Summer 2019

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Recommended Citation

Davis, R.(2019). *Potassium Fertilization Effects on Yield for Wheat, Soybean, and Corn Grown in Coastal Plain Soils.* (Master's thesis). Retrieved from https://scholarcommons.sc.edu/etd/5473

POTASSIUM FERTILIZATION EFFECTS ON YIELD FOR WHEAT, SOYBEAN, AND CORN GROWN IN COASTAL PLAIN SOILS

by

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Submitted in Partial Fulfillment of the Requirements

For the Degree of Master of Earth and Environmental Resources Management in

Earth and Environmental Resources Management

College of Arts and Sciences

University of South Carolina

2019

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DEDICATION

I would like to specially thank Dr. Kloot for his patience, understanding, guidance, wisdom, support, and faith in me throughout my years of study at the University of South Carolina and through the completion of this thesis. Thank you for giving me the opportunity to work and learn under you. I would also like to thank the other members of my committee Dr. Geidel and Dr. Porter for their continued support and guidance through this process. I would like to express my gratitude to everyone who helped in the collection of samples, harvest data, and analysis. I would also like to acknowledge the farmers and other supporters of this project, whom without them would not have been possible. Lastly, I'd like to dedicate this to my family and friends who have supported me throughout out all of my years of study and continuously offered their support and encouragement.

ACKNOWLEDGEMENTS

The resources for this project were supplied through crowdfunding on Experiment.com through two projects, namely “How Much Fertilizer do we Really Need?” (Kloot 2014) and “No but Seriously now, How Much Fertilizer do we Really Need?” (Kloot and Coleman 2016). Most of the funders were farmers.

ABSTRACT

A study conducted on wheat, soybean, and corn crops was designed to assess the effect of potassium fertilization based on current potassium (K) fertilizer recommendations on crop yield, soil K levels, and plant tissue K concentration. The objectives of this study were to 1) evaluate the effect K fertilization has on crop yield; 2) To assess soil K levels through the duration of the experiment and the effect fertilization may have on soil K levels; and 3) to evaluate the effect of fertilization on plant tissue K concentrations. There was no statistical difference in yields between plots treated with the full amount of fertilizer K based on the current recommendations[1] and the plots that did not receive any K. For five crops between December 2014 and December 2017, there was no significant reduction in soil test K levels on plots that were not receiving any supplemental fertilizer K. This suggests that exchangeable K was being replaced by sources other than applied fertilizer K.

The results of this research could indicate that the application of K fertilizer on soils with medium levels of K may be an unnecessary expense to growers. Fertilization may also have the potential to harm future crops if soils are unable to leach Cl additions efficiently from KCl fertilizer. Methods for measuring soil K levels and accompanying fertilizer recommendations may need to be re-examined and adjusted to include all forms of K in a soil. This, coupled with a more comprehensive evaluation of a soil's ability to

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[1] Recommendations made according to Clemson Ag Services Lab recommendations (see references)

release and hold K, would allow growers to take a more holistic approach when deciding fertilizer treatments. This could help reduce their environmental impact while also reducing their input cost

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LIST OF ABBREVIATIONS

CEC	Cation Exchange Capacity
Cl^-	Chloride
K	Potassium
KCl	Potassium chloride (muriate of potash)
K_2O	Potassium Oxide
N	Nitrogen
P	Phosphorus
SLAN	Sufficiency Level of Available Nutrients

CHAPTER 1
INTRODUCTION

1.1 Literature Review

Potassium (K) is an essential nutrient for optimal production of wheat, soybean, and corn crops (Barker and Pilbeam 2015). It is the most abundant cation in plants involved in many physiological processes which include activating over 80 enzymes, regulating cellular osmotic water potential, photosynthesis, protein metabolism, and helping plants adapt to environmental stresses (Kafkafi et al. 2001). K is taken up in large quantities, equivalent to amount the of nitrogen (N) taken up (Kafkafi et al. 2001). A normal, healthy leaf tissue can have a range of K between 1-4% with the critical concentration in a range between 0.5-2% (Zörb et al. 2014). K taken up by the plant remains in ionic form and is very mobile in the plant allowing it to move freely where it is needed (Weil and Brady 2017). If a plant becomes deficient, K will translocate from older tissues to younger tissue. Deficiency symptoms of K include chlorosis and necrosis starting at the edge of oldest leaves and the plants reduced resistance to pests and diseases (Weil and Brady 2017). To ensure adequate amounts of K are available to crops during the growing season, fields are amended with organic or inorganic fertilizers. The rate at which fertilizer is applied is understood to be derived from long-term fertility experiments that provide soil nutrient and crop response data. These data are then used to determine sufficiency levels of available nutrients (SLAN) for crops and calibrate fertilizer rates with soil test data (Cope 1981).

Fertilizer recommendations have been based on soil testing that was conducted in the mid 1900's, when extensive research was done to produce calibrated soil tests and specified nutrient recommendations for optimal crop yields (Voss 1998). Since then, research to amend soil tests and update recommendations has declined steadily. A survey of 44 land grant universities was conducted by Regis Voss in 1998 which showed that there has been a general decrease of employees involved in calibrating soil test data, although all expressed the need to update the database on which recommendations were made (Voss 1998). The advancement of research tools today has helped define soils as a dynamic and complex system of chemical and biological interactions rather than the previously held notion of soil as a simplistic medium in which plants grow (Harmel et al. 2013). Currently, most methods for testing soils focus on the chemical aspect without consideration of the other biological and physical processes that are taking place simultaneously. It is the synergy of the physical, chemical and biological processes that constantly change the levels and availability of nutrients for plants (Haney et al. 2018). With improvements in technology and advances in research, these processes are better understood today. These new paradigms when coupled with changes in technology that include no-till, reduction of fallow periods, increases in the use of crop rotations, and cover cropping to retain, recycle and replenish nutrients, have raised questions on the validity of the current, and as of now antiquated, fertilizer recommendations (Liebhardt 1977).

K is considered an immobile nutrient in the soil, thus recommendations are based on the concentration of plant available K in the soil (Zhang and Raun 2006). A range of "low", "medium" and "high" levels of nutrients is established based on the potential yield when the K is limited and independent of then environment. Fertilizer Recommendations are then made using respective interpretations of a crop's response to applied nutrients (Voss 1998). There are two main philosophies that extension services at land grant universities use when making fertilizer recommendations (Voss 1998). One being the "build-up and maintenance" approach which advocates the application of nutrients until a specified critical value, typically when maximum yield potential can be achieved, and then maintaining nutrients in the soil at that steady state. The schematic of this approach can be seen in Figure 1.1, once the critical value has been reached through fertilization maintenance of that level is achieved through continued fertilization at rates equivalent to crop removal (Vitosh, et al. 1995).

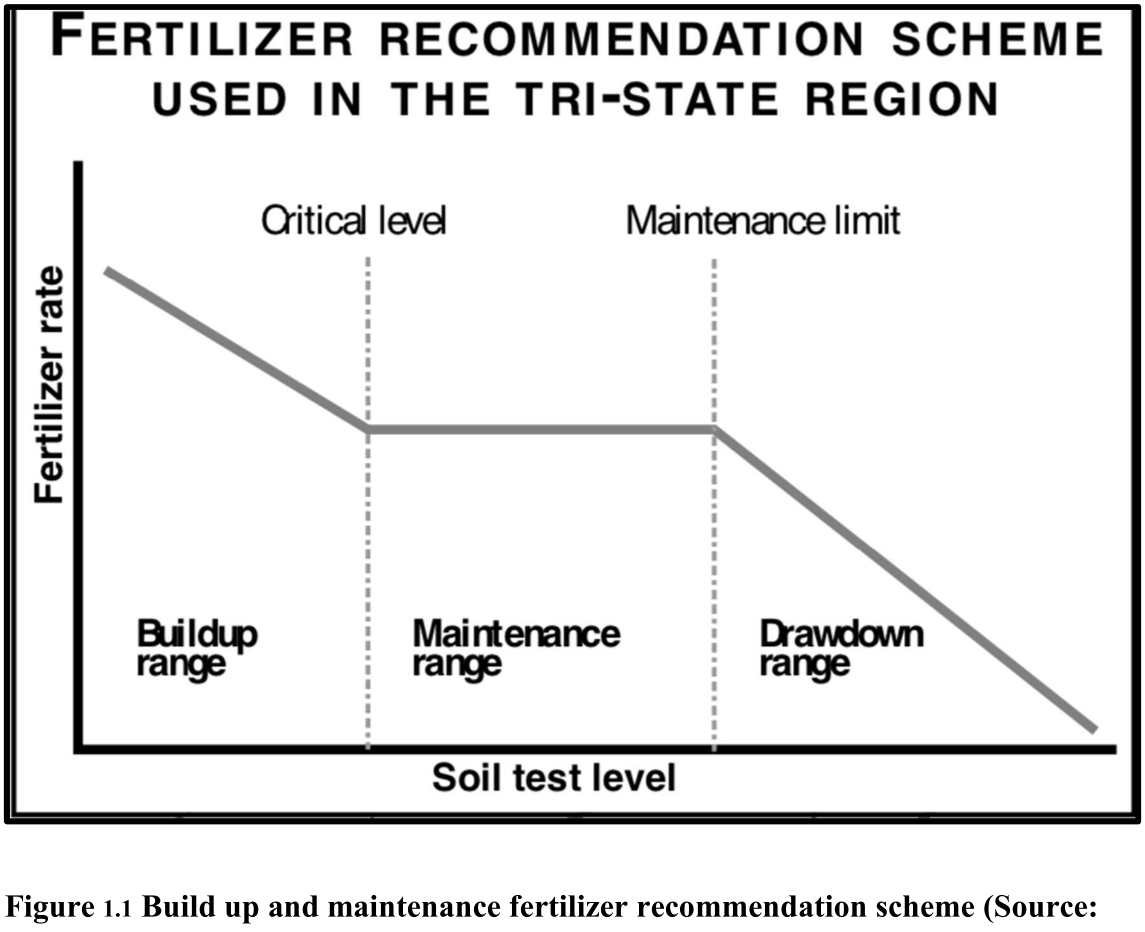

Figure 1.1 Build up and maintenance fertilizer recommendation scheme (Source: Vitosh et al. 1995)

In contrast, the other is a “nutrient sufficiency”, or “fertilizing the crop”, approach where the critical value, typically when maximum yield potential can be achieved, and accompanying recommendations are made with the goal of maximizing profitability in the crop being grown while minimizing input costs. Recommendations are based on increasing the soil test value to the critical level. If soil test value is above the critical value, no fertilizer is recommended. Once a primary range of “low”, “medium” and “high” levels of nutrients is established using respective interpretations of a crop’s response to applied nutrients (Voss 1998).

The interpretation of the soil test data and fertilizer recommendations made by land grant universities, soil testing laboratories, and commercial laboratories can vary significantly depending on which of the two modalities the lab chooses to endorse. The recommendations can vary between institutions, even for the same soil test data, calling into question their efficacy. A study conducted by R. A. Olson et al. (1982) spanning from 1973 to 1980 compared the yield of 29 fields with varying fertilizer recommendations made by five different labs in Nebraska. Their research revealed no real yield differences despite the wide variation in recommendations made by the labs. Olson concluded that recommendations based on the sufficiency approach provided ample amounts of nutrients in contrast to the build-up and maintenance approach, which had no economic or agronomic basis (Olson et al. 1982).

As agricultural practices progress to improve soil health and technological advancements are made that can provide a better understanding of nutrient pools and availability, it becomes imperative to recalibrate soil tests data with recommendations that are more precise (Beringer 1985). An advancement of critical importance is the method used for extracting available nutrients from soil samples. Various extraction methods have been developed since the inception of soil testing to produce results for multiple elements within a single test and are suitable for analyzing soils of various characteristics (Jones 2008).

One new method of particular interest is the use of the soil extractant H_3A that was developed by Haney, Haney, Hossner, and Arnold in 2006 (Haney et al. 2006). This extractant was developed to offer a multi-nutrient extraction without sacrificing accuracy. The final combination of chemicals include weak organic acids, lithium citrate, and two synthetic chelators that allow nutrient extraction near the soil pH while mimicking a soil environment with actively growing plants (Haney et al. 2006). This extraction method offers an alternative to the current method of using multiple harsh exractants with some limited to specific soil pH (Haney et al. 2006). Nutrient extraction with the H_3A exctratant, when paired with the Soil Health Tool integrates chemical and biological properties to assess soil fertility and make recommendations based on crop nutrient requirements and acknowledging available and potentially available forms of nutrients in the soil (Haney et al. 2018). Research conducted on the implementation of the H_3A extraction method and Soil Health Tool by Haney et al. in (2018) found that the average amount of nitrogen (N), phosphorus (P), and K fertilizer applied was more than what was recommended based on nutrient requirements minus available soil test N, phosphorus (P), and K. The study concluded that many producers have the ability to reduce their fertilizer application while maintaining yields, decreasing input costs thus increasing profit (Haney et al. 2018).

Because of the emphasis placed on N application due to water contamination by run-off from agriculture land, evaluating available N has advanced considerably and has led to improvements in N fertilizer recommendations (Bock and Hergert 1991). Unfortunately, other nutrients have seen fewer revisions over the years and rely on archaic data. Many potassium fertilizer recommendations are made on a build-up and maintenance approach which can vary drastically depending on the testing method used, which questions the reliability of the soil test data and recommendation alike. Potassium recommendations were originally based on the sufficiency philosophy with the acknowledgement of the abundant K reserves in some soils. This approach was then replaced by a build-up and maintenance approach when Canada introduced a new source of potassium chloride, also known as muriate of potash (KCl), to the fertilizer market in the 1960s (Khan et al. 2014). Soil tests were conducted on the "plow layer" (top 6 ¾ inch layer of soil) and were used to represent amounts of plant-available potassium, even though there is evidence that K reserves can be found in subsoil horizons (Woodruff 1980). The same build-up and maintenance approach is used today, backed by the essentiality of K for crop yield and quality, without careful evaluation and consideration of existing K both within and below the plow layer.

Although 90-98% of potassium in the soil is unavailable for immediate plant uptake, the transition between unavailable forms to available forms within the soil is very dynamic (Zörb et al. 2014). Figure 1.2 depicts mean in parts per million (ppm) of total, exchangeable, and water-soluble K in kaolinitic soils. Exchangeable and water-soluble K, also known as plant-available K, make up a less 2% of K in the soil. An interrelationship exists between each form of K in the soil where K in the soil solution that is depleted, through uptake or leaching, is replenished by the release of exchangeable and non-exchangeable forms until equilibrium is re-established.

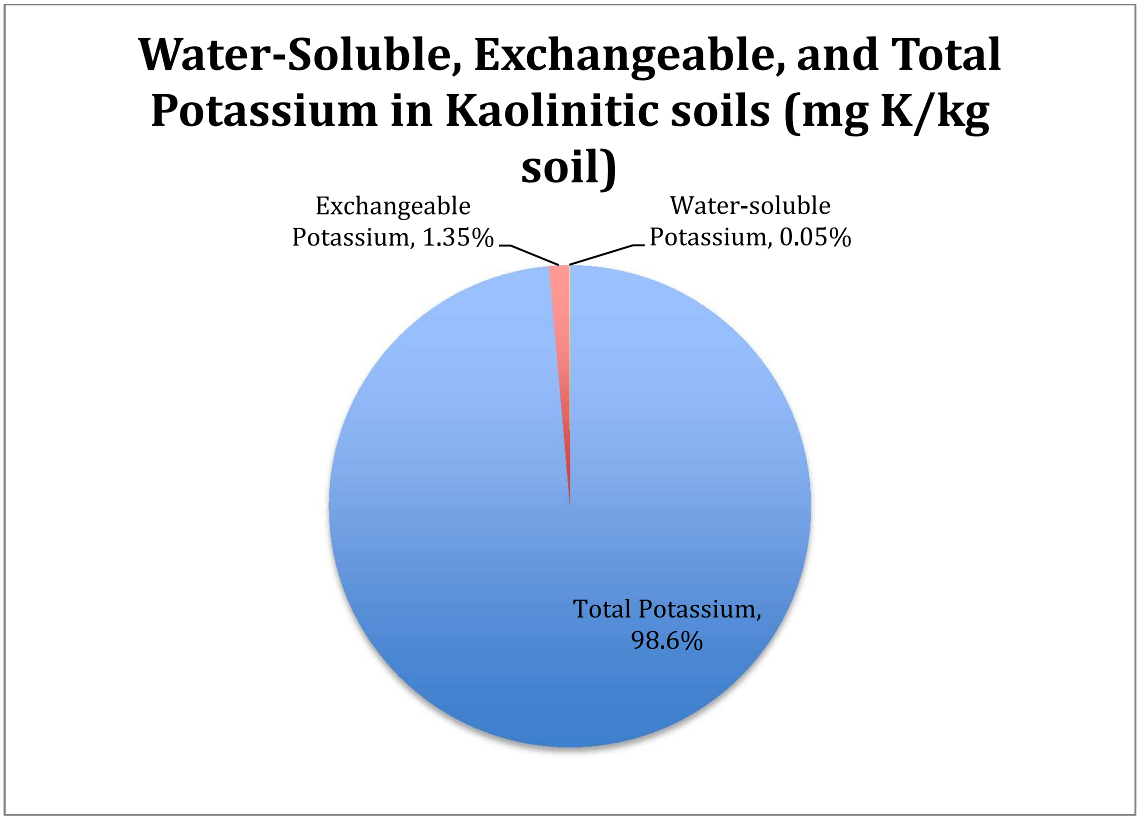

Figure 1.2: The amount of water-soluble, exchangeable, and total potassium in soils dominated by kaolinitic clay (Source: Weil and Brady 1990)

This dynamic fluctuation between available and non-available forms of K is important to take into consideration when sampling (Liebhardt and Teel 1977). A study conducted by Liebhardt and Teel in 1977 noted the seasonality of exchangeable K and the importance of proper sampling times. They found that soil K levels decreased during the growing season and did not re-establish equilibrium until late March to late May. Most soil samples are taken in the fall or early spring directly after harvest or before the next crop before soil K equilibrium is re-established resulting in soil test values that do not accurately indicate the K supplying power of the soil (Liebhardt and Teel 1977). This can result in recommendations and K fertilizer applications higher than necessary.

Another concern that arises when determining soil K levels is the method in which samples are prepared for testing. Soil samples are oven-dried before mixed with extracting solution, which can influence the amount of K extracted (Barbagelata 2012). This can also cause inaccurate analysis of soil K levels and recommendations. Both the fluctuation of soil K seasonally and when oven dried emphasize the need to update guidelines for sampling and method of analysis to obtain the most accurate information regarding soil K levels, the K supplying power of soils, and more precise recommendations.

Several studies have highlighted the lack of crop response to K fertilization on Atlantic coastal plain soils (Leibhardt and Teel 1977; Woodruff and Parks 1980; Parker et al. 1989). Kahn et al 2013 also did an extensive study on crop response to KCl fertilization on and found that out of 2,121 short-term field trials conducted by land grant universities, 76% showed no statistically significant response to KCl fertilization. The trials that did show a significant response to fertilization occurred on course-textured, highly weathered, and organic soils (Khan et al. 2013). This lack of response has been attributed to several factors including built up levels of soil K due to excessive fertilization, which has leached to lower subsoil horizons, soil characteristics including mineralogy, texture, pH, and temperature (Parker et al. 1989). Although this lack of response has been recorded across multiple studies, the extensive research done on the importance of K for crop development and quality, and the detrimental impacts of insufficient supply, has inculcated the perception that routine K fertilization is necessary to maintain soil K levels for optimal yield quantity and quality (Khan et al. 2014). Producers relying on soil tests may be receiving inaccurate recommendations thus continuing the cycle of excessive fertilization, ultimately at the expense of the producer (Magdoff et al. 1997). With the increase in input costs and more emphasis being placed on the reduction of nutrient runoff and pollution, it is critical to minimize fertilization over the needed amount for maximum economic return (Magdoff et al. 1997).

The potential consequences of excess KCl fertilizer in soils have been mitigated by the profound necessity for sufficient amounts of potassium readily available for the crop. KCl contains 52% K_2O and 48% Chloride (Cl^-) (Kafkafi, U., et al. 2001). Cl^- is recognized as another essential nutrient for plant growth but is required in amounts much smaller than K. What is left in the soil once K is taken up can accumulate causing a reduction in soil N availability, suppress plant uptake of NO_3^-, and increase the leaching of calcium (Khan 2014). The potassium that is not taken up by plants also has the ability to be leached into lower soil horizons (Woodruff and Parks 1980). This continues the cycle of over-fertilization if soil samples at lower depths are not taken and subsoil K that can be reached by certain crop roots is not accounted for.

1.2 Research Purpose and Hypothesis

Previous research may have been done on degraded soils where conventional practices like tillage and fallow periods were used causing reduced soil functions. This research was conducted to evaluate the effect current K fertilization rate recommendations have on yield and soil K levels in potentially better functioning soils due to the elimination of tillage and the use of cover crops to eliminate fallow periods. The hypothesis tested are 1) that wheat, soybean, and corn yield does not respond to recommended K fertilizer rates when grown in a medium K soil test range soil, 2) soil test K in the top six inches does not change or “build up” in response to K fertilizer applications and 3) that plant tissue K concentration does not increase with the recommended K fertilization. If results show no significant yield response or soil K changes, it could provide more evidence that soils have a higher potential to provide adequate K than is currently estimated to determine K fertilizer recommendations. Results may also suggest a need to re-evaluate how soils are tested for K and what forms are taken into consideration when rating soil K levels and making fertilization recommendations.

CHAPTER 2
MATERIALS AND METHODS

The study was conducted on a farm field in the Atlantic Southern Loam Plains near Dillon, South Carolina (34.501698, -79.425096). Figure 2.1 shows the location of the field and the soil series for the field. The soil was an Orangeburg loamy sand (thermic typic kandiudult) with a transitional BA horizon between 0.18 and 0.3 m, a Bt1 horizon typically fully developed at 0.3m, and kaolinitic subsoil clay (Soil Survey Staff N.D.). The experiment design consisted of two levels of K fertilization (control and recommended fertilizer rate by land grant university) across a three-year crop rotation of wheat, soybean, corn, wheat, and soybean, beginning in November 2014. Both treatments received the recommended rates for N, and no phosphorus (P) fertilizer, micronutrient fertilizer, or lime was applied. Treatments were replicated ten times resulting in 20 plots total. Plots size was 30.5 x 18.3 m plots separated by a 1.1 m gap, and randomly assigned fertilizer rate treatments. Potassium (K) Fertilizer rating was "medium" based on soil test analysis from soil samples taken and subsequent recommendations made by Clemson Extension Services Laboratory were used for each plot. Prior to the initiation of the study, a cover crop of sorghum sudangrass (*Sorghum bicolor*), buckwheat (*Fagopyrum esculentum*), and sunn hemp (*Crotalaria juncea L.*) was established after a corn crop of 5335 kg/ha was harvested.

Figure 2.1: Location and survey of experimental field (source: Web Soil Survey N.D.)

2.1Crop Yield Response

Beginning in November 2014, a rotation of wheat, soybeans, and corn was grown to assess the effect of K fertilization on crop yield. Table 2.1 shows the rotation, planting date, variety, and planting density for each crop grown.

Table 2.1: Crop rotation of wheat, soybeans, and corn grown from 2014 through 2017

Crop	Plant Date	Variety	Planting Density
Wheat	11/19/2014	SS8641 (Southern States, Virginia)	135 kg/ha
Soybeans	6/15/2015	2015 Syngenta S74-M3	247,100 seeds/ ha
Corn	3/3/2016	Phoenix 5564	65,500 seed/.ha
Wheat	11/18/2016	Syngenta Oakes	135 kg/ha
Soybeans	6/12/2017	Cheraw (Clemson Public Variety)	247,100 seeds/ha

Wheat was planted into the cover crop that was frost terminated and burned down with paraquat in November of 2014. Fertilizer K was applied on K treated plots as muriate of potash or KCl (52% K) at 104 kg/ha K by a spreader truck. N was applied at 117 kg/ha for both control and treated plots. Fertilizer rates were recommended at a level that would provide sufficient amounts of nutrients for the wheat crop as well as the following soybean crop. Wheat was harvested in May of 2015 using a Kinkaid 8XP research harvester (Kincaid Inc., Haven, KS), which harvested 2.1 m wide swaths in the center of each plot to provide yield, moisture content, and test weight. Soybean was planted in June of 2015 directly behind the wheat harvest. Soybeans were harvested in November of 2015 with the same combine used to harvest the previous wheat crop.

Corn grown for grain was planted the following spring in March of 2016. Fertilizer K was applied as KCl (52% K) at two different treatment rates of 0 kg/ha and 71 kg/ha K prior to planting. N was applied at 157 kg/ha for both control and treated plots. Corn was harvested in August of 2016 using a John Deere combine and weighed using a weigh wagon on loan from Syngenta Inc. A warm season cover crop mix of sorghum sudangrass (*Sorghum bicolor*), cowpea (*Vigna unguiculata*), daikon radish (*Raphanus sativus* L. var. *niger* J. Kern.), and sunflower (*Helianthus annuus*) was grown following the corn harvest until the planting of the following winter wheat.

The second rotation of wheat was planted into the frost-terminated cover crop in November of 2016. Fertilizer K was applied as KCl (52%K) at two different treatment rates of 0 kg/ha and 75 kg/ha. N fertilizer was applied at 100 kg/ha for both control and treated plots. Wheat was harvested in July of 2017. The final rotation of soybeans was planted in June following the second rotation of wheat and was harvested with a Gleaner G2 (AGCO, Duluth, GA) plot combine in November with the same combine used to harvest the second rotation of wheat.

2.2 Soil Analysis

Soil composites were taken at a depth of 15 cm using a 19 mm diameter soil probe from each plot. Twenty cores were taken randomly from each plot and thoroughly mixed together to create a representative sample of the plot. Samples were taken before planting of each crop with additional samplings after corn harvest and after the final wheat harvest. Each sample was sent to Clemson Agriculture Service Laboratory to be analyzed for soil nutrient levels. A standard soil test using the Mehlich 1 extraction was conducted by Clemson University's Agricultural Service Laboratories that provided analysis for soil pH, buffer pH, soil test phosphorus, potassium, calcium, magnesium, zinc, copper, boron, and sodium, lime requirements and recommendations. The standard test also provided calculations for the cation exchange capacity (CEC), acidity, and percent base saturation. The Mehlich 1 method used by Clemson Lab, which mixes 5 g of soil sample with 20 mL Mehlich 1 extracting solution (0.05 N HCl + 0.025 N H_2SO_4) and collecting the extract for analysis (Clemson, N.D.).

2.3 Plant Tissue K Concentration

Plant tissue samples were taken from the 2015 wheat, 2016 corn, and 2016 wheat rotations. For wheat tissue samples, the entire plant was taken. For corn tissue samples, the most recent fully expanded leaf was taken. The protocol used was taken from Campbell (2000) in the document “Reference Sufficiency Ranges for Plant Analysis in the Southern Region of the United States”. Samples were sent to Clemson University’s Agriculture Services Laboratories for analysis.

2.4 Statistical Analysis

All statistical analysis for this project was conducted on SAS software. For crop yields, data was analyzed using a two sample T-test. For analysis of soil samples, Control and K treated plots were compared to analyze the effect of K fertilization on soil K levels. A two sample T-test was used to compare soil test K levels in control plots and K treated plots. In all statistical analysis, the significance level (α), was set at 0.05.

CHAPTER 3
RESULTS AND DISSCUSION

3.1 Crop Yield Response

Table 3.1 compares the yields for all five crops from the plots that received the full KCl fertilizer rate recommended by Clemson University Agriculture Services Laboratory and the control plots. There were no significant differences ($p \leq 0.05$) between the treatments; therefore, we cannot reject the null hypothesis that wheat, soybeans, and corn grown in a medium potassium regime soil do not respond to recommended fertilizer applications of potassium.

Table 3.1: Comparison of mean yield results between control plots and plots that received the full recommended rate of fertilizer K.

Crop	Year	Yield Control Plots (kg/ha)	Yield K applied Plots (kg/ha)	Difference In Yield (Control – K Treatment)	p-value
Wheat	2015	3209	3060	149	0.592
Soybeans	2015	2694	2640	54	0.548
Corn	2016	9189	9021	168	0.778
Wheat	2017	3331	3477	-146	0.545
Soybeans	2017	4328	4305	23	0.824

According to Clemson's soil test rating system, a medium soil test nutrient level is adequate for moderate crop yields with a 50% expected response to fertilization, but no significant response was observed on plots that received the recommended K fertilizer rate.

K fertilization is recommended for all crops when soil test levels are “medium” or less, a replacement rate for some crops is recommended when soil test level is “sufficient” and a few crops when soil test level is “high” (Clemson Ag Services, N.D.). The differences between the two treatments in Table 3.1 shows that the yield produced by the first rotation of wheat, both rotations of soybeans, and corn were all higher, but not significantly, in the control plots than the plots that received the full KCl fertilization rate. The only crop to experience a numerically higher yield from fertilization was the second rotation of wheat. This could be attributed to the significant uptake and removal of K by the previous corn rotation and inability of the soil to release enough K from a non-exchangeable form to an exchangeable form in time for the wheat crop. Control plot yields did not experience the yield loss expected due to the removal of K from previous crops without replacement. This suggests the soil was able to supply adequate amounts of K for each crop.

3.2 Soil Test K level

Table 3.2 compares mean soil test potassium concentrations between the control plots and the plots that received the full KCl fertilizer rate recommended. The hypothesis was tested tested using a paired T-test and alpha was set at 0.05, n=20. With no significant differences ($p \leq 0.05$) between the plots, the hypothesis that soil test for potassium in the top six inches does not respond to potassium fertilizer application cannot be rejected. The differences in Table 3.2 show that the soil K levels in the control plots were lower at every sampling date except for the final sampling in November of 2017.

The average Soil test K levels were not reduced below medium levels by crop removal from each rotation in the control plots, despite not receiving any fertilizer. The

Table 3.2: Comparison of mean soil test K between control Plots and plots that received the full recommended rate of fertilizer K.

Sample Date	Soil Test K Control Plots (kg/ha)	Soil Test K for K applied Plots (kg/ha)	Difference in Soil Test K (Control – K Treatment)	p-value
12/3/2014	114	126	-12	0.323
6/15/2015	129	147	-18	0.097
12/10/2015	134	139	-5	0.785
9/3/2016	75	94	-19	0.087
11/23/2016	93	108	-15	0.166
6/23/2017	135	142	-7	0.606
11/27/2017	121	119	2	0.890

Samples taken in December of 2014and 2015 show a yearly increase in soil K levels after a wheat and soybean rotation. Between December 2015 and November of 2016 there was a decrease in both treatments after the corn rotation with the fertilized plots soil K level decreasing more than the control plots.

Following the "build up and maintenance" approach that is typically used for soil K recommendations, the plots that received full fertilizer rate recommended are expected to stay constant or increase while the plots that received no K fertilizer are expected to show significant decreases in soil K from depletion without replacement. The lack of response to fertilization corresponds to findings in previous research that the soil is able to replenish soil K levels higher than levels in the fertilized plots (Liebhardt and Teel 1977). The decrease in soil K on the fertilized plots suggest that once the soil K has reached equilibrium, the remainder of applied K not taken up by the crop is lost through leaching into the subsoil.

The similarities in soil test K fluctuations between the control plots and fertilized plots can be seen in Figure 3.1. The sharp decline between December 2015 and October 2016 could be due to high K removal by corn. Control plots and fertilized plots experienced a slight soil test K increase from the sampling taken in September to the sampling in November of 2016. An even larger increase in soil test K was recorded from the November 2016 soil sample to the June 2017 sample. Figure 3.1 characterizes the fluctuations of soil test K from depletion of plant available K and the release of fixed soil K to reach equilibrium between soil K forms.

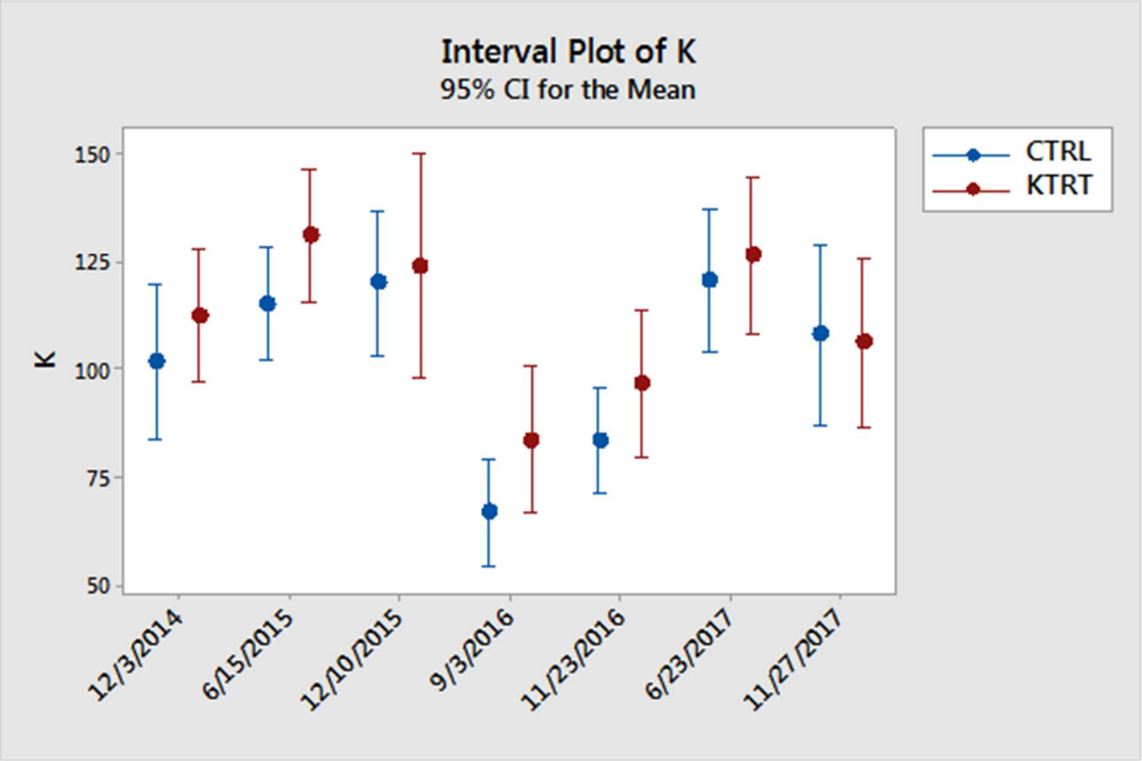

Figure 3.1: mean soil K levels from soil sample analysis of control plots and plots that received the full recommended rate of fertilizer K.

The fertilized plot did not maintain a steady soil K level or increase due to fertilization and followed the same seasonal fluctuations as the control plots. The increase in soil test K in the control plots demonstrates the ability of the soil to release non-exchangeable to exchangeable and plant available forms of K in the soil over time until equilibrium is reached (Liebhardt and Teel 1977).

3.3 Plant Tissue K Concentration

Plant tissue samples were taken from both wheat rotations and corn to compare K uptake by the crop from the control plots and the fertilized plots (Table 3.3). There was no significant difference (p≤ 0.05) between the control and fertilized wheat rotations.

Table 3.3Comparison of plant tissue K concentration for corn and wheat grown in control plots and plots that received the full recommended rate of fertilized K.

Crop	Year	Sample Date	Tissue K Concentration (%)		Control Plot - K Treatment Plot	P-value
			Control	K Treatment		
Wheat	2015	2/12	2.65	2.95	-0.3	0.1715
Corn	2016	6/28	1.65	1.86	-0.21	0.0572
Wheat	2017	1/26	2.63	2.55	0.08	0.6442

The control plots in the first rotation of wheat recorded lower plant tissue K concentrations than the K treated plots but stayed within the optimal range of concentration for optimal production. The second rotation of wheat had more plant tissue K in the control (2.63% K) than the fertilized plots (2.55% K). This was unexpected considering traditional understanding of nutrient management suggests that removal of nutrients without additions to replace nutrients removed with harvest will cause depletion of that nutrient until eventually the soil test levels become extremely low and optimal production will be unattainable.

Although the hypothesis that plant tissue K does not increase with the addition of K fertilization is not rejected for all treatments, the corn plant tissue K was marginally significant with a p-value of 0.0572. This was not expected considering K is a luxury nutrient that can be taken up in quantities larger than needed when it is accessible to the crop. One explanation could be the leaching and binding up of excessive soil K, causing it to be unavailable to the crop (Parker et al. 1989).

3.4 Discussion

The lack of yield response observed in this study corresponds with the results of studies previously conducted that examined yield response to K fertilization on coastal plain soils (Leibhardt and Teel 1977; Woodruff and Parks 1980; Parker et al. 1989; Khan et al. 2013). This lack of response can be ascribed to indigenous soil K levels that are sufficient for optimal crop yields and the accumulation of K in subsoil horizons due to leaching of excessive K (Sparks 1980). Although yield was not affected by KCl fertilization, one concern would be a reduction in K uptake by the crop. Plant tissue K concentration results showed there was no reduction with the control plots recording higher plant tissue K concentrations in the first wheat and corn rotation than the fertilized plots. This indicates the crops were able to take up plant available K from the soil in adequate and higher amounts even in the absence of K fertilization. Fertilizer K was applied based on Clemson Agriculture Services Lab recommendations with the expectation of a crop response 50% of the time and replacing what was removed by the harvest (Clemson 2017). Soil test K levels did not stay at a constant level when soil was amended to account for removal, negating the notion that soil K can be built up and maintained at a certain level.

According to the "build up and maintenance" approach, additional K fertilizer is applied with the intention of building up soil K levels to a specific level and then maintaining them at that level through continuous fertilization (Olson et al. 1982; Voss 1998). But soil K fluctuated similarly for both the control and fertilized plots through the four-year experiment. Plant available soil test K was depleted from crop removal and then increased slowly, peaking between April and June except when corn was grown. This correlates with other studies focusing on the dynamics of K in the soil and emphasizes the importance of sampling times (Liebhardt and Teel 1977). The dynamics of soil K did not change because of fertilization and no significant differences between the soil test K levels of the control and fertilized plots were recorded (Figure 3.1). Therefore, we postulate that any excess soluble K was either taken up by the crop or leached below sampling depth.

There were no significant differences of plant tissue concentrations between the fertilized and control plots. All plant tissue concentrations were above critically low levels suggesting the control plots were able to supply sufficient amounts of plant available K for each crop (Liebhardt et al. 1976). Our findings contrasted with those from a study conducted by Woodruff and Parks (1980), which recorded a general increase in plant tissue concentrations with increasing K fertilization, though not always significant. They also recorded low plant tissue concentrations in crops grown on no-K plots on Orangeburg soils (Woodruff and Parks 1980). This could be attributed to higher leaching of K to the B_2 horizon that was observed in the study. Soil test K in the top six inches of the soil remained in the medium range before each crop was planted implicating the soil's ability to re-equilibrate plant-available K in control plots while potentially leaching any excess water-soluble forms to lower layers.

CHAPTER 4
CONCLUSION

This research was conducted to examine the efficacy of fertilizer recommendations and the impact it has on yield and soil test K levels in no-tilled, cover-cropped soils. There was no statistical difference in yields between plots treated with the full amount of fertilizer K based on the current recommendations and the plots that did not receive any of the fertilizer K. Furthermore; there was no significant reduction in soil test K levels on plots that were not receiving any supplemental fertilizer K. This suggests that exchangeable K was being replaced by sources other than applied fertilizer K.

The results of this research could indicate, as previous studies have done, that the application of K fertilizer on soils with medium range of K may be an unnecessary expense to growers. Further research should be conducted on K build up in subsoil horizons and K dynamics within coastal plain soils. This could help gain a better understanding of the K holding capacity and the supplying power of coastal plain soils. Once these mechanisms are better understood, adjustments to fertilizer recommendations can be made accordingly to ensure efficient and economical use of K fertilizers. Methods for measuring soil K levels and accompanying fertilizer recommendations may also need to be re-examined and adjusted to include all forms of K in a soil. This, coupled with a more comprehensive evaluation of a soil's ability to release and hold K, would allow growers to take a more holistic approach when deciding fertilizer treatments. This could help reduce their environmental impact while also reducing their input cost.

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