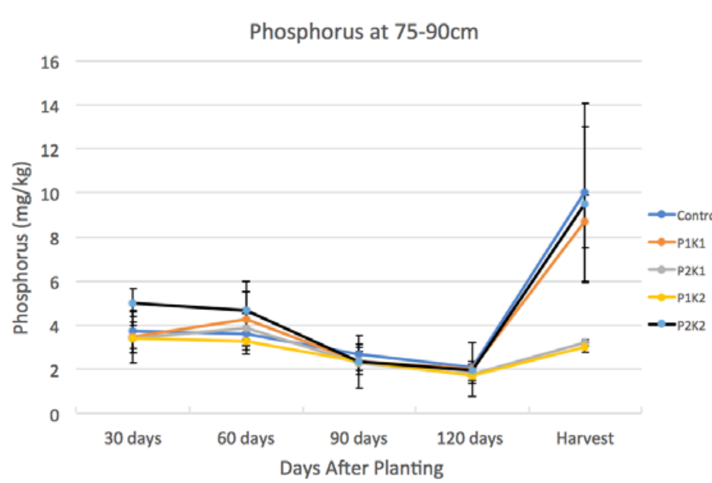

Figure e.6: Phosphorus 75-90cm from planting to harvest

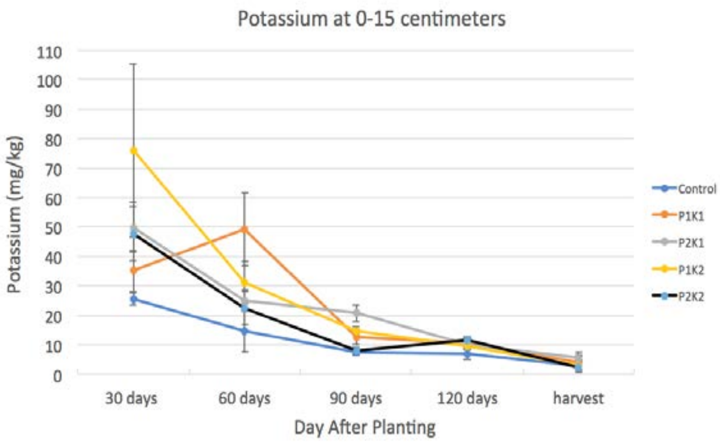

Figure f.1: Potassium at 0-15cm from planting to harvest

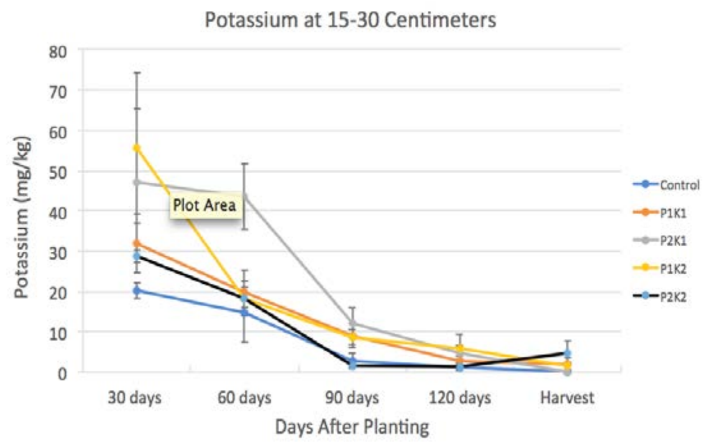

Figure f.2: Potassium at 15-30cm from planting to harvest

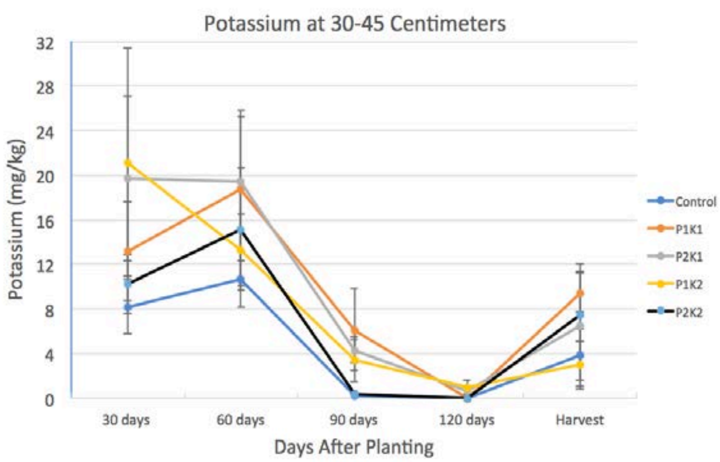

Figure f.3: Potassium at 30-45cm from planting to harvest

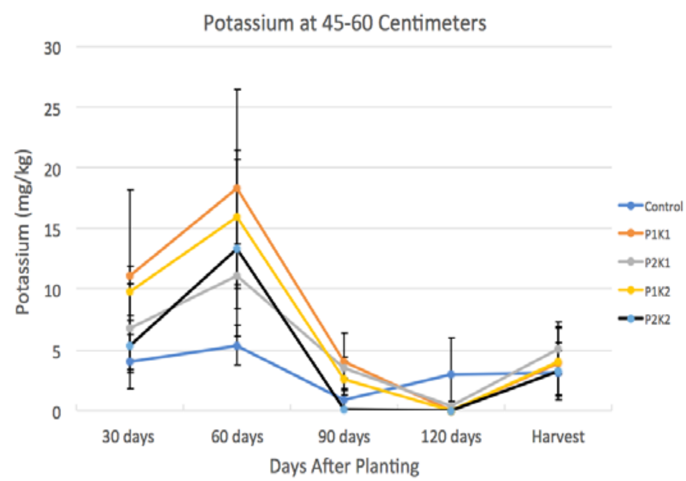

Figure f.4: Potassium at 45-60cm from planting to harvest

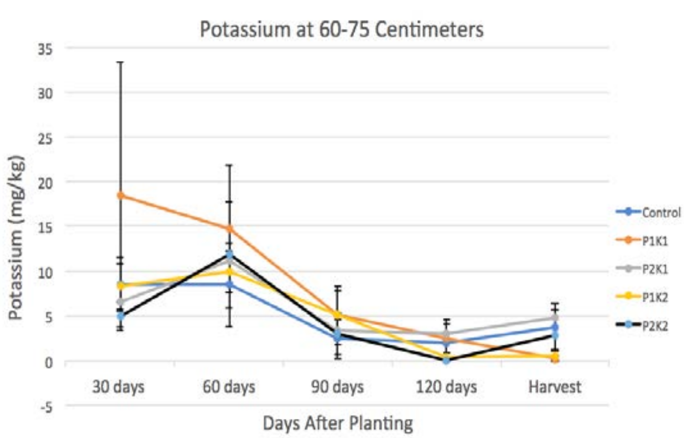

Figure f.5: Potassium at 60-75cm from planting to harvest

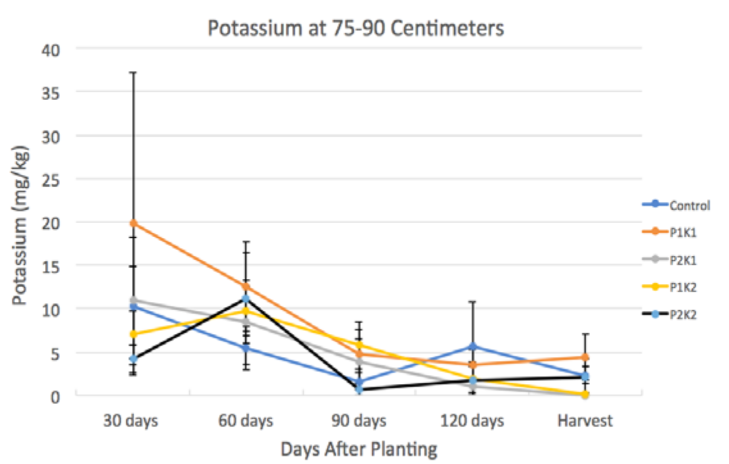

Figure f.6 Potassium at 75-90cm from planting to harvest

Soil samples taken at 30 DAP revealed no significant difference in P and K levels between treatments at any of the six depths upon means separation using Tukey testing (figures b.1 & c.1). As expected, P and K levels decreased significantly with soil depth. Phosphorus and potassium levels begin to stabilize at approximately 45cm. The occurrence could be due to a presence of higher Fe and Al levels or a result of a plow pan. By 60 DAP, P and K levels have both decreased substantially, especially in the surface soil where levels were the highest (Figures b.2 & c.2). The drop in P and K levels was expected as nutrients were taken up by the plants and moved downward through the soil profile. Data analysis did not show significant difference between the treatments. Potassium levels in the 0-15cm ranges in the plots began to distinguish themselves with P1K1 containing the highest amount of K. The control group contained the lowest amount of K. In the 15-30cm range, P2K1 had the highest rate of K. Control again contained the lowest amounts. At 90 and 120 DAP, P and K levels continued to decrease due to plant uptake, leaching, and gradual movement through the soil profile (Figures b.3, b.4, c.3 & c.4). Through this time, no significant difference in soil P concentrations among treatments was observed. The samplings at 90 DAP revealed a significant difference between the treatments in the 0-15cm range. The P2K1 treatment had the highest rate of K and was designated “a,” while P1K1 and P2K1 were both designated “ab.” Control and P2K2 were the lowest and designated “b” by tukey testing. At the 120 DAP sampling there was no significant difference in any data with P or K. This is thought to be a result of little nutrients in the soil compared to the amount the experiment began with. The sampling at harvest revealed nutrient fluctuations within the profile. This is likely due to peanut plants being inverted prior to sampling. Data taken over the course of the experiment when categorized by depth reveals the decrease of the nutrients in the soil over time (Figures e.1-6 & f.1-6). Both P and K levels increase between 30 and 60cm at 60DAP and decrease as time progresses due to possible leaching of the nutrients through the lower depths of the soil profile. Nutrient levels dropped significantly at all depths by 90 DAP and continues to drop until harvest. A spike in P levels in lower soil depths (45cm and deeper) at harvest was recorded (Figures e.3-e.7). This is most likely a result of a change in soil texture. Further analyses of textures will be conducted to more conclusively determine the cause of the nutrient level elevation.

Yield data results revealed all treatments that received P and K fertilizer amendments to be similar with P2K2 having the highest production average with 7540kg/ha. Treatments P1K1, P1K2, and P2K2 all averaged close to 7200kg/ha. The control group had the lowest production rate with 6617kg/ha. However, ANOVA testing determined the confidence interval was 94.7%, just below the necessary 95% or higher needed to classify the data as significantly different. One plot of P1K1 and one plot of P1K2 were found to contain an average of 19% silicate clay in the ranges between 45-90cm. These ranges contained significantly higher amount of potassium in earlier sampling dates, but these levels did not significantly influence data averages.

CONCLUSIONS

The peanuts industry is extremely important in the United States and world. Phosphorus and potassium are essential macronutrients for healthy peanut growth. Sandy soils present a unique challenge to growers who must decide how much fertilizer to apply for optimal yield without causing concern for leaching. UF/IFAS recommendations for nutrient application to soils continue to need up-to-date accuracy validation. A field experiment was established on a peanut farm with four replications of a control group and four treatments of varying P and K fertilizer rates. Soil samples were taken in ranges of 15cm through the soil profile to 90cm at 30, 60, 90, and 120 DAP and at harvest. Tissue samples were also taken at this time. It was determined there was no statistical difference between treatments in terms of P in the soil. Analysis revealed statistical difference with K between the treatments only in the upper levels of the soil profile. No significant difference was found between treatments in tissue samples for either nutrient. Yield data determined the treatments that received P and K amendments to be higher on average than the control group, although analysis determined the data differences to be non-significant. These data helped validate the current IFAS nutrient recommendations supporting optimal peanut yields. Even where higher than recommended rates of P and K were applied, data did not result in a corresponding yield increase. This information will help farmers realize fertilizer cost savings and simultaneously help minimize nutrient losses to the environment.

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