EVALUATION OF ORGANIC BIO-SOLIDS FOR SOIL AMENDMENT AND FERTILIZATION OF NORTH CAROLINA RIGHTS-OF-WAY

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16. Abstract

These studies were conducted to evaluate the use of materials derived from swine waste solids as pre-plant soil incorporated and topdressing fertilizers for roadside grass mix establishment. Four locations in North Carolina were used to determine the stability of the applied nutrients. Plots were established beginning in 2004, at the Horticultural Crops Research Station in Castle Hayne, Sandhills Research Station in Jackson Springs, Lake Wheeler Turfgrass Field Laboratory in Raleigh, and Mountain Horticultural Crops Research Station in Fletcher. Initially, a material derived from an anaerobically digested swine lagoon solid (Orbit) was used. In 2005, the use of this material was discontinued due to unavailability and a second material, SuperSoil which was an aerobically composted combination derived from swine waste solids and cotton gin residue was used. Soils were fertilized with either a standard check inorganic fertilizer of a 10-8.8-16.6 (N-P-K) material at 45 lbs/acre or using the organic source at either 0.5% v/v or 1.0% v/v incorporated to a depth of 6 inches. For the runoff studies, in year 2, a single topdressing application was made at rates equivalent to 45 lbs/acre. Soil samples were taken every week for the first 2 to 4 weeks depending on location and then every 4 to 6 weeks thereafter and the nutrient concentrations analyzed. Overall, the nutrient and pH results in the soil treated with 0.5% v/v SuperSoil are not different from the soil treated with a standard inorganic fertilizer. However the 1% v/v SuperSoil treatment consistently showed higher nutrient concentrations and higher pH values than the other two treatments. However, the Fletcher location showed the least change in nutrients or pH due to any fertilizer augmentation. Twenty-four plots were constructed at the Lake Wheeler Turfgrass Field Lab in Raleigh North Carolina specifically to collect surface runoff. Two types of fertilizer were applied to the plots -- an organic fertilizer, SuperSoil (4% N, 0.88% P, 2.5% K) and an inorganic fertilizer (10% N, 8.8% P, 16.6% K), referred to in this study as standard. Additionally, non treated plots were used as a check. Both a linear regression test and an analysis of variance using Least Squared Means found that there was no significant difference in nitrogen or phosphorus concentrations in runoff depending on type of fertilizer and the control. Therefore, this study concludes that there is no greater environmental threat from runoff from organic fertilizers than from inorganic fertilizers or unfertilized areas. Two nitrogen mineralization experiments were conducted using a Cecil Sandy Loam soil from the Lake Wheeler Turfgrass Field Lab in Raleigh and a Wakulla soil from Sandhills Research Station in Jackson Springs, North Carolina. This study found that Wakulla soil has about three times less NH_4^+-N than the Cecil soil. The Orbit treatment seems to bind nitrogen in both Cecil and Wakulla soils so that is not immediately accessible for mineralization or plant nutrient uptake. The SuperSoil treatment has a similar effect. Therefore using either the Orbit or the SuperSoil treatments does not appear to contribute immediate nitrogen in accessible forms for plant uptake and that an additional nitrogen component may need to be added to the final fertilizer product to fulfill immediate plant needs.

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SUMMARY

Three studies were conducted as components of this project to evaluate the use of materials derived from swine-lagoon solids as pre-plant soil incorporated fertilizers for roadside grass mix establishment at four locations in North Carolina. The objectives of the studies were 1) to determine the stability of the applied nutrients within the soil profile; 2) to evaluate the nutrient runoff and leaching potential of these materials; and 3) to determine the nitrogen mineralization rate of the swine-lagoon solids for to assess their potential for supplying nitrogen for grass growth. Plots were established beginning in 2004, at the Horticultural Crops Research Station in Castle Hayne, the Sandhills Research Station in Jackson Springs, the Lake Wheeler Turfgrass Field Laboratory in Raleigh, and the Mountain Horticultural Crops Research Station in Fletcher. Initially, one material was selected for evaluation derived from an anaerobically digested swine lagoon solid. In 2005, the use of this material was discontinued due to unavailability and a second material, SuperSoil which was an aerobically composted combination derived from swine waste solids and cotton gin residues was used.

Soil Nutrient Content - Overall, the nutrient and pH results in the soil treated with 0.5% v/v SuperSoil are not different from the soil treated with a standard inorganic fertilizer. However the 1% v/v SuperSoil treatment consistently showed higher nutrient concentrations and higher pH values than the other two treatments. However, the Fletcher location showed the least change in nutrients or pH due to any fertilizer augmentation. At Castle Hayne, the phosphorus concentration in the 1% SuperSoil treated plots was significantly higher for both bahiagrass and bermudagrass plots. However, there was no significant change in phosphorus concentrations at Castle Hayne, irrespective of treatment or grass type. At the Sandhills location, while the 1% SuperSoil treatment had significantly higher concentrations than the other treatments, none of the treatments showed a significant change in phosphorus concentration over the course of the study. At the Lake Wheeler location the plots treated with 1% SuperSoil showed significantly higher phosphorus concentrations and also had a significantly greater increase in phosphorus concentration over time, than the other treatments. Overall there is a significant increase in phosphorus concentration at Fletcher; however, none of the treatments are significantly different from each other.

At the Castle Hayne location, the 1% SuperSoil treatment had the greatest effect on the potassium concentrations and showed the greatest change in potassium level over the course of the study for both grass types. At the Sandhills location, the plots treated with 1% SuperSoil had both a significantly greater potassium concentration than the other treatments and significantly increased in potassium concentration over time; however, the 0.5% SuperSoil treatment plots and the inorganic fertilizer treatment plots were statistically similar. Similar to the Sandhills, Lake Wheeler plots treated with 1% SuperSoil had the greatest significant increase in potassium concentration as well as significantly more potassium than the other treatments, which were not statistically different. Unlike the other location, Fletcher plots showed no significant change in potassium concentration for any of the treatments over time, nor were any of the treatments significantly different.

At Castle Hayne, the pH for plots treated with SuperSoil was not statistically different from plots treated with inorganic fertilizer. In plots at the Sandhills, the pH was greatest in plots treated with 1% SuperSoil however; there was a significant increase in pH for all the treatments over the course of the study. At Lake Wheeler and at Fletcher, all treatments showed a significant increase in pH over the course of the study, but none of the treatments were statistically different.

Nutrient Runoff - Both a linear regression test and an analysis of variance using Least Squared Means found that there was no significant difference in nitrogen or phosphorus concentrations in runoff depending on type of fertilizer and the control.

Nitrogen Mineralization - This study found that soil type plays a role in how the biosolid materials mineralize. The Wakulla sandy soil has about three times less NH_4^+ -N than the Cecil soil (Figures 1 and 3). Since Wakulla sandy soil does not have as high a capacity to bind ammonium in the soil as Cecil soil, as evident by a lower CEC, the overall extractable ammonium concentrations in the Wakulla sandy soil are much lower than those in the Cecil soil. Since Wakulla soil is excessively well-drained, even in the controlled conditions, evaporation and condensation may cause redox reactions and therefore would promote faster nitrification of NH_4^+ to NO_3^-. The thicker, Cecil soil is less aerobic than the Wakulla soil, and has a greater CEC, so the NH_4^+ would likely be bound in the soil and undergoes nitrification at a slower rate.

The Orbit treatment seems to bind nitrogen in both Cecil and Wakulla soils so that is not accessible for mineralization or plant nutrient uptake. The SuperSoil treatment has a similar effect, but not as dramatic. In fact, in Wakulla soil, the SuperSoil treatment provides more accessible nitrogen than untreated soil. However, in Cecil soil the SuperSoil treatment also seems to bind nitrogen in inaccessible plant forms. Therefore using either the Orbit or the SuperSoil treatments does not appear to contribute additional nitrogen in accessible forms for plant uptake.

Therefore, these studies conclude that there is no greater environmental threat from nutrient loss, particularly from phosphorus which creates water quality problems from organic fertilizers than from inorganic fertilizers or unfertilized areas.

TABLE of CONTENTS

LIST of FIGURES

CHAPTER 1: SOIL NUTRIENT CONTENT OF ORGANIC AND INORGANIC FERTILIZER TREATED TURFGRASS PLOTS

CHAPTER 3: NITROGEN MINERALIZATION STUDY

INTRODUCTION

Soil modification with organic materials, such as bio-solids, is becoming an increasingly popular soil treatment since it can often improve physical and chemical conditions and enhance the performance of turf grass establishment (Eghball, 2002). The use of bio-solids can improve soil qualities, particularly soil water retention and nutrient levels (Rigueiro-Rodriguez et al, 2000; Chantigny et al, 2002). In fact, the use of bio-solids can improve plant growth and subsequently decreases the loss of soil due to erosion (Meyer et al, 2001). The increase in plant growth occurs within the first year of application, possibly due to increases in carbon and nitrogen availability and therefore provides the desired results in a timely manner (Meyer et al, 2004). This elevated nutrient content, as well as other soil properties, may continue to improve soil conditions for several years after application (Ginting et al, 2003). However, nutrient values can vary depending on the material and processes used and the concentrations of essential nutrients such as nitrogen, phosphorus and potassium (Eghball, 2002; Vietor et al, 2002). In some cases, when nutrient availability is low, use of organic fertilizers help sustain the nitrogen availability in soils (Chand et al, 2006).

Nitrogen

Nitrogen is the nutrient turfgrass managers use to regulate growth. As the most limiting factor in turfgrass growth, most fertilizers are applied on an amount of nitrogen per unit area basis. Therefore, turfgrass managers pay close attention to the rate and amount of nitrogen applied to the soil in order to prevent excess nitrogen buildup (Easton and Petrovic, 2004; Watschke et al, 2000). The rate of fertilizer application depends on local, state and industry recommendations, as well as climate, soil type and turf species. Application of organic fertilizers, such including manure based materials may raise the amount of nitrogen in the soil. However, it is unclear how much of a nitrogen increase may occur with organic fertilizers and what the response of the turf being established will be. Organic sources of nitrogen that are composed of large amounts of proteins (blood meal) have been shown to release more nitrogen compared to materials that have gone through previous digestion, such as animal manure. However, the rate of nitrification in soils amended with organic sources of nitrogen is largely unknown and may be important for developing application rates of organic fertilizers. Nitrogen mineralization obeys the theories of first order kinetics: the first stage of nitrogen mineralization is ammonification where the nitrogen is converted to ammonium. Ammonification occurs independently from many external factors, such as aerobic or anaerobic conditions, and soil moisture content (Myrold, 1998). The process of ammonium turning to nitrate occurs within weeks of ammonification and depends on aerobic conditions in the soil. The two organic fertilizers used in these experiments were standardized for constant nitrogen, phosphorus and potassium values.

Phosphorous

Phosphorus is important in the establishment and rooting of plants. Fertilizers are usually applied on a per nitrogen basis, leaving the application of phosphorus largely unmonitored, and leading to phosphorus buildup. Increases in fertilizer phosphorus levels do not result in increases in the amount of phosphorus recovered from plant material. This indicates that once a plant uptakes sufficient phosphorus it will not continue to uptake more phosphorus, even if it is available in the soil (Easton and Petrovic, 2004). These assertions are particularly true in bio-solids where phosphorus accumulation many times exceeds phosphorus crop removal rates (Ippolito et al, 2007).

In some cases there is little evidence of phosphorus leaching 20 years after soil was amended with bio-solids, even though they found that phosphorus was still 5 times higher in bio-solid amended soils than in untreated soils (Harrison et al, 1994). In other cases it may leach into groundwater through very sandy and organic soils. Because phosphorus is generally attached to soil particles, most phosphorus movement comes from sediment eroding from disturbed soils. Maryland now requires phosphorus based agronomic rates in order to protect the Chesapeake Bay from excess nutrient runoff.

Potassium

Most of the potassium found in liquid effluent remains in solution. The concentration of potassium in the effluent is dependent on the climate where the effluent is collected. In arid climates, evaporation and lagoon liquid recycling increase potassium concentrations (Safley et al 1993). The application of bio-solids increases the levels of extractable potassium but over time, potassium significantly decreases in bio-solid amended soils (Wright et al, 2007). This potassium decrease could be due to plant uptake or organic matter binding, but is not thought to be caused by leaching or runoff (Wright et al, 2007).

pH

While bio-solids add organic matter to soil continued use of bio-solids has not been found to alter the pH level of soils (Meyer et al, 2004). Even several years after bio-solid application, pH remains constant and neutral (Meyer et al, 2004).

CHAPTER 1: SOIL NUTRIENT CONTENT OF ORGANIC AND INORGANIC FERTILIZER TREATED TURFGRASS PLOTS

ABSTRACT

This study was conducted to evaluate the use of materials derived from swine-lagoon solids as pre-plant soil incorporated fertilizers for roadside grass mix establishment at four locations in North Carolina and determine the stability of the applied nutrients within the soil profile. Plots were established beginning in 2004, at the Horticultural Crops Research Station in Castle Hayne, the Sandhills Research Station in Jackson Springs, the Lake Wheeler Turfgrass Field Laboratory in Raleigh, and the Mountain Horticultural Crops Research Station in Fletcher. Initially, one material was selected for evaluation derived from an anaerobically digested swine lagoon solid. In 2005, the use of this material was discontinued due to unavailability and a second material, SuperSoil which was an aerobically composted combination derived from swine waste solids and cotton gin residue was used. Soils were fertilized with either a standard check inorganic fertilizer of a 10-8.8-16.6 (N-P-K) material at 45 lbs/acre or using the organic source at either 0.5% v/v or 1.0% v/v incorporated to a depth of 6 inches. In year 2, a single topdressing application was made at rates equivalent to 45 lbs/acre. Soil samples were taken every week for the first 2 to 4 weeks depending on location and then every 4 to 6 weeks thereafter and the nutrient concentrations analyzed.

Overall, the nutrient and pH results in the soil treated with 0.5% v/v SuperSoil are not different from the soil treated with a standard inorganic fertilizer. However the 1% v/v SuperSoil treatment consistently showed higher nutrient concentrations and higher pH values than the other two treatments. However, the Fletcher location showed the least change in nutrients or pH due to any fertilizer augmentation. At Castle Hayne, the phosphorus concentration in the 1% SuperSoil treated plots was significantly higher for both bahiagrass and bermudagrass plots. However, there was no significant change in phosphorus concentrations at Castle Hayne, irrespective of treatment or grass type. At the Sandhills location, while the 1% SuperSoil treatment had significantly higher concentrations than the other treatments, none of the treatments showed a significant change in phosphorus concentration over the course of the study. At the Lake Wheeler location the plots treated with 1% SuperSoil showed significantly higher phosphorus concentrations and also had a significantly greater increase in phosphorus concentration over time, than the other treatments. Overall there is a significant increase in phosphorus concentration at Fletcher; however, none of the treatments are significantly different from each other.

At the Castle Hayne location, the 1% SuperSoil treatment had the greatest effect on the potassium concentrations and showed the greatest change in potassium level over the course of the study for both grass types. At the Sandhills location, the plots treated with 1% SuperSoil had both a significantly greater potassium concentration than the other treatments and significantly increased in potassium concentration over time; however, the 0.5% SuperSoil treatment plots and the inorganic fertilizer treatment plots were statistically similar. Similar to the Sandhills, Lake Wheeler plots treated with 1% SuperSoil had the greatest significant increase in potassium concentration as well as significantly more potassium than the other treatments, which were not statistically different. Unlike the other location, Fletcher plots showed no significant change in potassium concentration for any of the treatments over time, nor were any of the treatments significantly different.

At Castle Hayne, the pH for plots treated with SuperSoil was not statistically different from plots treated with inorganic fertilizer. In plots at the Sandhills, the pH was greatest in plots treated with 1% SuperSoil, however there was a significant increase in pH for all the treatments over the course of the study. At Lake Wheeler and at Fletcher, all treatments showed a significant increase in pH over the course of the study, but none of the treatments were statistically different.

METHODS and MATERIALS

Three types of fertilizer were used in this study and included two bio-solids, Orbit and SuperSoil, and the current DOT standard 10-20-20 inorganic fertilizer which was considered a control. SuperSoil is composed of swine lagoon sludge composted with cotton residues and contains < 5% moisture. This bio-solid has a nutrient composition of 4% N, 2% P_2O_5 and 3% K_2O. SuperSoil came ready-to-use and therefore did not undergo any additional treatments prior to turf application. Orbit is anaerobically digested swine lagoon slurry that was dried down to an easily spreadable mixture. This slurry originally contained 88% water and 12% solids. The slurry was first dried in large pools with industrial forced air heating units until it reached approximately 45% moisture. The mixture was then moved to a tarp for further drying and processed with a ribbon mixer. Small amounts of the mixture were added to the ribbon mixer until it reached 60% moisture. With each pass of the ribbon mixer, the fertilizer was rewetted with 10% of the original slurry by weight. Upon processing, the mixture was pelletized to 4% moisture content through a Jet-Pro fluidized bed dryer at the NCSU Animal and Poultry Waste Management Center (APWMC). The final fertilizer contained 2.5% N, 2.5% P_2O_5, 1.25% K_2O. Unfortunately after processing, a large portion of the fertilizer was lost in a fire during the summer of 2005.

This three-year research project contained three main components, a greenhouse study to analyze germination rates of turf seed in various NC soils, a field study to assess the effectiveness of the fertilizers, and a topdressing runoff study to quantify nutrient loss.

Greenhouse study

A greenhouse study was conducted to determine if either of the materials used as a soil amendment would inhibit seed germination. Soil taken from the Lake Wheeler Turfgrass Field Laboratory was mixed 1% v/v with the materials and placed in pots. Seed to be used in the field trials was established in the pots. No detrimental effects were found.

Field Studies

A 2-year field study was initiated in Fall 2004 to evaluate the use of organic bio-solid material as a soil amendment and fertilizer for DOT turfgrass right-of-ways. The experiment was designed to test the potential of these materials as soil incorporation amendments. The two year duration of the study enabled continued nutrient and viability monitoring. Year 2 research was continued at the NCSU Research Farms and additional experimental right-of-way sites in North Carolina were added. These sites were selected after consultation with Mr. Don Lee, State Roadside Environmental Engineer with the NC DOT State Roadside Environmental Unit and included the following:

- Raleigh (Div. 5) – Lake Wheeler Turfgrass Field Lab
- Jackson Springs (Div. 8) – Sandhills Research Station
- Castle Hayne (Div. 3) – Horticultural Crops Research Station
- Fletcher (Div. 13) – Mountain Horticultural Crops Research Station

A stripped-stripped-split plot experimental design (Figure 1) was used to test varying rates of bio-solids as a soil amendment and for annual fertilization maintenance over various planting dates. Plots were prepared by first by an application of glyphosate to kill current vegetation. Lime was then applied to all locations at a rate of 50 lbs/1000 sq.ft. based on North Carolina Department of Agriculture (NCDA) recommendations. All plots except the Castle Hayne location were tilled to a six inch depth. Castle Hayne was raked to a six inch depth due to the absence of a tiller. All plots were lined with red spray paint to outline plot location. Seed mixtures were based on DOT specs and were pre-weighed and bagged. The turf seed was hand raked into the soil and covered with fresh wheat straw (1.5 bale/100 ft^2). A timing factor that included six seeding dates (Fall:

September, October, November; Spring: March, April, May) was used. Upon plot initiation, incorporated organic matter (OM) treatments consisted of three levels (0%, 0.5%, and 1% OM by volume) raked into the ground to a six inch depth prior to turf establishment. Beginning in Year 2, a single topdressing application was made at rates equivalent to 0.5 lb. and 1 lb. of N/1000 ft^2. Turf plots were maintained at a height of five inches by mowing a maximum of five times per year until the centipedegrass component was fully established, upon which the mowing frequency was decreased to two or three times per year. Upon application of fertilizer, plots were sampled once per week after 2 to 4 weeks, then once every 4 to 6 weeks thereafter.

Three to four soil samples were collected from the first six inches of each plot with a soil core sampling tool and then brought to the NCDA soils lab for analysis. The parameters which were tested were soil moisture content, soil fertility levels, heavy metal loading, and soil nitrate levels. Additional parameters measured included pH, bulk density, particle size, and soluble salt concentrations. Overall turfgrass performance was evaluated on a 1 to10 scale for ground cover. In Year 3, plot evaluation was continued at all experimental sites and final data was analyzed.

Statistics

After the data was reviewed for outlying observations, the data was transformed in SAS using a log transformation for potassium and phosphorus concentrations in order to make the data fit a more normal curve. A comparison analysis was conducted for four variables as follows: location, date planted, fertilizer treatment and collection date. The comparison statistics provided p-values for all the possible combinations of the variables, and an alpha of 0.01 was used to show significance. To compare specific treatments within a location, LSD was used.

Diagram 1. Experimental plot design for each NCSU Research Farm location.

……………. F A L L …………...   ……….…... S P R I N G …………..

Sep.	Oct.	Nov.	March	Apr.	May
0%	0%	0%	0%	0%	0%
0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
1%	1%	1%	1%	1%	1%
0%	0%	0%	0%	0%	0%
0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
1%	1%	1%	1%	1%	1%
0%	0%	0%	0%	0%	0%
0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
1%	1%	1%	1%	1%	1%

Plot size: 10 ft. x 10 ft. individual plots were split three ways to accommodate for topdressing fertilizer application in Years 2 & 3.

RESULTS and DISCUSSION

When analyzing the data across locations, statistical analysis, as expected, that the location played a highly significant ($p<0.0001$) role in soil phosphorus and potassium concentrations as well as pH. Therefore all three points of interest were separated by location. Additionally, in most cases, the month in which the plot was established also played a significant role in the soil pH, phosphorus and potassium concentrations so within a location the data is further separated into months of establishment.

PHOSPHORUS

Castle Hayne

Overall at Castle Hayne, for bahiagrass plots, there was a significant change in the soil phosphorus concentration depending on which month the plot was established, except for plots that were established in May, September and November ($P<0.01$). The same was true for bermudagrass plots, except in plots established in May and October ($P<0.01$). However, for both grasses, there was not a significant difference in soil phosphorus concentration between the plots with different establishment months. Therefore, plots are examined within an establishment month to better determine the effect of the treatment on the plots nutrient concentration.

MARCH

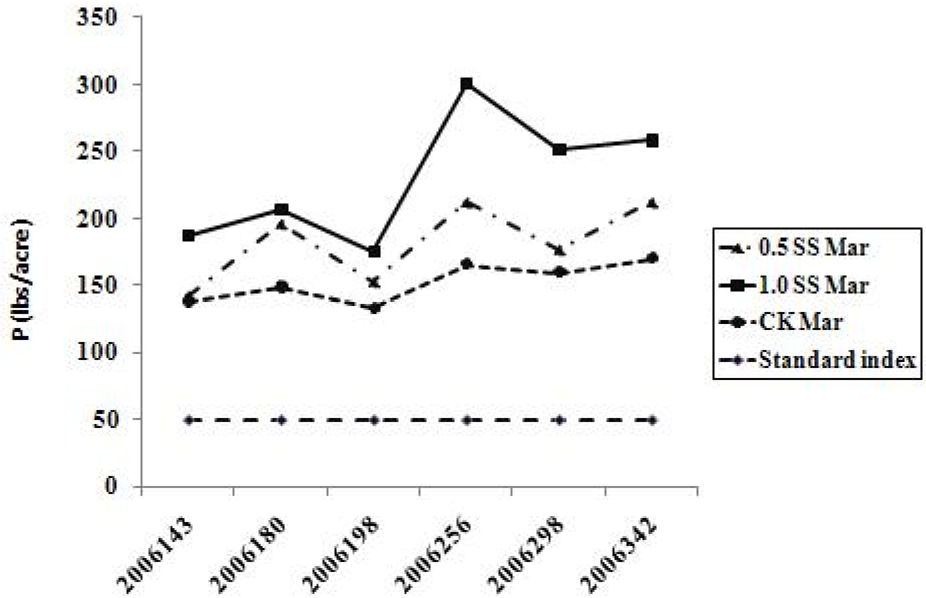

Figure 1. Phosphorus concentrations for Castle Hayne plots established in March, 2006 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there is no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in March, 2006. However, bermudagrass plots treated with 1% SuperSoil had a significantly higher phosphorus concentration than plots treated with the inorganic fertilizer ($P<0.01$). However, bermudagrass plots treated with 0.5% SuperSoil did not have a significantly different phosphorus concentration from either of the other two treatments ($P<0.01$). Overall, in bahiagrass plots, there was no significant difference between the three treatments. In conclusion, the 1% SuperSoil treatment led to higher phosphorus concentrations; however there was very little change in phosphorus concentration over the study period for any of the treatments.

MAY

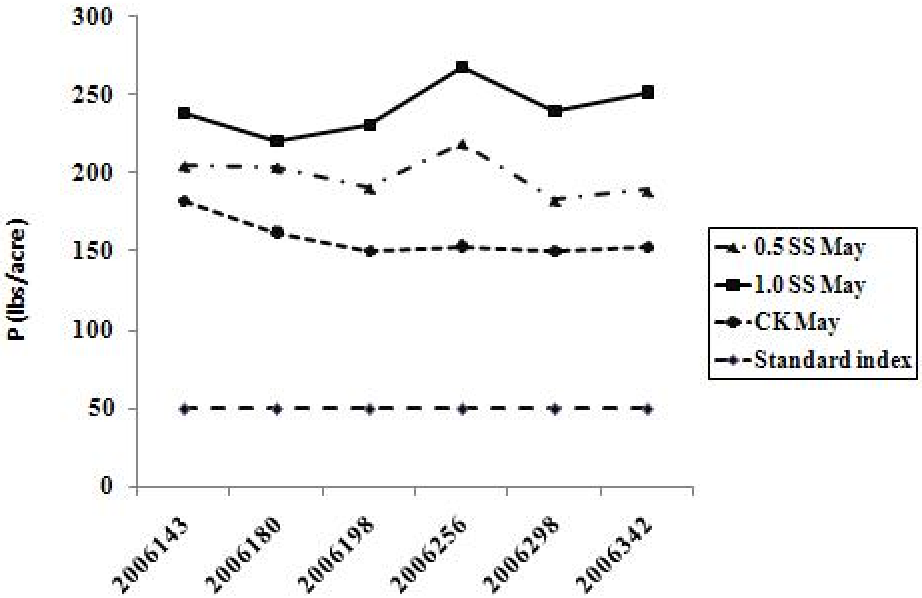

Figure 2. Phosphorus concentrations for Castle Hayne plots established in May, 2005 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there was no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in May, 2005. Bermudagrass plots treated with 1% SuperSoil had a significantly higher phosphorus concentration than plots treated with the inorganic fertilizer ($P<0.01$). However, plots treated with 0.5% SuperSoil did not have a significantly different phosphorus concentration from either of the other two treatments ($P<0.01$). Overall in bahiagrass plots, there was no significant difference between the three treatments. Similar to the March plots, the 1% SuperSoil treatment led to higher phosphorus concentrations; however there was very little change in phosphorus concentration over the study in any of the treatments.

SEPTEMBER

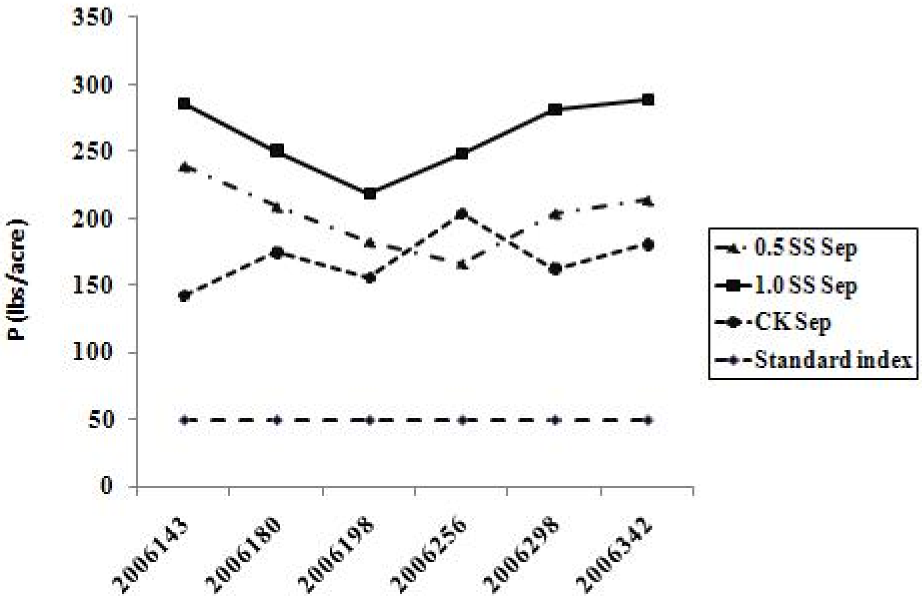

Figure 3. Phosphorus concentrations for Castle Hayne plots established in September, 2005 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there was no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in September, 2005, except in bermudagrass plots treated with 1% SuperSoil, which showed a significant increase in phosphorus concentration over the course of the study ($P=0.0074$). Bermudagrass plots treated with 1% SuperSoil had significantly higher phosphorus concentrations than plots treated with the inorganic fertilizer ($P<0.01$). However, plots treated with 0.5% SuperSoil did not have a significantly different phosphorus concentration from either of the other two treatments ($P<0.01$). Overall in bahiagrass plots, there was no significant difference between the three treatments. Although there was a significant increase in already high phosphorus concentrations in the bermudagrass plots treated with 1% SuperSoil, all the other treatments showed no change in phosphorus concentrations, nor were they different from each other.

OCTOBER

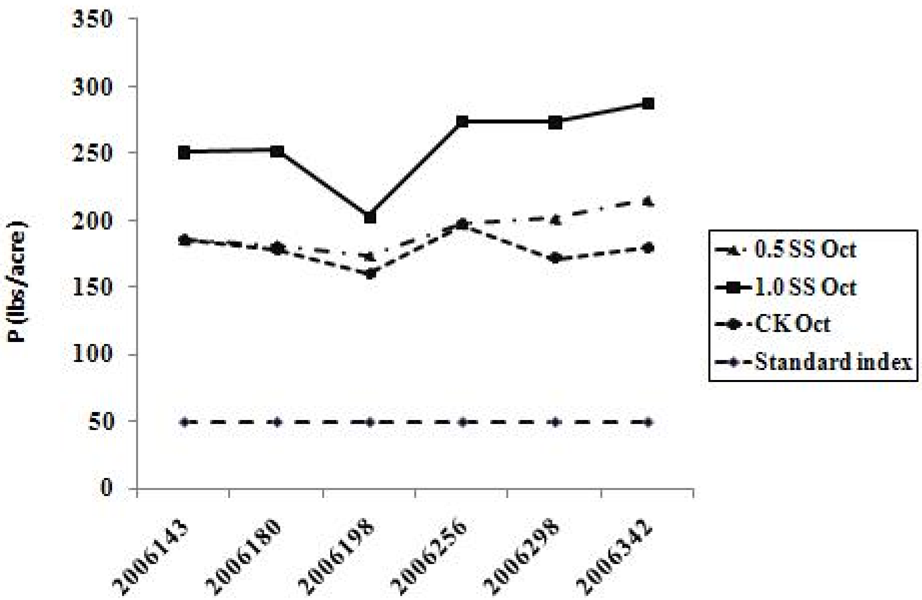

Figure 4. Phosphorus concentrations for Castle Hayne plots established in October, 2005 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there is no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in October, 2005. Bermudagrass plots treated with 1% SuperSoil had a significantly higher phosphorus concentration than plots treated with the inorganic fertilizer ($P<0.01$). However, plots treated with 0.5% SuperSoil did not have a significantly different phosphorus concentration from either of the other two treatments ($P<0.01$). Bahiagrass plots treated with 1% SuperSoil had a significantly higher phosphorus concentration than plots treated with either the inorganic fertilizer or 0.5% SuperSoil ($P<0.01$). Although plots treated with 1% SuperSoil had higher phosphorus concentrations than the other treatments, none of the treatments changed significantly over the course of the study.

NOVEMBER

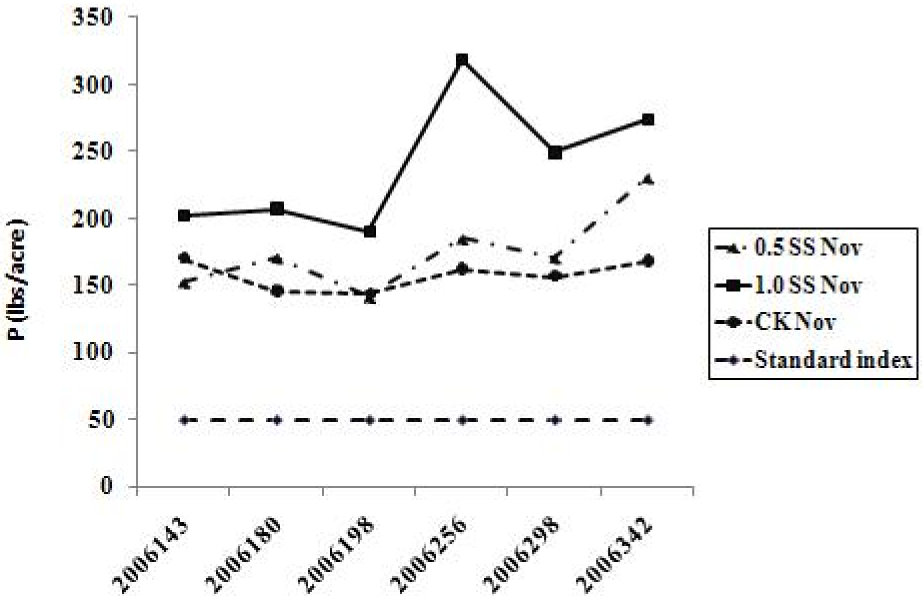

Figure 5. Phosphorus concentrations for Castle Hayne plots established in November, 2005 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there was no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in November, 2005, except in bermudagrass, 1% SuperSoil treatment plots, which showed a significant increase in phosphorus concentrations ($P=0.0033$). However, in bermudagrass plots, there was no significant overall difference between the three treatments. Bahiagrass plots treated with 1% SuperSoil had a significantly higher phosphorus concentration than plots treated with the inorganic fertilizer ($P<0.01$). However, bahiagrass plots treated with 0.5% SuperSoil do not have a significantly different phosphorus concentration from either of the other two treatments ($P<0.01$). While the 1% SuperSoil bermudagrass plots did show a significant increase in phosphorus concentration over time, overall, there was no significant difference between that treatment and the other two treatments. Bahiagrass plots showed no significant change over the course of the study; however the 1% SuperSoil treatment was significantly higher than the other two treatments, despite no significant change over time.

Castle Hayne Conclusions

For both grass types and irrespective of establishment month, there was no significant change in soil phosphorus concentrations at the Castle Hayne location. Overall for the bahiagrass plots, the 1% SuperSoil treatment showed a significantly higher soil phosphorus concentration for both the 0.5% SuperSoil treatment and the inorganic fertilizer ($P<0.01$), which are not significantly different from each other. In the bermudagrass plots, all three treatments show significantly different soil phosphorus concentrations, with the 1% SuperSoil showing the highest phosphorus concentration and the inorganic fertilizer having the lowest phosphorus concentration ($P<0.01$). Therefore, the 1% SuperSoil has a significantly higher phosphorus concentration than the other two treatments over all the plots; however it showed no significant change over the course of the study. The other treatments also showed no overall change over the course of the study.

Sandhills

At the Sandhills plot location, there was no significant change in the phosphorus amount found in the soil based on the date of establishment. There was also no significant difference in the phosphorus concentration between plots with different establishment dates. However, it is still useful to look at the plots based on establishment date in order to analyze the change in treatments.

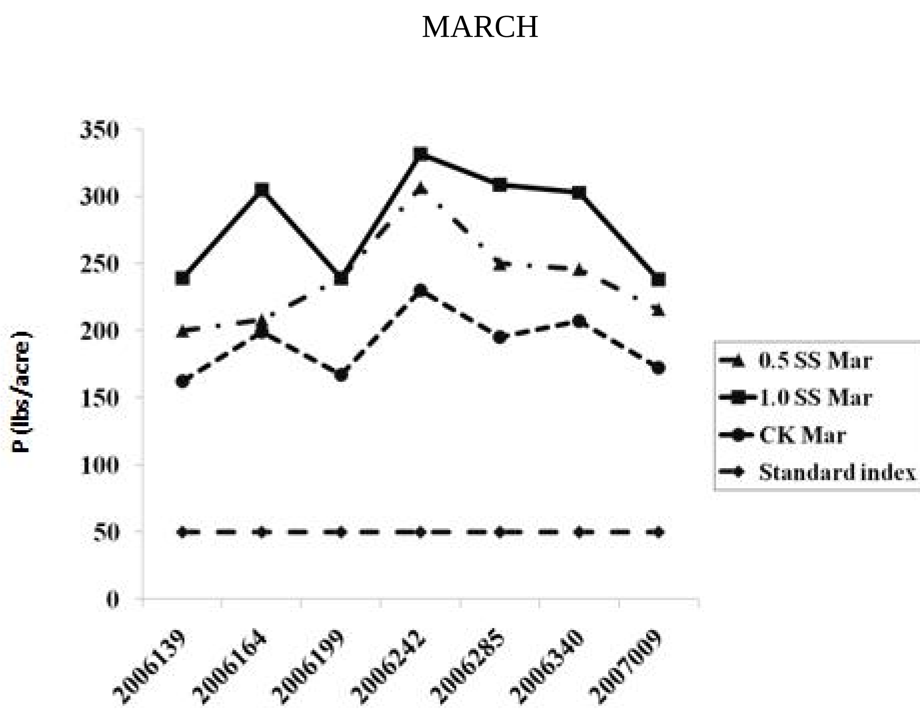

Figure 6. Phosphorus concentrations for Sandhills plots established in March, 2006 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there was no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in March, 2006. Plots treated with 1% SuperSoil had a significantly higher phosphorus concentration than plots treated with inorganic fertilizer ($P<0.01$). However, 0.5% SuperSoil treated plots were not significantly different from either of the other two treatments. In conclusion, while 1%

SuperSoil treated plots had a higher phosphorus concentration than the other treatments plots there was no change over the course of the study in the phosphorus concentration of any of the treatments.

APRIL

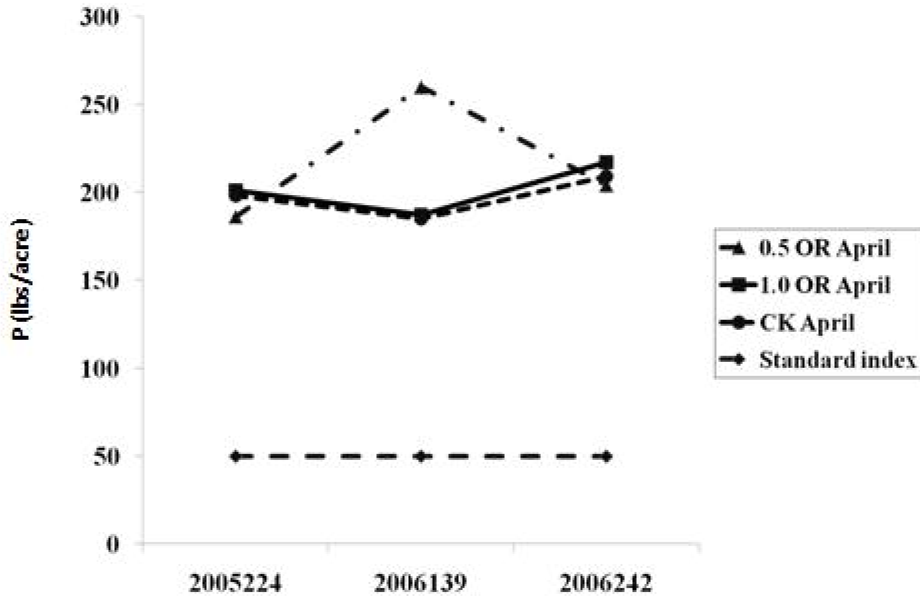

Figure 7. Phosphorus concentrations for Sandhills plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Due to the lack of Orbit product for the study, few plots were treated with Orbit. Additionally, few data points were taken, since it was decided to focus on the SuperSoil product. However, from the data available, there appears to be no significant difference in the 0.5% Orbit, 1% Orbit treatments or the inorganic fertilizer. There is additionally no significant change over time in any of the treatments.

MAY

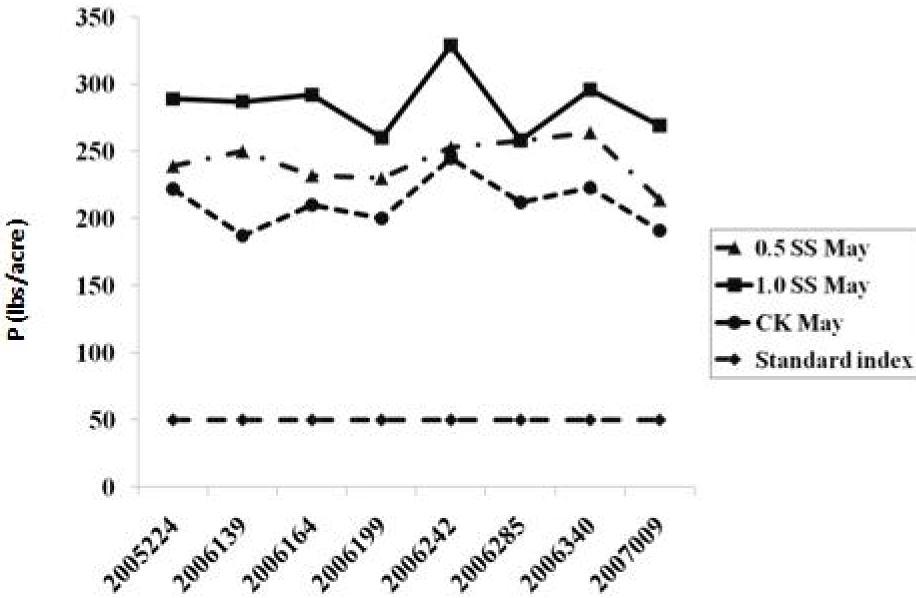

Figure 8. Phosphorus concentrations for Sandhills plots established in May, 2006 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there was no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in May, 2005. Additionally, there was no significant difference between the three treatments over the course of the study.

SEPTEMBER

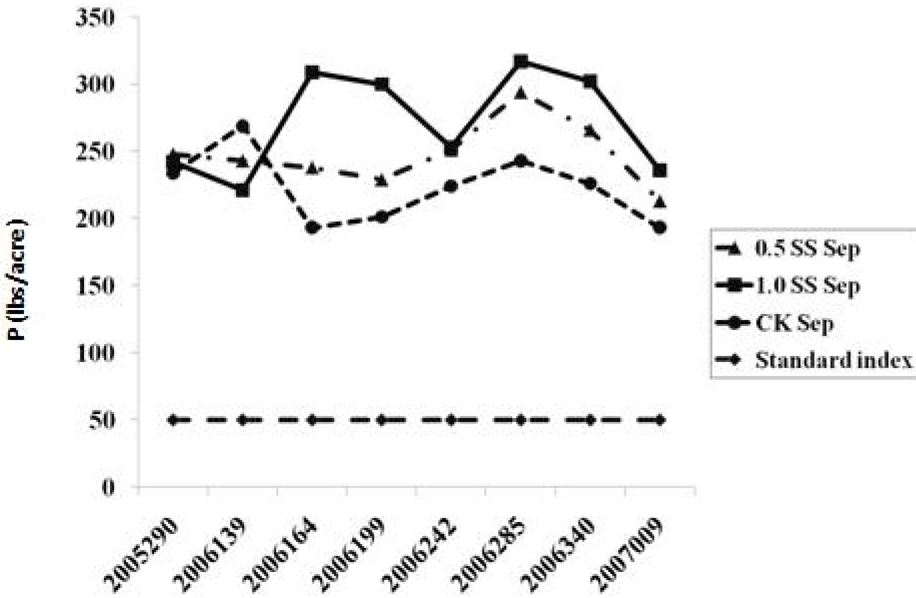

Figure 9. Phosphorus concentrations for Sandhills plots established in September, 2005 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Overall, there was no significant difference between the three treatments, nor is there significant change over the course of the study.

OCTOBER

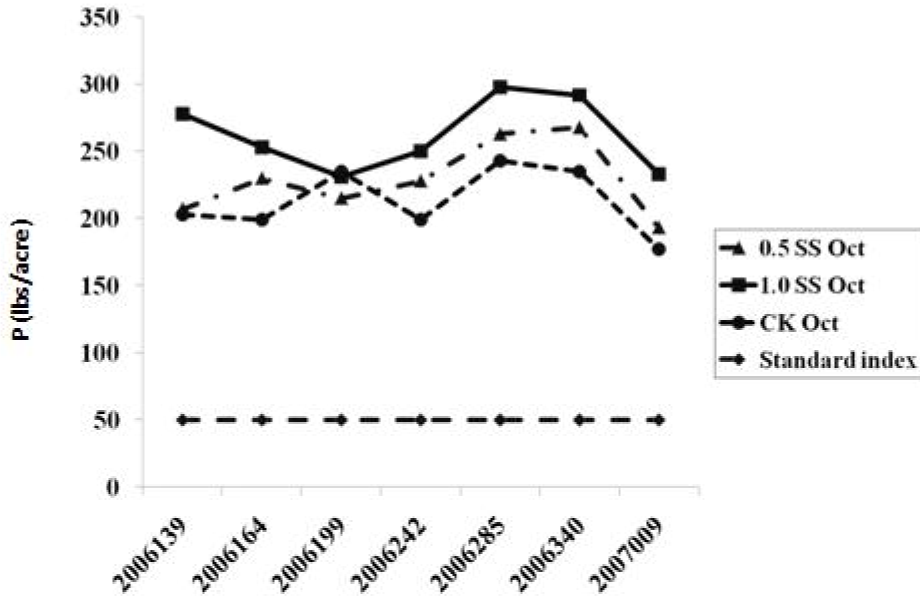

Figure 10. Phosphorus concentrations for Sandhills plots established in October, 2005 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there was no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in October, 2006. Additionally, there was no significant difference between the three treatments over the course of the study.

NOVEMBER

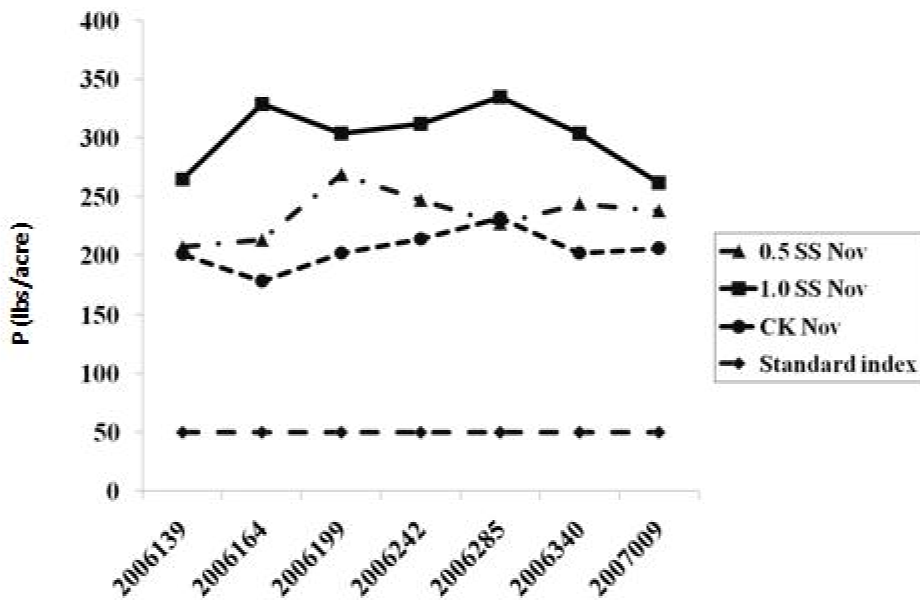

Figure 11. Phosphorus concentrations for Sandhills plots established in November, 2005 for both bahiagrass and bermudagrass plots. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there was no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in November, 2005. Additionally, there was no significant difference between the three treatments over the course of the study.

Sandhills Conclusions

Overall, there was no significant change in the amount of phosphorus in the soil at the Sandhills irrespective of treatment. However, the 1% SuperSoil treatment levels were significantly higher from both the 0.5% SuperSoil treatment and the inorganic fertilizer ($P<0.01$), which are not significantly different from each other. In conclusion, while the 1% SuperSoil treatment soil levels were higher than the other treatments, none of the treatments show a change in phosphorus concentration over the course of the study.

Lake Wheeler

There was a significant change in the phosphorus levels found in the soil at Lake Wheeler based on the date of establishment. Plots established in March had significantly higher ($P<0.01$) soil phosphorus concentration than all the other plots, except those established in September. Plots established in May, September and October were not statically different in soil phosphorus concentration ($P<0.01$). However, plots established in May and September were significantly higher in soil phosphorus concentration than plots established in November ($P<0.01$). Therefore, it was necessary to look at the treatments based on establishment date.

MARCH

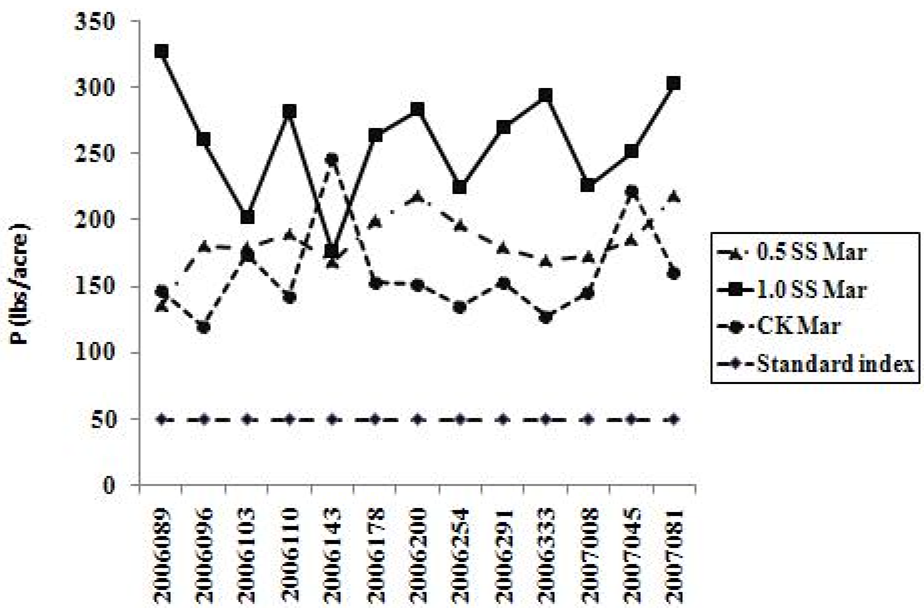

Figure 12. Phosphorus concentrations for Lake Wheeler plots established in March, 2006. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in March, 2006, except in plots treated with 0.5% SuperSoil which significantly increased in phosphorus concentration (P=0.0037). Plots treated with 1% SuperSoil have significantly higher phosphorus concentrations than either of the other two treatments (P<0.01). So, while the plots treated with 1% SuperSoil were consistently higher in phosphorus concentration than the other treatment plots, they do not show a significant change over time, where the plots treated with 0.5% SuperSoil showed a significant increase in phosphorus concentration over time, although it continued to have significantly lower amounts of phosphorus than the higher SuperSoil treatment.

APRIL

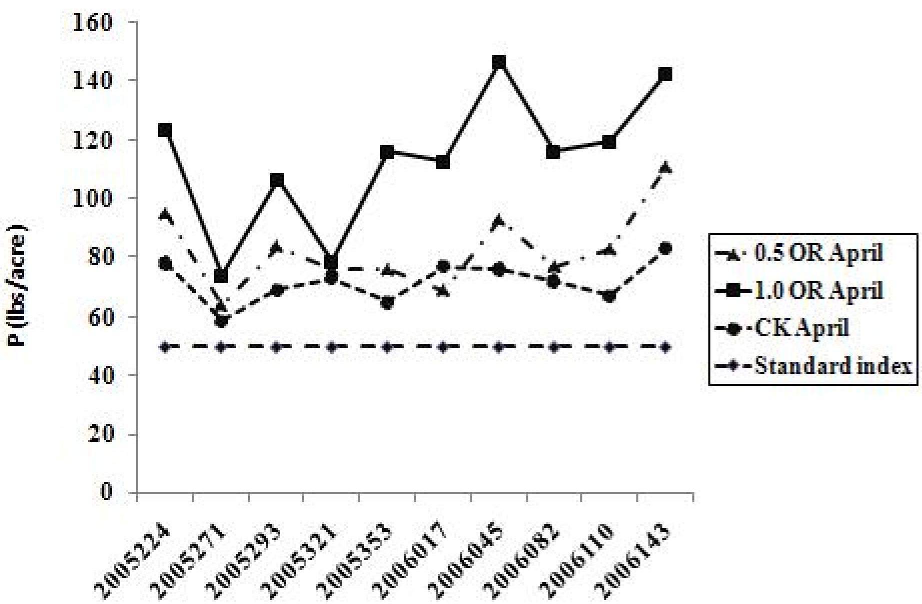

Figure 13. Phosphorus concentrations for Lake Wheeler plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

While there is a significant decrease in the phosphorus concentration in plots treated with Orbit during the first year of the study, overall there is little change in the phosphorus concentration. Like the SuperSoil treatments, the plots treated with 1% Orbit treatment showed significantly ((P<0.01) overall greater phosphorus concentration than the other treatments.

MAY

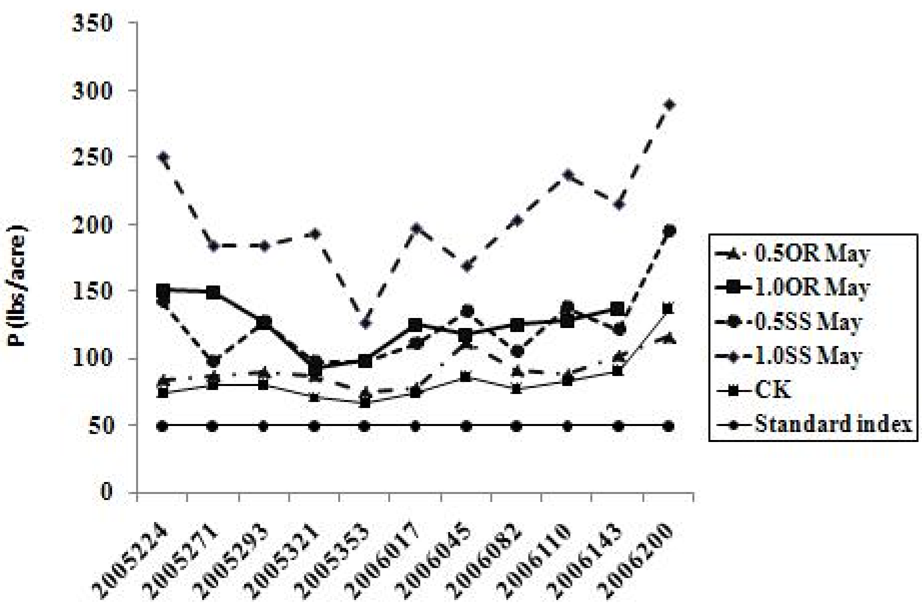

Figure 14. Phosphorus concentrations for Lake Wheeler plots established in May, 2005. The treatment legend indicates the amount of Orbit (OR) or SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there is no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in May, 2005. Plots treated with 1% SuperSoil have significantly higher phosphorus concentrations that the other two treatments (P<0.01), and plots treated with 0.5% SuperSoil have significantly higher phosphorus concentrations than plots treated with the inorganic fertilizer (P<0.01). While plots treated with either SuperSoil treatments have significantly higher phosphorus concentrations than plots treated with inorganic fertilizer, none of the plots show a significant change in phosphorus concentration over time.

There is no significant change over time in the phosphorus concentration in plots treated with either of the Orbit treatments. The phosphorus concentration in plots treated with 0.5% Orbit are not significantly higher than plots treated with the inorganic fertilizer; however, plots treated with 1% Orbit do show significantly higher phosphorus concentrations than plots treated with the inorganic fertilizer ($P<0.01$). Therefore, while plots treated with the 1% Orbit treatment shows significantly higher phosphorus concentration than the other orbit treatment or the inorganic fertilizer, none of the treatments change in phosphorus concentration over the course of the study.

SEPTEMBER

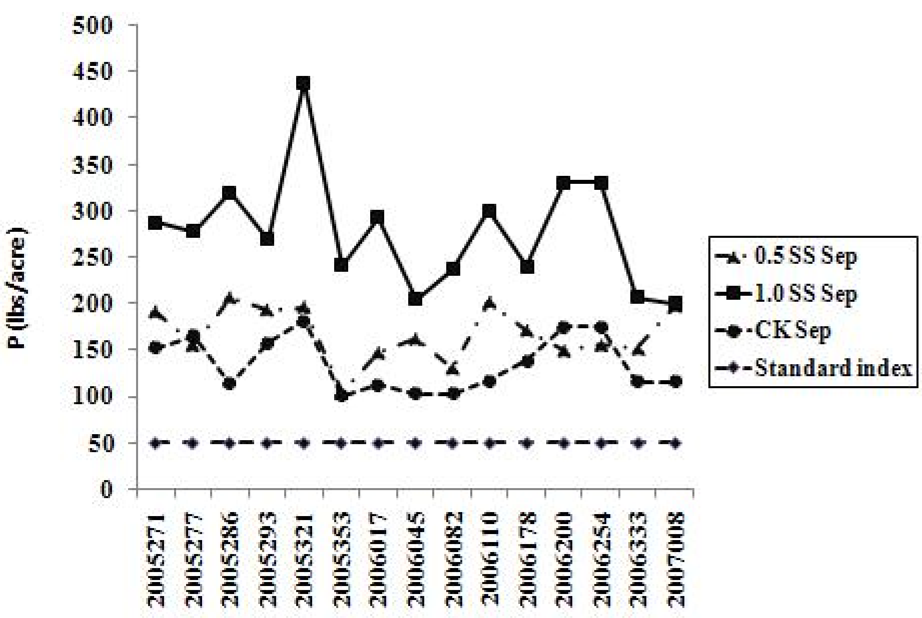

Figure 15. Phosphorus concentrations for Lake Wheeler plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Plots established in September, 2005 and treated with 1% SuperSoil had a significantly higher phosphorus concentration than plots treated with inorganic fertilizer; however it is not significantly different from plots treated with 0.5% SuperSoil. However, over time, there is no significant change in the amount of phosphorus found in the soil, irrespective of treatment.

OCTOBER

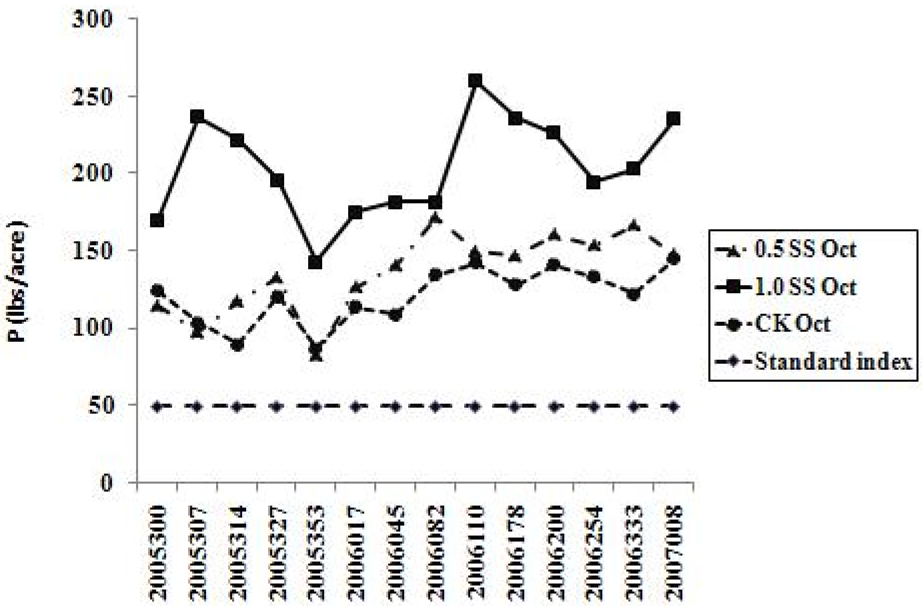

Figure 16. Phosphorus concentrations for Lake Wheeler plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Plots established in October, 2005 and treated with 1% SuperSoil had significantly higher phosphorus concentrations than either of the other two treatments, which do not significantly differ from each other. However none of the treatments showed a significant change in the amount of phosphorus found in the soil over the course of the study.

NOVEMBER

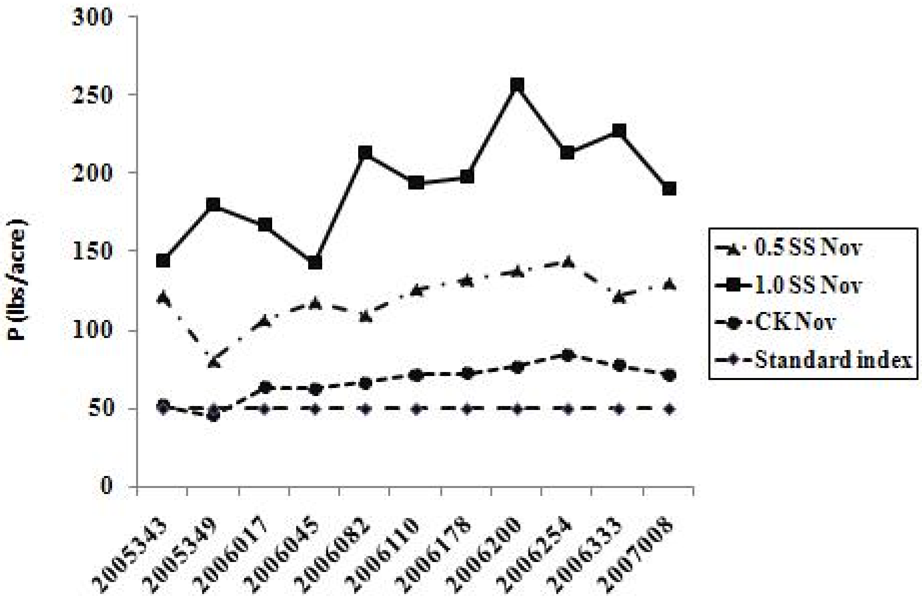

Figure 17. Phosphorus concentrations for Lake Wheeler plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there is no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in November, 2005. Although there is no change over the course of the study, plots treated with either SuperSoil treatment show significantly higher phosphorus concentrations than the plots treated with the inorganic fertilizer throughout the study.

Lake Wheeler Conclusions

At Lake Wheeler, all three treatments, inorganic fertilizer, 0.5% and 1% SuperSoil had significantly different soil phosphorus concentrations from each other ($P<0.01$) when examined across establishment months. Overall there was also a significant change in phosphorus amounts at Lake Wheeler in plots treated with the 1% SuperSoil treatment ($P<0.0001$). In conclusion, at Lake Wheeler, the plots treated with 1% SuperSoil showed significantly higher phosphorus concentrations and also increased in phosphorus concentration over time.

Fletcher

At Fletcher, there is a significant effect on the phosphorus amount found in the soil based on the date of establishment. Plots established in March had a significantly higher phosphorus concentration than any other plot, while plots established in September had significantly lower phosphorus concentrations than the other plots ($P<0.01$). Plots established in May, October and November did not have significantly different phosphorus concentrations from each other ($P<0.01$). Therefore it is important to look at the treatments within the establishment month in order to separate out the establishment date effect.

MARCH

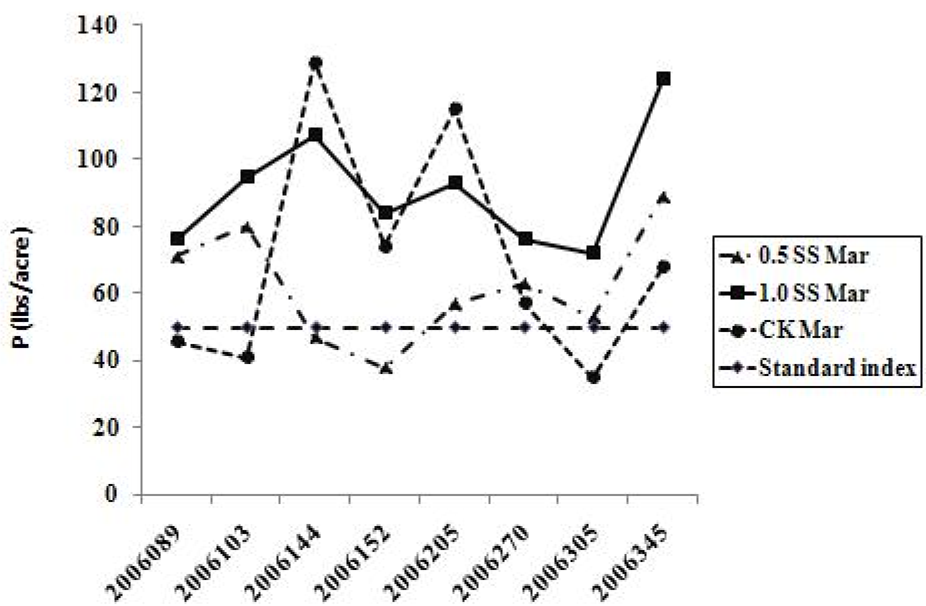

Figure 18. Phosphorus concentrations for Fletcher plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Plots treated with both 1% and 0.5% SuperSoil had significantly higher phosphorus concentrations than plots treated with the inorganic fertilizer ($P<0.01$). Over time, there is no significant change in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in March, 2006. Therefore, while the plots treated with both SuperSoil concentrations had significantly higher phosphorus concentrations than the plots treated with inorganic fertilizer, none of the treatments show a significant increase or decrease in phosphorus concentration over the course of the study.

APRIL

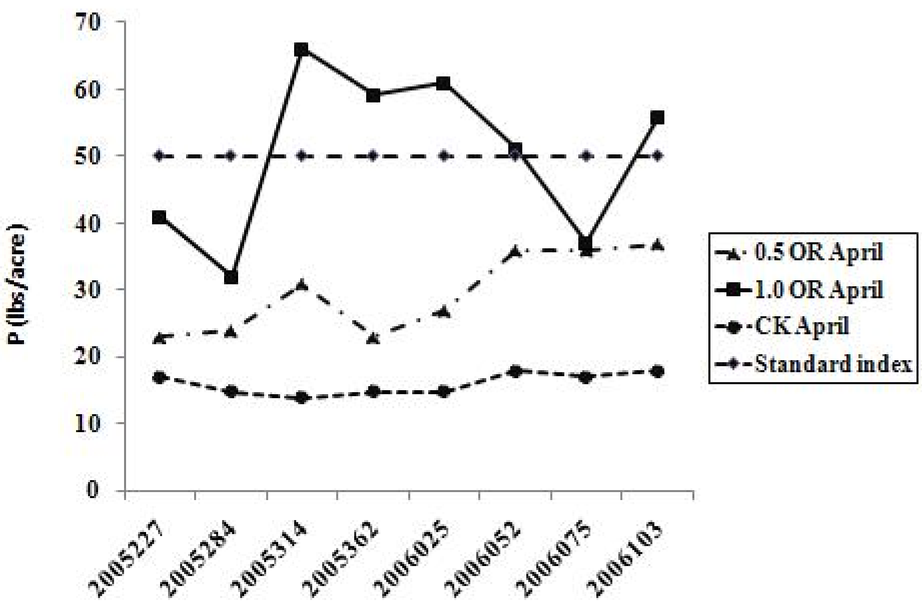

Figure 19. Phosphorus concentrations for Fletcher plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Overall, the plots treated with 1% Orbit showed significantly higher phosphorus concentration than plots treated with either of the other two treatments, which are not significantly different from each other ($P<0.01$). Both the 0.5% and 1% Orbit treated plots show a significant increase in phosphorus concentration over the course of the time; however the inorganic fertilizer does not show a significant change over time.

MAY

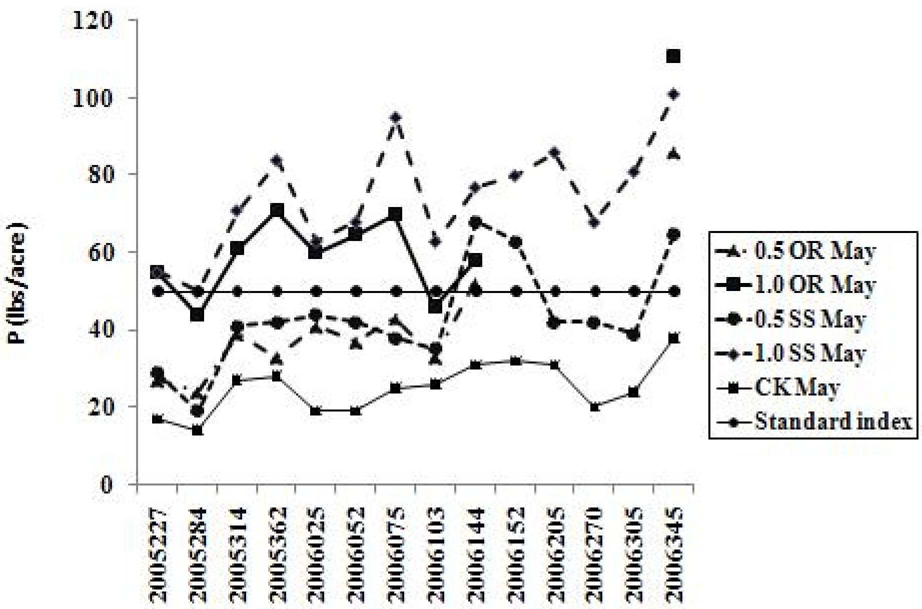

Figure 20. Phosphorus concentrations for Fletcher plots established in May 2005. The treatment legend indicates the amount of Orbit (OR) or SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

There was a slight increase in phosphorus concentration with the May, 2005 establishment date plots over time (P<0.0001). Plots treated with 1% SuperSoil showed significantly higher phosphorus concentrations that either of the other two treatments (P<0.01). Additionally, plots treated with 0.5% SuperSoil had significantly higher phosphorus concentrations than plots treated with the inorganic fertilizer (P<0.01).

The plots treated with 1% Orbit were significantly higher in phosphorus concentration than plots treated with either of the other treatments (P<0.01). Additionally, the plots treated with 0.5% Orbit had a significantly higher phosphorus concentration than plots treated with the inorganic fertilizer (P<0.01). All treatments increased significantly over the course of the study (P<0.0001).

SEPTEMBER

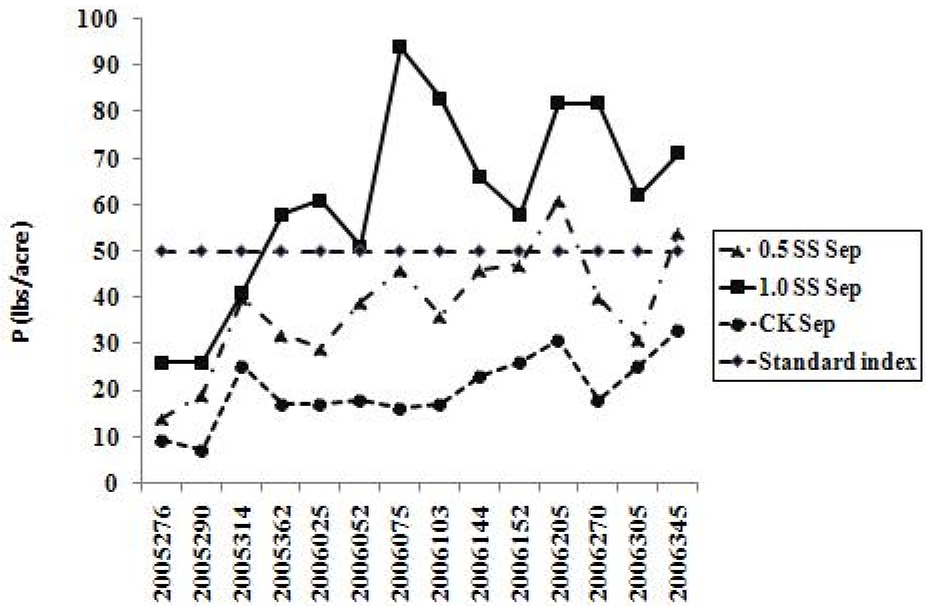

Figure 21. Phosphorus concentrations for Fletcher plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

With the September, 2005 initiated plots, all three treatments had increased phosphorus concentration over the course of the study (P<0.0001). Plots treated with 1% SuperSoil showed significantly higher phosphorus concentrations that either of the two treatments (P<0.01). Additionally, plots treated with 0.5% SuperSoil had significantly higher phosphorus concentrations than plots treated with the inorganic fertilizer (P<0.01).

OCTOBER

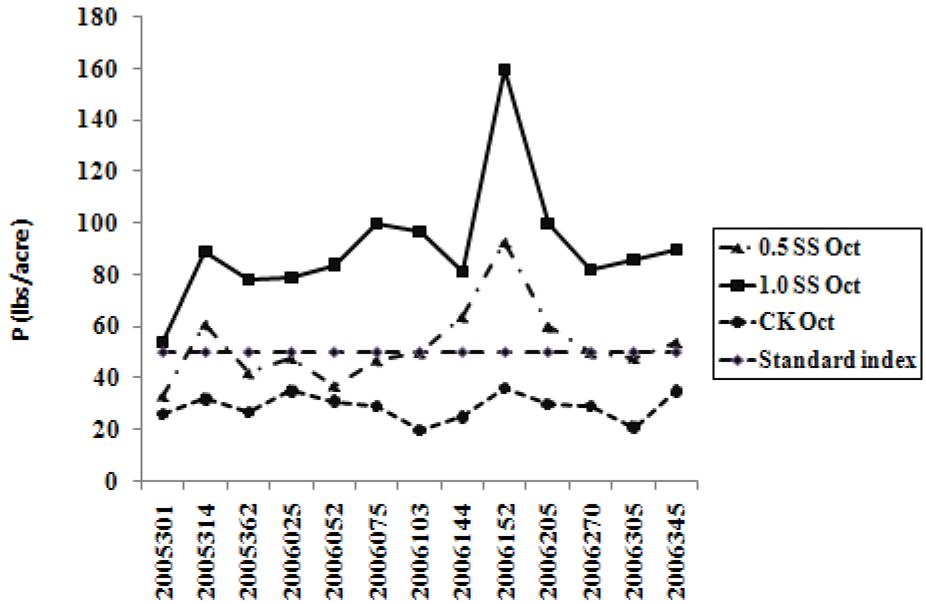

Figure 22. Phosphorus concentrations for Fletcher plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

In October, 2005 plots, both SuperSoil treatments significantly increased in phosphorus concentration over time ($P<0.001$). However, the phosphorus concentration in plots treated with inorganic fertilizer did not significantly change over time. Plots treated with 1% SuperSoil show significantly higher phosphorus concentrations that either of the two treatments ($P<0.01$), which were not significantly different from each other.

NOVEMBER

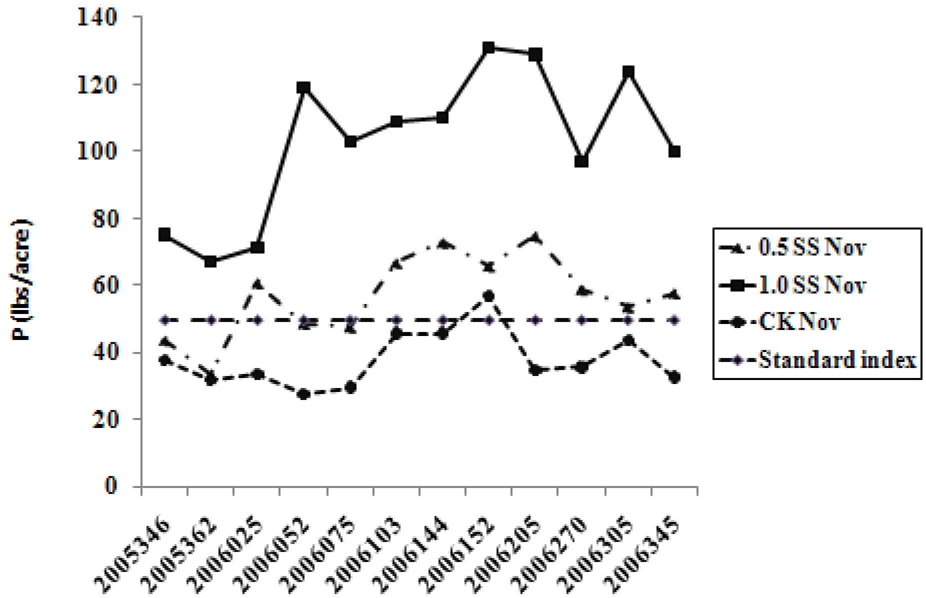

Figure 23. Phosphorus concentrations for Fletcher plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus index. The Julian date for each collection period is shown on the x-axis.

Over time, there were no significant differences in the amount of phosphorus found in the soil, irrespective of treatment, in plots planted in November, 2005. Plots treated with 1% SuperSoil show significantly higher phosphorus concentrations that either of the two treatments ($P<0.01$), which were not significantly different from each other.

Fletcher Conclusions

Overall there is a significant change in phosphorus concentration at Fletcher ($P<0.0001$). In most cases, this indicates a significant increase in the phosphorus concentration in the Fletcher plots. However, none of the treatments, inorganic fertilizer, 0.5% and 1% SuperSoil, are significantly different from each other ($P<0.01$). There was a trend toward a rate response with the organic materials.

POTASSIUM

Castle Hayne

Overall there is a significant effect on the potassium amount in the soil depending on which month the plot was established, except for plots that were established in March or May. In both the bermudagrass and bahiagrass plots, the potassium concentration found in the plots with March, September and October establishment dates were not significantly different from each other, but potassium amounts were significantly different from the plots with November and May establishment dates, which did have significantly different potassium amounts from each other. Therefore it is important to look at the treatment effect within an establishment month in order to analyze the treatment effect.

MARCH

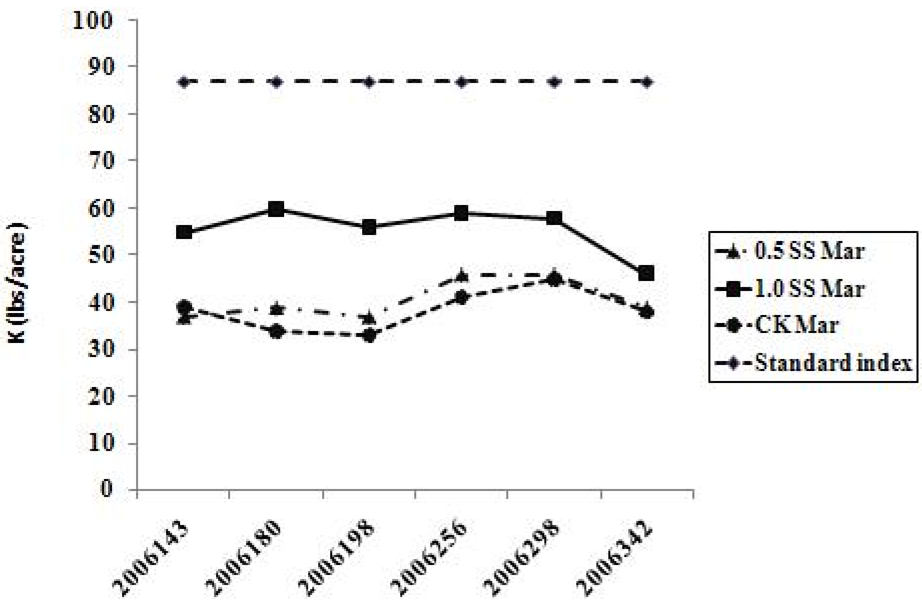

Figure 24. Potassium concentrations for Castle Hayne plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

There is a significant change over time in the potassium concentration found in soil in Bahia grass plots treated with inorganic fertilizer (P=0.0091). Over the course of the study, Bermuda grass plots treated with 1% SuperSoil are significantly different from both the plots treated with 0.5% SuperSoil and the inorganic fertilizer (P<0.01), which are not significantly different from each other. Within the Bahia grass plots, there is no significant difference between the three treatments. Therefore, while there are differences in fertilizer effect on the different grasses, when looking across all plots, there is no significant difference between the treatments and there is no change in the potassium concentration over the course of the study.

MAY

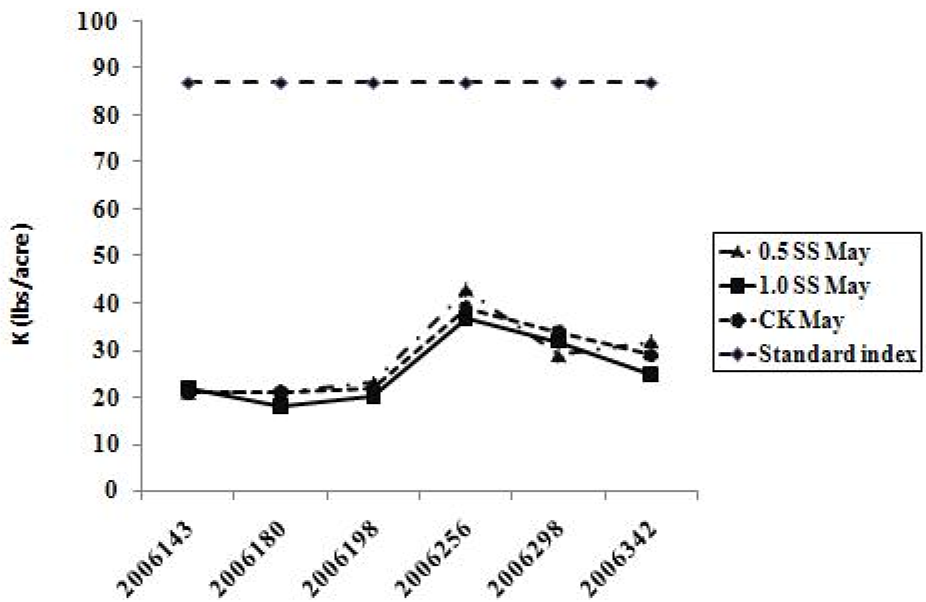

Figure 25. Potassium concentrations for Castle Hayne plots established in May, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, May 2005, played a significant role in the change in potassium levels in the soil for bahiagrass plots (P=0.0021), but not for bermudagrass plots. There is a significant change over time in the potassium concentration found in soil in bahiagrass plots treated with 0.5% SuperSoil (P<0.0001). However, within the bahiagrass plots, there was no significant difference between the three treatments. For the bermudagrass plots, there was no significant difference between the three treatments, nor was there a significant change over the course of the study. Similar to the plots established in March 2006 in Castle Hayne, the bahiagrass and bermudagrass showed different treatment effects and different potassium concentrations over time.

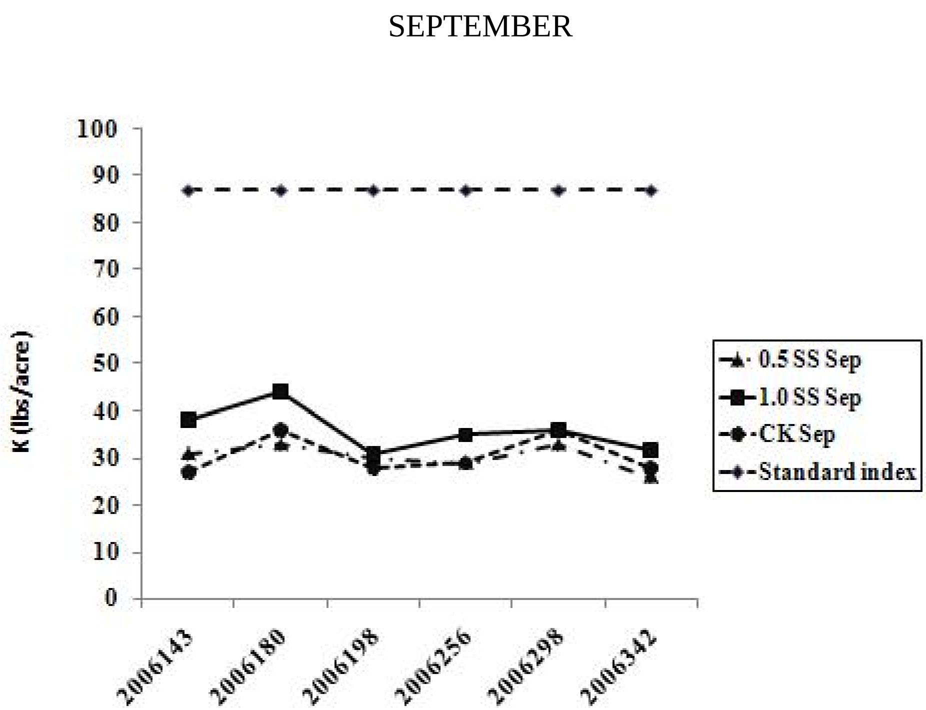

Figure 26. Potassium concentrations for Castle Hayne plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, September 2005, played a significant role in the change in potassium concentration levels in the soil for both bahiagrass plots (P<0.0001) and bermudagrass plots (P<0.0001). There was a significant change over time in the potassium concentration found in soil in bahiagrass plots for all three treatments

(P<0.0001). However, within the bahiagrass plots, there was no significant difference between the three treatments. For bermudagrass plots, there was a significant change over time in the potassium concentration between the inorganic fertilizer (P<0.0001) and 1% SuperSoil treatments (P<0.0001). Over the course of the study, for the bermudagrass plots, the 0.5% SuperSoil treatment was significantly different from the 1% SuperSoil treatment (P<0.01), but neither treatment was significantly different from the inorganic fertilizer.

OCTOBER

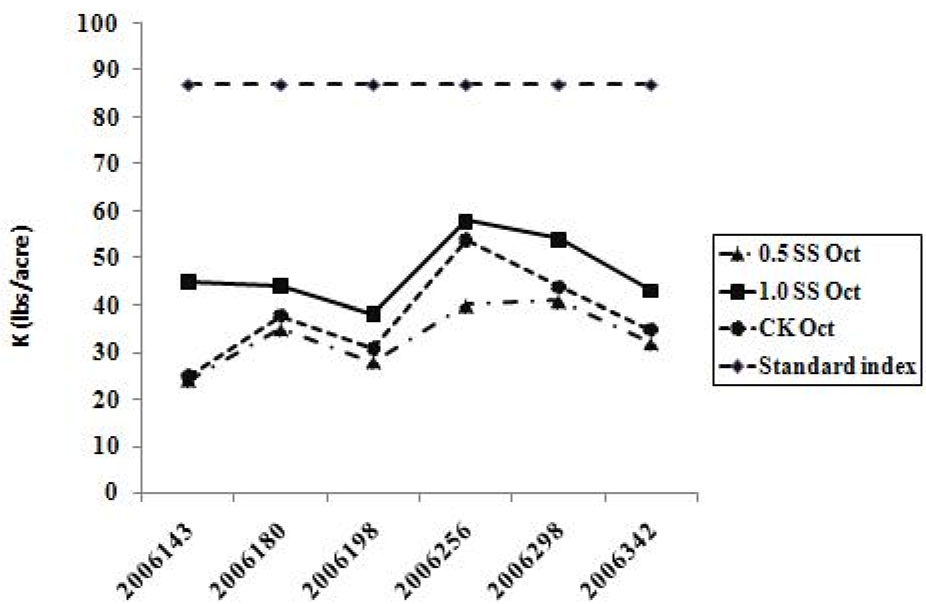

Figure 27. Potassium concentrations for Castle Hayne plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, October 2005, played a significant role in the change in potassium levels in the soil for both bahiagrass plots (P=0.0001) and bermudagrass plots (P<0.0001). There was a significant change over time in the potassium concentration found in soil in bahiagrass plots treated with 0.5% SuperSoil (P=0.0001) and 1%

SuperSoil (P<0.0001). In these plots, the 1% SuperSoil treatment was significantly higher in potassium levels than the other two treatments (P<0.01), which were not significantly different from each other.

Over the course of the study, the 1% SuperSoil treatment in the bermudagrass plots was significantly different from the inorganic fertilizer (P<0.01), but neither treatment was significantly different from the 0.5% SuperSoil treatment. However, the plots treated with 0.5 % SuperSoil showed a significant change over time in the potassium concentration (P=0.0028).

NOVEMBER

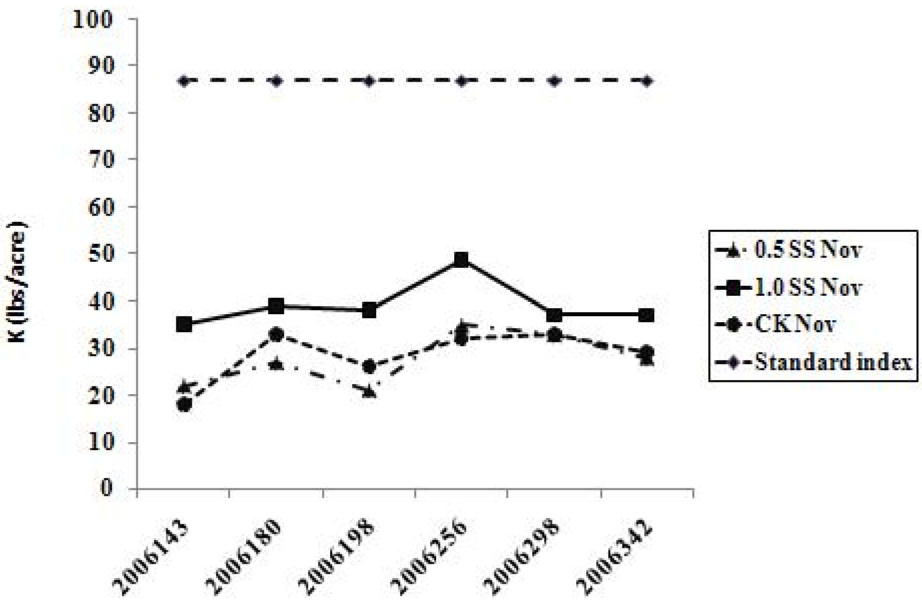

Figure 28. Potassium concentrations for Castle Hayne plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, November 2005, played a significant role in the change in potassium levels in the soil for both Bahia grass plots and Bermuda grass plots (P<0.0001). There was a significant increase over time in the potassium concentration found in soil in bahiagrass plots treated with inorganic fertilizer ($P=0.0096$), however the other two treatments did not significantly change over the course of the study. For these plots, the 1% SuperSoil treatment was significantly different from the other two treatments ($P<0.01$), which were not significantly different from each other.

There was a significant increase over time in the potassium concentration found in soil in bermudagrass plots treated with inorganic fertilizer ($P<0.0001$). Overall for the bermudagrass plots, the 1% SuperSoil treatment was significantly different from the inorganic fertilizer ($P<0.01$), but neither treatment was significantly different from the 0.5% SuperSoil treatment.

Castle Hayne Conclusions

Over the course of the study, there was a significant increase in potassium concentration due to the 1% SuperSoil treatments at Castle Hayne when examined across establishment months. Over all the establishment months, plots treated with 1% SuperSoil showed significantly higher potassium concentrations than the other two treatments in both the bahiagrass and bermudagrass plots ($P<0.01$). Therefore, the 1% SuperSoil treatment had the greatest effect on the potassium concentrations, where the 0.5% SuperSoil treatment and the inorganic fertilizer treatment had the same effect on potassium concentrations.

Sandhills

Overall there is a significant effect on the potassium concentration depending on the establishment month. Plots established in September, March and May did not significantly differ from each other in the potassium concentration found in the soil. Also the plots established in May, October and November plots did not significantly differ from each other in potassium concentrations. However, September and March plots did have significantly different potassium concentrations from October and November plots. Therefore it is important to look at the treatment effect within an establishment month in order to analyze the treatment effect.

MARCH

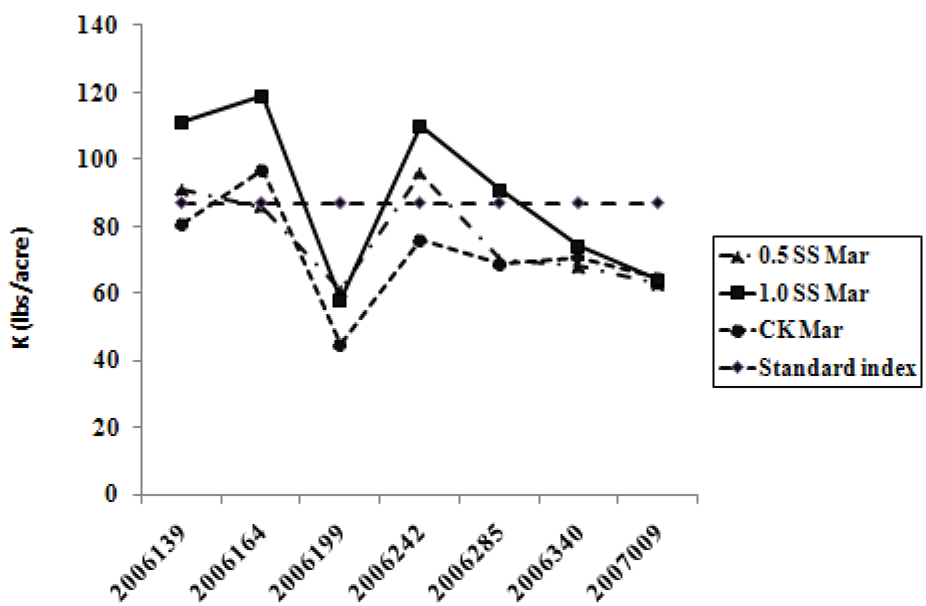

Figure 29. Potassium concentrations for Sandhills plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1.0 % and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, March 2006, plays a significant role in the change in potassium levels in the soil (P=0.0001). There is a significant decrease over time in the potassium concentration found in soil in plots treated with 1% SuperSoil (P=0.0001), however there is no significant change over time for the other two treatments. Overall, there is no significant difference between the three treatments.

APRIL

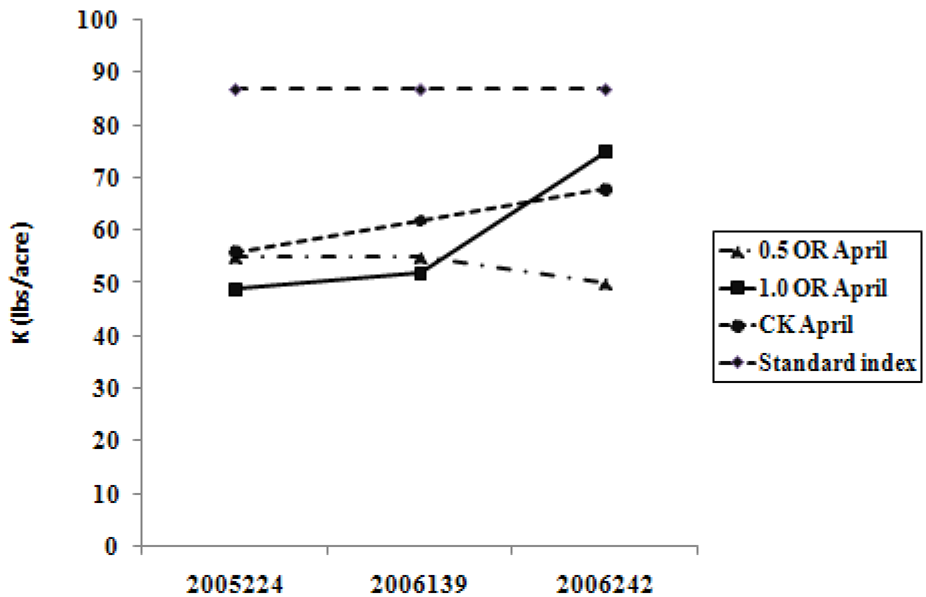

Figure 30. Potassium concentrations for Sandhills plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The plots treated with 1% Orbit show a significant ($P<0.01$) increase in potassium concentration over time. However, overall the three treatments are not significantly different from each other.

MAY

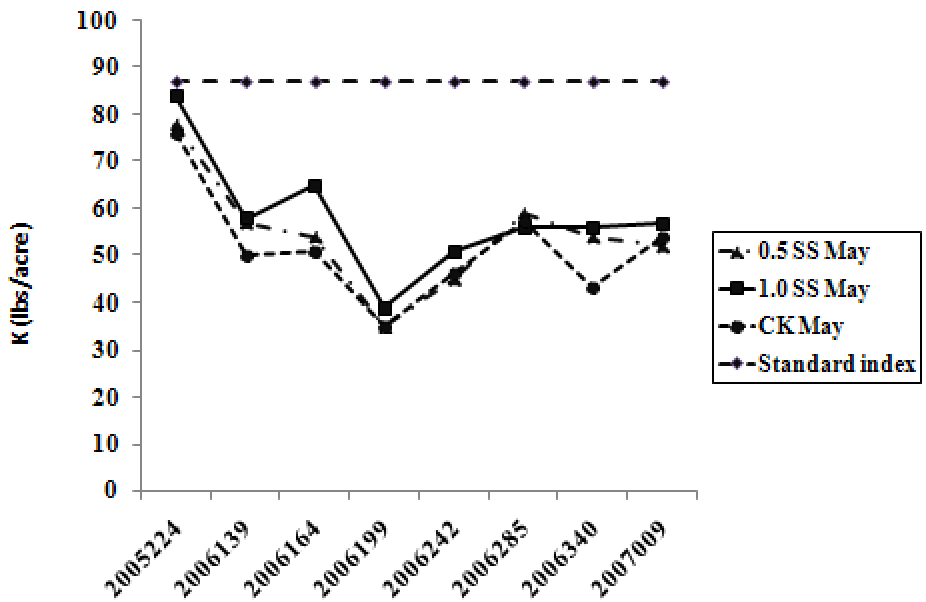

Figure 31. Potassium concentrations for Sandhills plots established in May, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, May 2005, plays a significant role in the change in potassium levels in the soil (P=0.0003). There is a significant increase over time in the potassium concentration found in soil in plots treated with inorganic fertilizer (P=0.0075). There is also a significant decrease over time in the potassium concentration found in soil in plots treated with both 0.05% SuperSoil (P=0.0037) and 1% SuperSoil (P=0.0049). Despite the changes in potassium concentration over time in all the treatments, there is no significant difference overall between the treatments.

SEPTEMBER

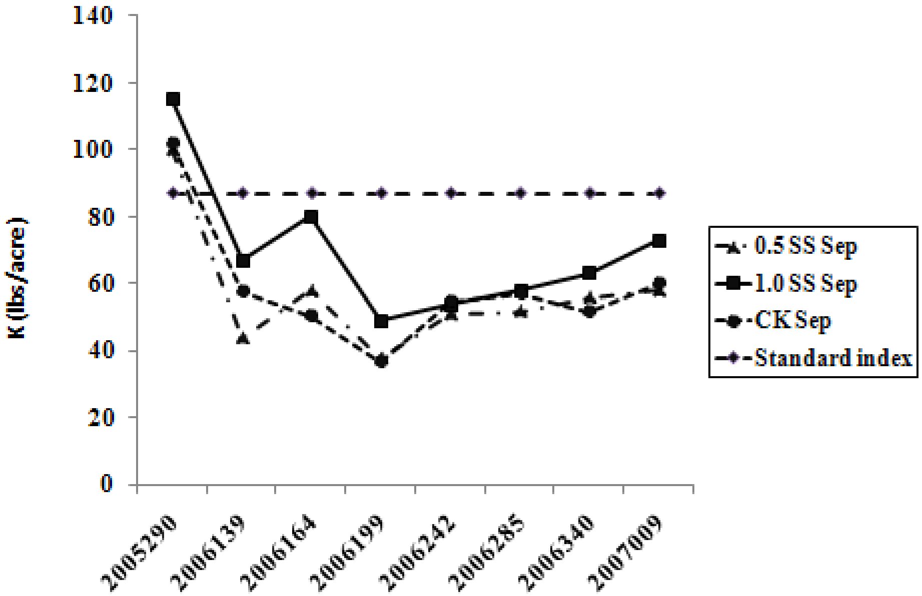

Figure 32. Potassium concentrations for Sandhills plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, September 2005, plays a significant role in the change in potassium levels in the soil ($P<0.0001$). Although there is no significant difference between the three treatments, there is a significant decrease over time in the potassium concentration found in soil in plots treated with 0.5% SuperSoil ($P=0.0001$), 1% SuperSoil ($P=0.0014$) and plots treated with inorganic fertilizer ($P=0.0002$).

OCTOBER

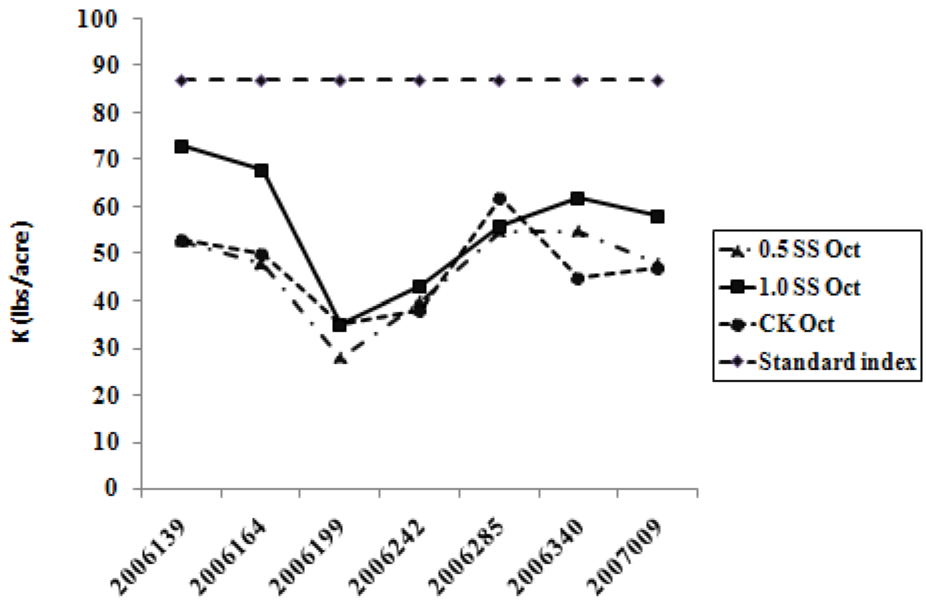

Figure 33. Potassium concentrations for Sandhills plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in October, 2005, nor is there a significant difference between the three treatments.

NOVEMBER

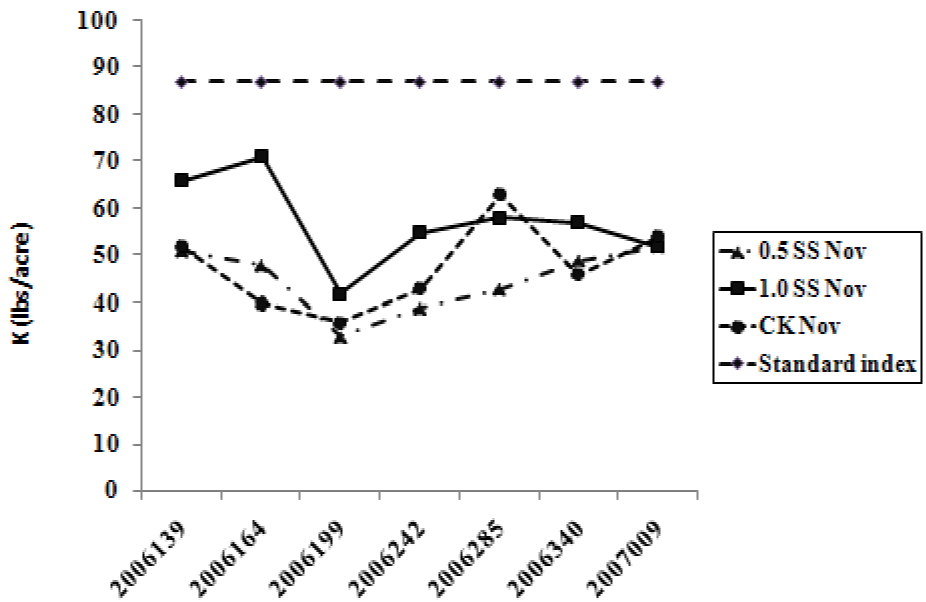

Figure 34. Potassium concentrations for Sandhills plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in November, 2005, nor is there a significant difference between the three treatments.

Sandhills Conclusions

When examined over all the establishment months, there is a significant increase in the potassium concentration in plots treated with 1% SuperSoil, at the Sandhills. Over all the establishment months, plots treated with 1% SuperSoil also showed significantly higher potassium concentrations than the other two treatments ($P<0.01$).

Lake Wheeler

Overall, there was no significant difference in the potassium concentration due to establishment date in Lake Wheeler plots. March, May, September and October plots were not significantly different in potassium concentrations; however these plots were significantly different from the potassium concentration in November plots. Even though there is no overall significant effect due to the date of establishment, it is still useful to look at treatments within an establishment month.

MARCH

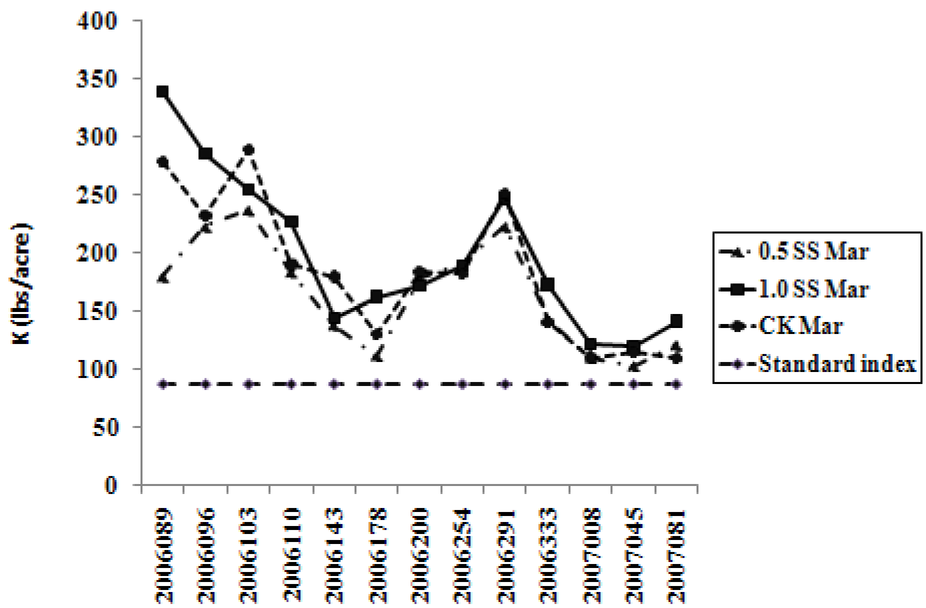

Figure 35. Potassium concentrations for Lake Wheeler plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, March 2006, plays a significant role in the change in potassium levels in the soil ($P<0.0001$). There is a significant decrease over time in the potassium concentration in plots treated with 0.05% SuperSoil (P=0.0036), 1% SuperSoil (P<0.0001) and plots treated with inorganic fertilizer (P<0.0001). Overall, the 1% SuperSoil treatment is significantly different from the 0.5% SuperSoil treatment (P<0.01). The inorganic fertilizer is not significantly different from either the 1% or the 0.5% SuperSoil treatments.

APRIL

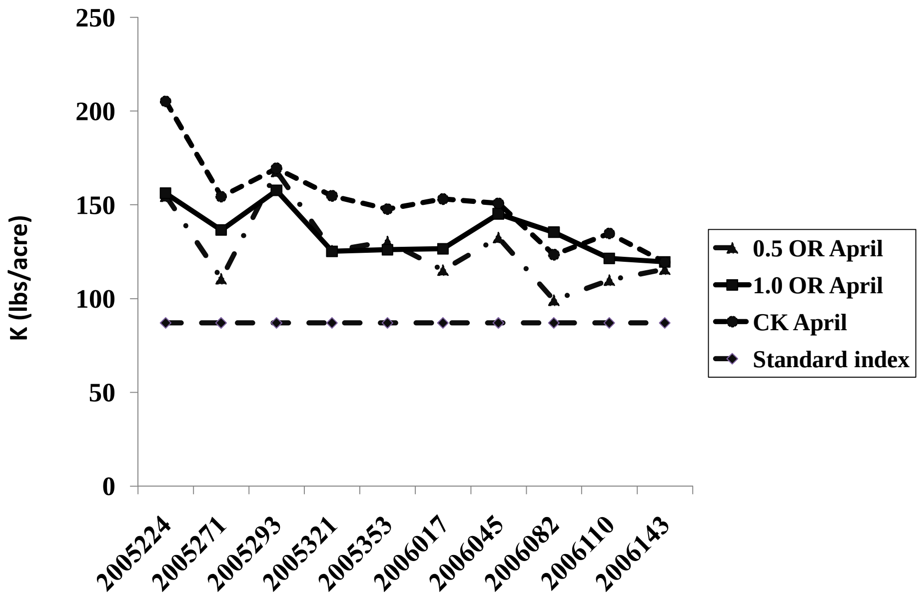

Figure 36. Potassium concentrations for Lake Wheeler plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The plots treated with 0.5% Orbit show a significant decrease in potassium concentration, while the plots treated with 1% Orbit show a significant increase in potassium concentration (P<0.01). There is no significant change in the potassium concentration in the plots treated with inorganic fertilizer. None of the treatments are significantly different from each other overall.

MAY

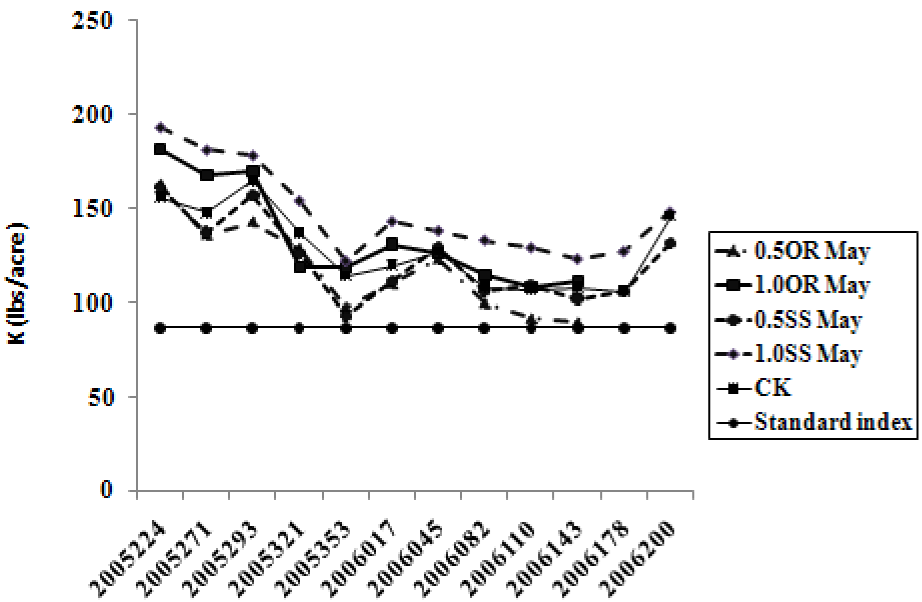

Figure 37. Potassium concentrations for Lake Wheeler plots established in May, 2005. The treatment legend indicates the amount of Orbit (OR) or SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

Over time, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in May, 2005. There is also no significant difference between the three treatments.

SEPTEMBER

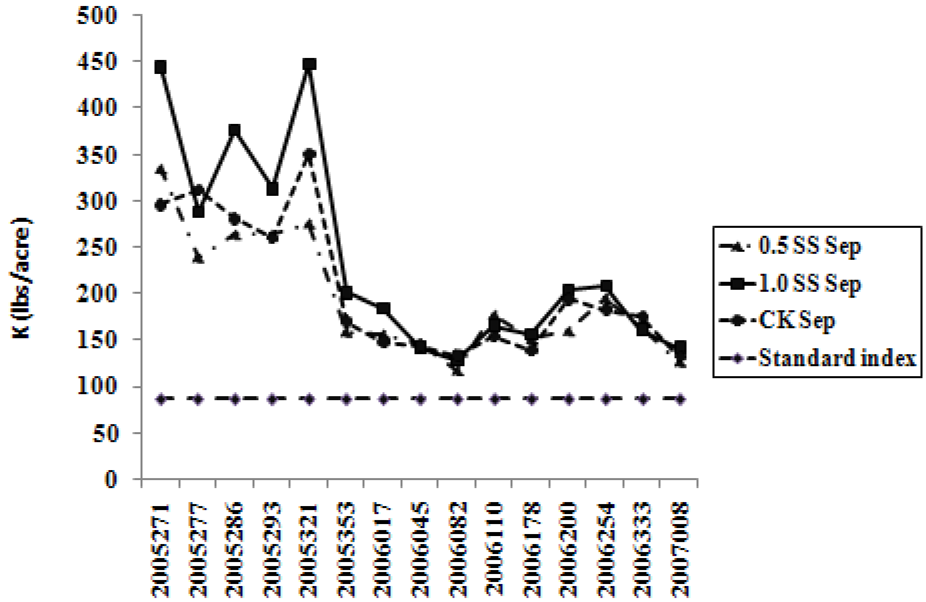

Figure 38. Potassium concentrations for Lake Wheeler plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, September 2005, plays a significant role in the change in potassium levels in the soil ($P<0.0001$). There is a significant change over time in the potassium concentration found in soil in plots treated with 0.5% SuperSoil ($P<0.0001$), 1% SuperSoil ($P<0.0001$) and plots treated with inorganic fertilizer ($P<0.0001$). However, there is no significant difference between the three treatments.

OCTOBER

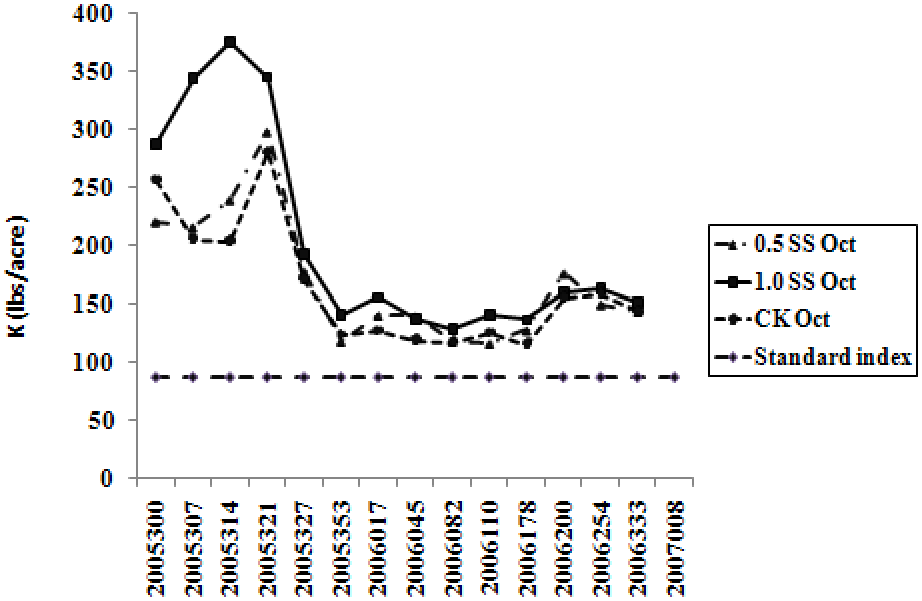

Figure 39. Potassium concentrations for Lake Wheeler plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, October 2005, plays a significant role in the change in potassium levels in the soil ($P<0.0001$). There is a significant change over time in the potassium concentration found in soil in plots treated with 0.5% SuperSoil ($P<0.0001$), 1% SuperSoil ($P<0.0001$) and plots treated with inorganic fertilizer ($P<0.0001$). However, there is no significant difference between the three treatments.

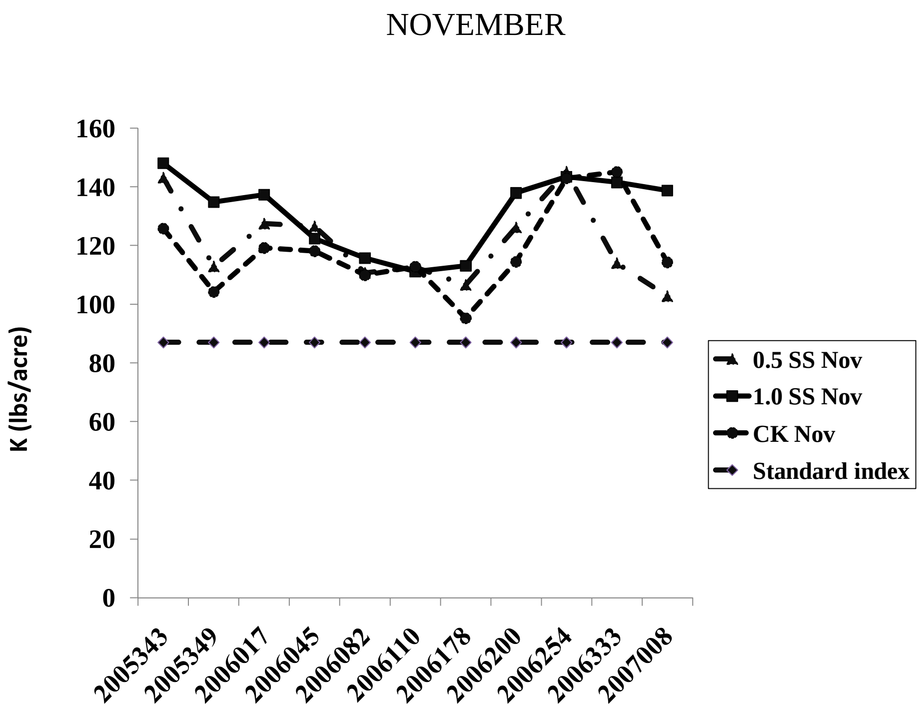

Figure 40. Potassium concentrations for Lake Wheeler plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in November, 2005. There is also no significant difference between the three treatments.

Lake Wheeler Conclusions

When examining the potassium concentration over all of the establishment dates, there is a significant increase in plots treated with 1% SuperSoil. Over all the establishment months, plots treated with 1% SuperSoil also showed significantly higher potassium concentrations than the other two treatments ($P<0.01$).

Fletcher

Overall there was a significant difference in potassium concentrations due to date of establishment. All plots were slightly significantly different in potassium concentrations from each other, except for November and October plots, which did not vary from each other and were also similar to May and September plots, which were significantly different from each other. Therefore, it is important to look at the treatment effect within an establishment month in order to analyze the treatment effect.

MARCH

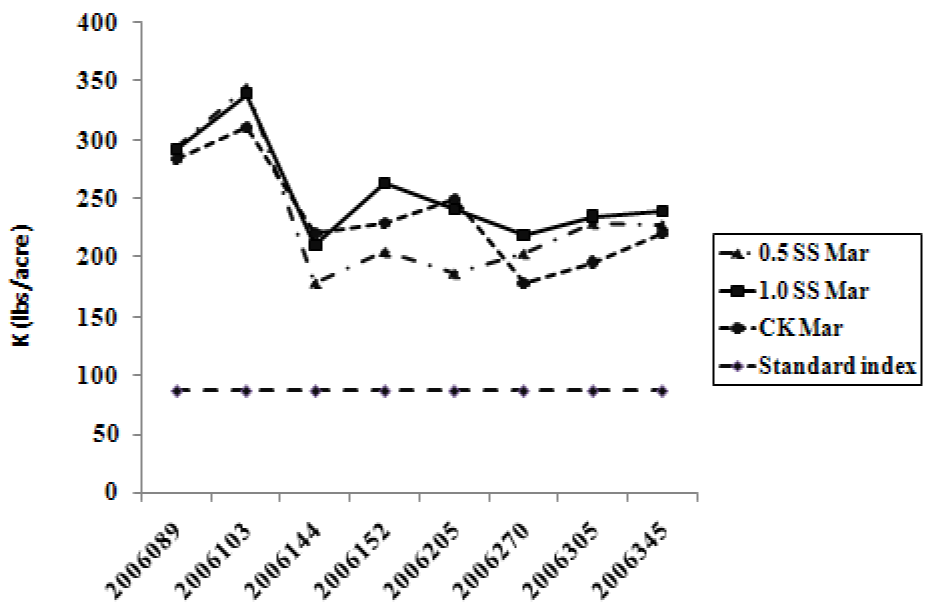

Figure 41. Potassium concentrations for Fletcher plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

Over time, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in March, 2006. There is also no significant difference between the three treatments.

APRIL

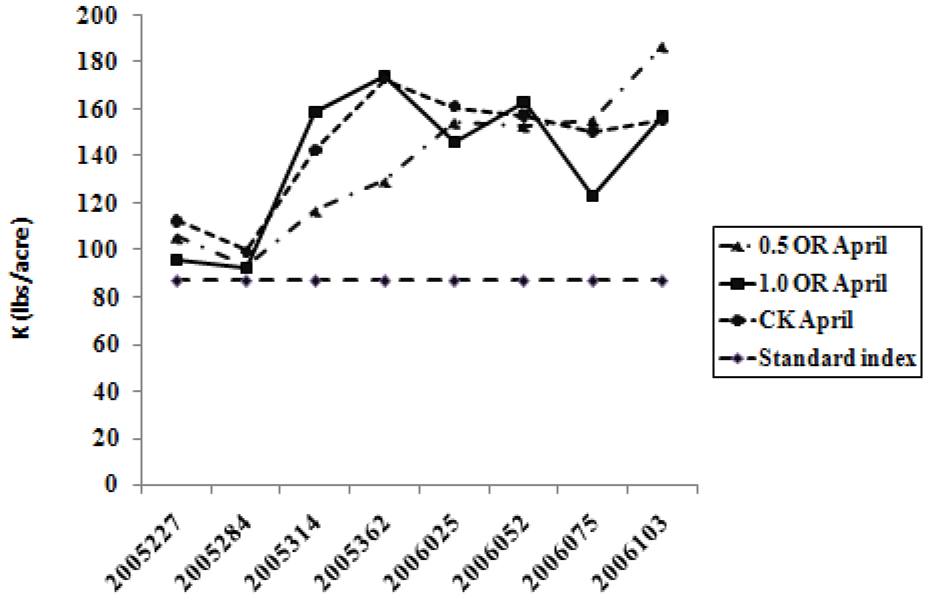

Figure 42. Potassium concentrations for Fletcher plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

There is a significant ($P<0.01$) increase in all three treatments over the course of the study. However, there is no significant difference between the treatments.

MAY

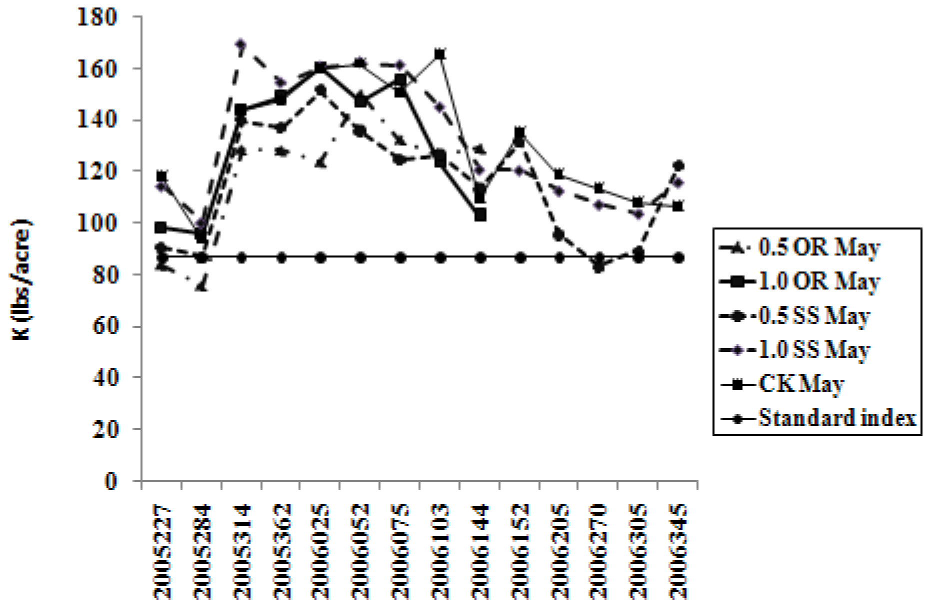

Figure 43. Potassium concentrations for Fletcher plots established in May, 2005. The treatment legend indicates the amount of Orbit (OR) or SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in May, 2005. There is also no significant difference between the three treatments.

SEPTEMBER

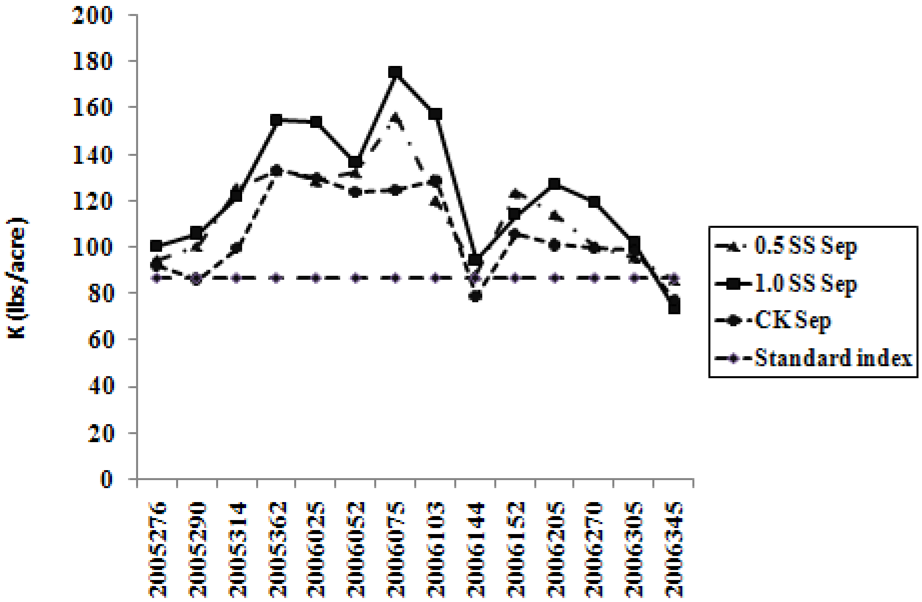

Figure 44. Potassium concentrations for Fletcher plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

Over time, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in September, 2005. Overall, there is no significant difference between the three treatments.

OCTOBER

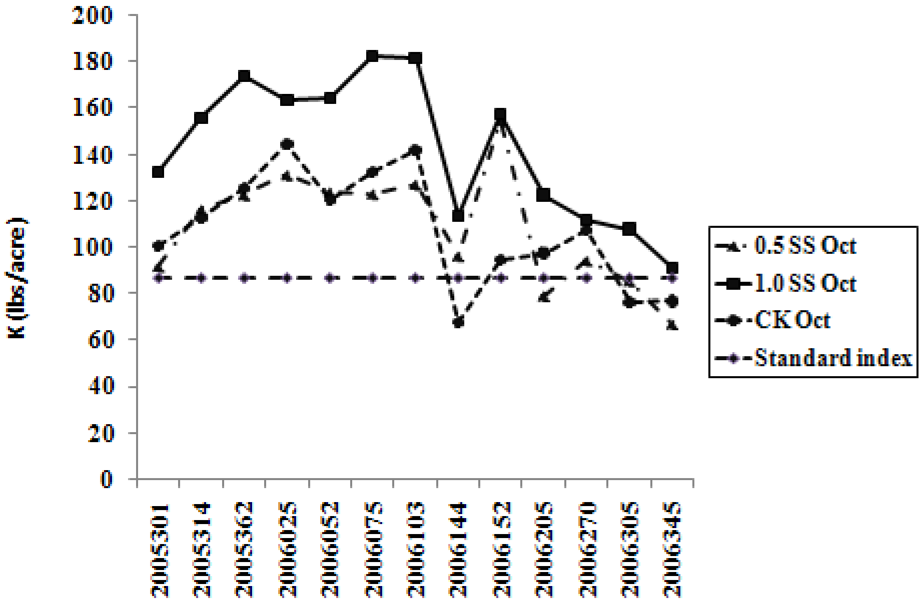

Figure 45. Potassium concentrations for Fletcher plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, October 2005, plays a significant role in the change in potassium levels in the soil ($P=0.0007$). Over time, there is no significant change in the potassium concentration found in the soil, irrespective of treatment, in plots planted in October, 2005. However, the potassium concentration in plots treated with 1% SuperSoil is significantly higher than the other two treatments ($P<0.01$), which are not significantly different from each other.

NOVEMBER

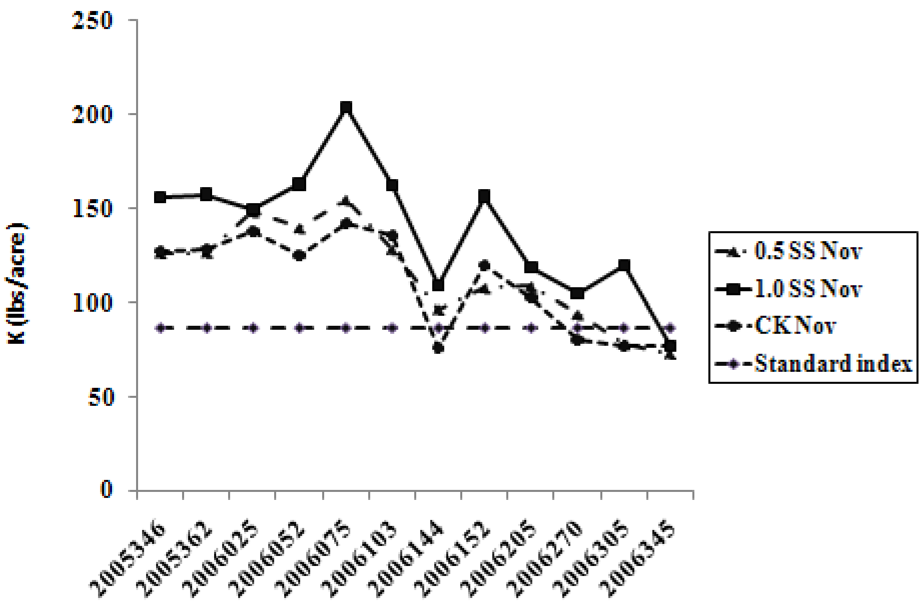

Figure 46. Potassium concentrations for Fletcher plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. Potassium concentrations are compared to the NCDA suggested potassium index. The Julian date for each collection period is shown on the x-axis.

The date of establishment, November 2005, plays a significant role in the change in potassium levels in the soil ($P<0.0001$). There is a significant decrease over time in the potassium concentration found in soil in plots treated with 0.5% SuperSoil ($P=0.0002$), 1% SuperSoil ($P<0.0001$) and plots treated with inorganic fertilizer ($P=0.0006$). However, there is no significant difference between the three treatments.

Fletcher Conclusions

When examining the potassium concentration over all of the establishment dates there is no significant fertilizer effect on potassium amounts at Fletcher. Over all the establishment months, there was no significant difference in potassium concentrations in any of the treatments.

pH

Castle Hayne

Overall there is a significant effect on the pH amount in the soil depending on which month the plot was established. There is a highly significant change in the pH due to date of establishment in bahiagrass plots planted in March (p=0.0083) and September (p=0.0051). Additionally, plots established in October are significantly higher in pH than plots established in May, September and November, which are not statistically significant from each other (p<0.01). In bermudagrass plots, March (p<0.0001), September (p=0.0051) and November (p<0.0001) establishment dates have a significant effect on pH. None of the bermudagrass plots show significant differences in pH. Therefore it is important to look at the treatment effect within an establishment month in order to analyze the treatment effect.

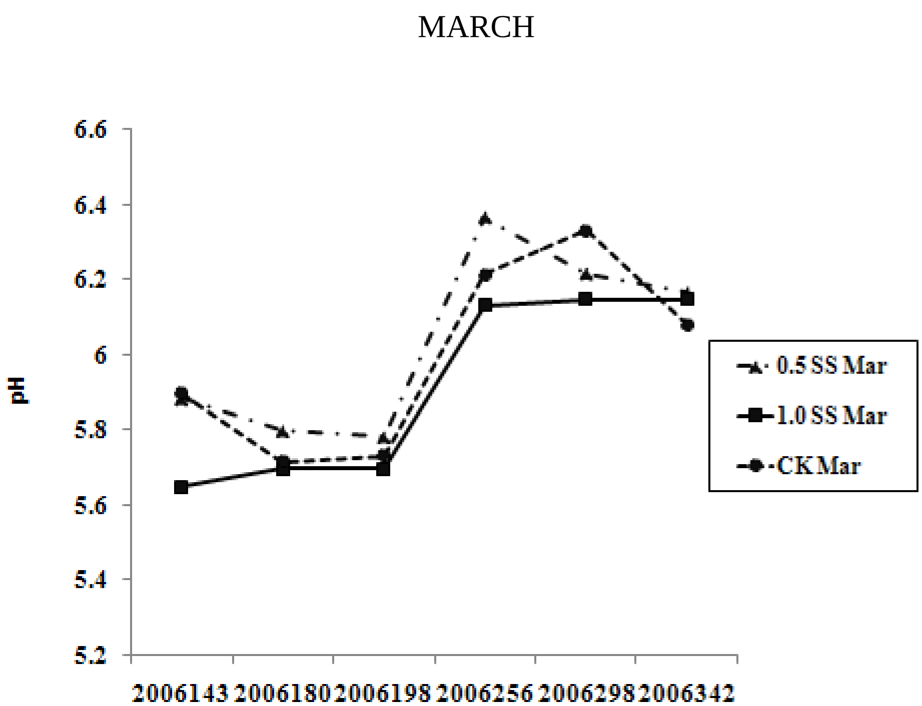

Figure 47. pH of soil at Castle Hayne plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, in bahiagrass plots, the inorganic fertilizer showed a significant increase in pH ($p=0.004$), however neither of the SuperSoil treatments showed a significant change over time, due to a higher pH at establishment than the inorganic fertilizer plots. However, apart from the initial establishment date, there was no significant difference between the three treatments in bahiagrass plots.

Similar to the bahiagrass plots, the bermudagrass plots only showed a significant change in pH in the plots treated with the inorganic fertilizer ($p<0.0001$). There was also no overall difference between the three treatments in bermudagrass plots.

MAY

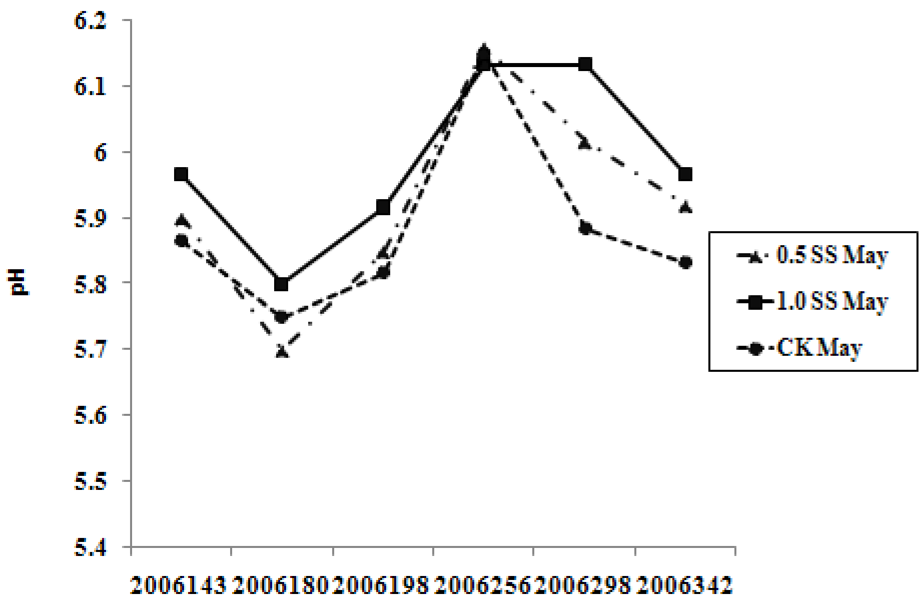

Figure 48. pH of soil at Castle Hayne plots established in May, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

In both bermudagrass and bahiagrass plots, there is no significant change in pH over the course of the study (p>0.01). The three treatments are also not statistically different from each other (p>0.01).

SEPTEMBER

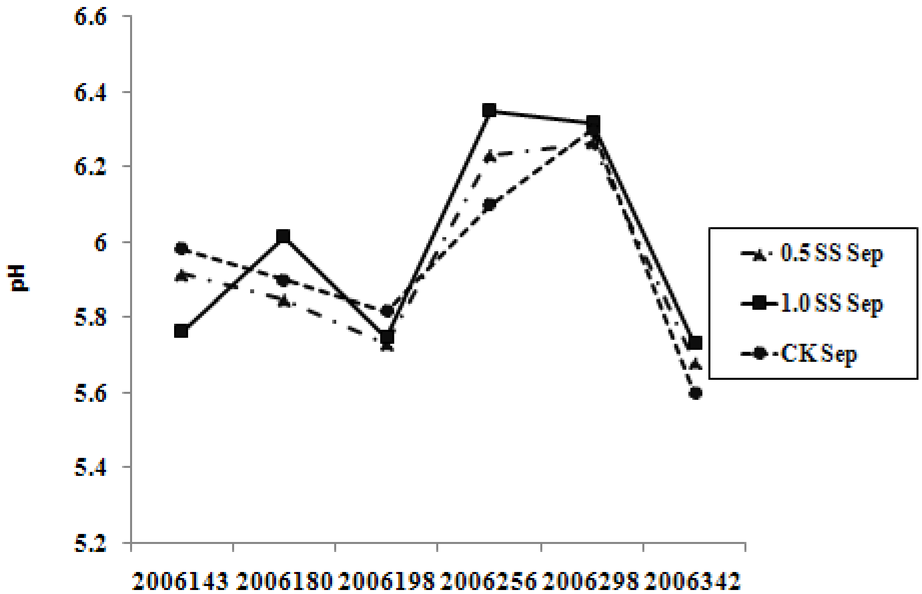

Figure 49. pH of soil at Castle Hayne plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

In both bermudagrass and bahiagrass plots, there is no significant change in pH over the course of the study (p>0.01). The three treatments are also not statistically different from each other (p>0.01).

OCTOBER

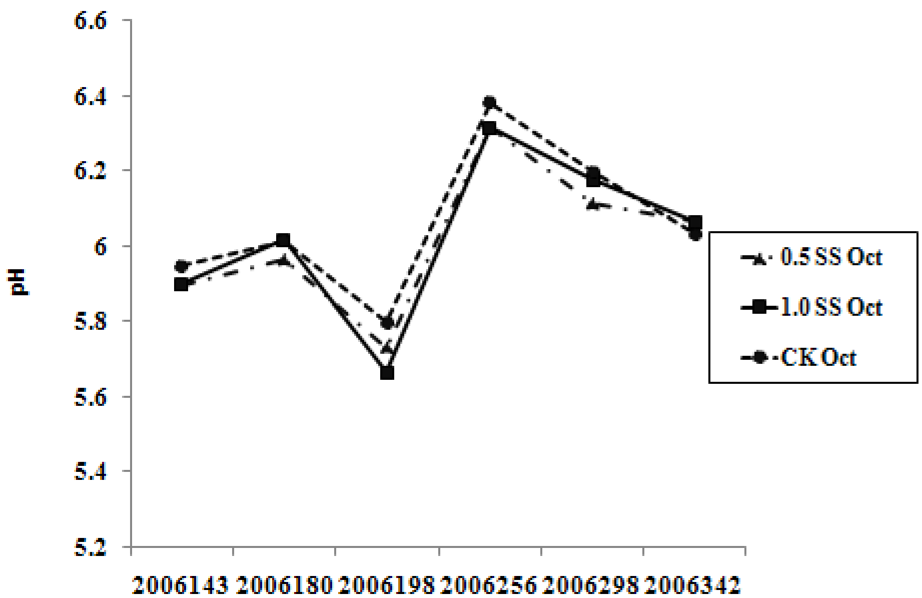

Figure 50. pH of soil at Castle Hayne plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

In both bermudagrass and bahiagrass plots, there is no significant change in pH over the course of the study ($p>0.01$). The three treatments are also not statistically different from each other ($p>0.01$).

NOVEMBER

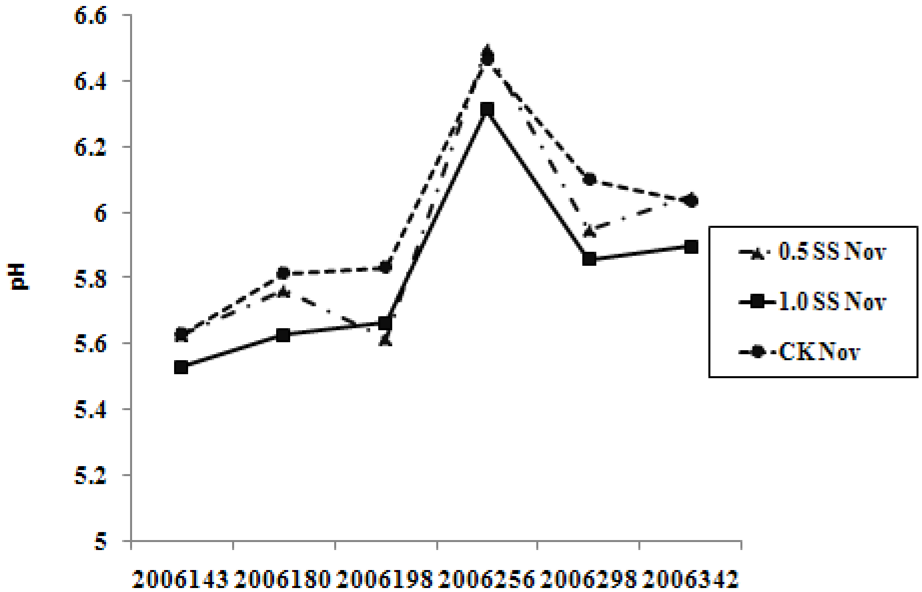

Figure 51. pH of soil at Castle Hayne plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

In bahiagrass plots, there is no significant change in pH over the course of the study ($p>0.01$). However, the 1% SuperSoil treatment has a significantly higher pH than the inorganic fertilizer treatment ($p>0.01$), throughout the course of the study. In bermudagrass plots, there is a significant change in the pH of all three treatments ($p<0.0001$). But, none of the treatments are statistically different from each other ($p>0.01$).

Castle Hayne Conclusions

When examined over all the establishment dates, there is no significant difference between any of the treatment within either of the bermudagrass and bahiagrass plots. However, there is a significant increase in pH for all the treatments over the course of the study. This increase in pH is not statistically different from any of the treatments.

Therefore the pH for plots treated with SuperSoil is not statistically different from plots treated with inorganic fertilizer.

Sandhills

Overall there is a significant effect on the pH amount in the soil depending on which month the plot was established. There is a highly significant change in pH due to date of establishment in planted in May (p<0.0001) and September (p<0.0001), October (p<0.0001) and November (p<0.0001). The pH in March plots is significantly higher than the pH in plots established in May, September and October. Therefore it is important to look at the treatment effect within an establishment month in order to analyze the treatment effect.

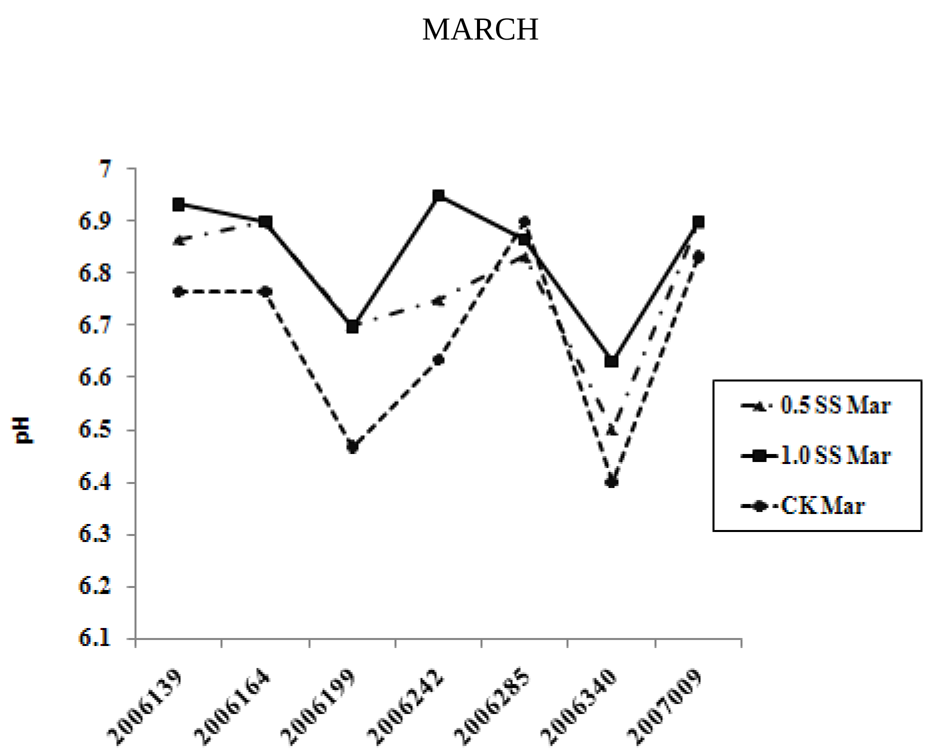

Figure 52. pH of soil at Sandhills plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the pH in any of the treatments for plots established in March, 2006 ($p>0.01$). Additionally, there is no significant difference between the treatments ($p>0.01$).

APRIL

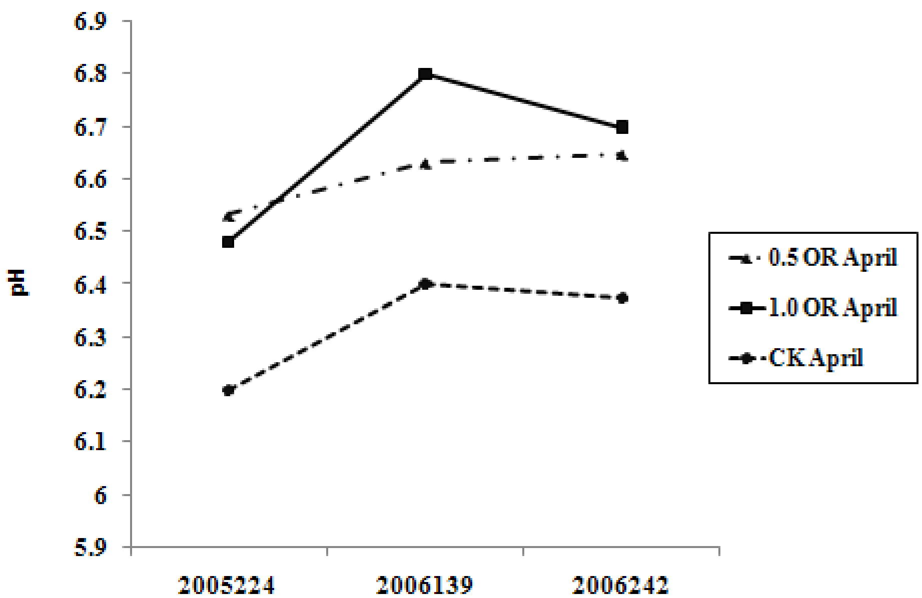

Figure 53. pH of soil at Sandhills plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

The pH in the plots for both Orbit treatments is significantly higher than the pH in the plots treated with the inorganic fertilizer. Although there is a slight decrease in pH over the course of the study, it is not statistically significant.

MAY

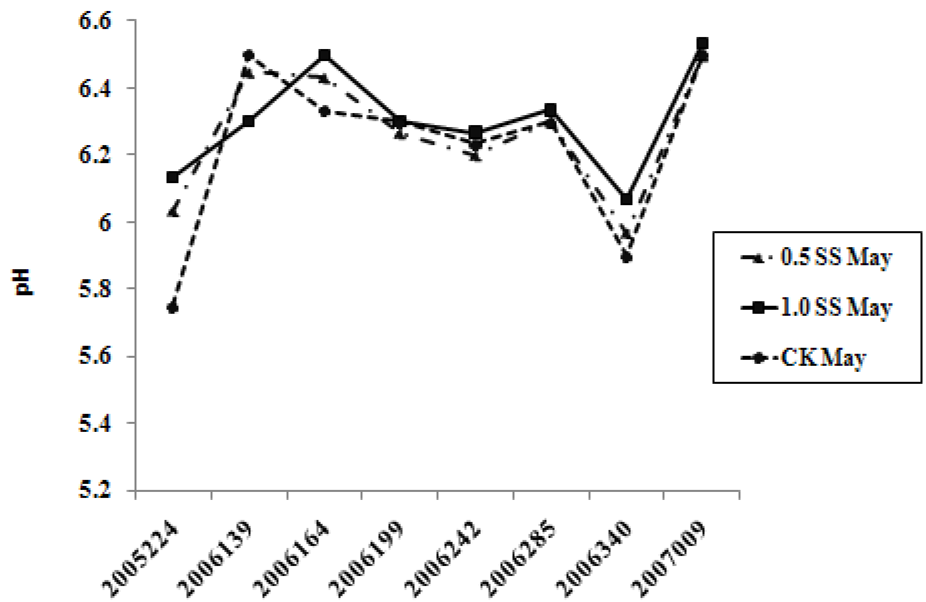

Figure 54. pH of soil at Sandhills plots established in May, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

All of the treatments had significant changes in pH over the course of the study ($p<0.0001$). Both of the SuperSoil treatments show a significant increase in pH, although the increase occurs in the last two months of the study. Overall the pH in the plots treated with the inorganic fertilizer decreased in pH, despite a spike in pH in the second to last month. Despite these changes, overall the three treatments are not significantly different from each other.

SEPTEMBER

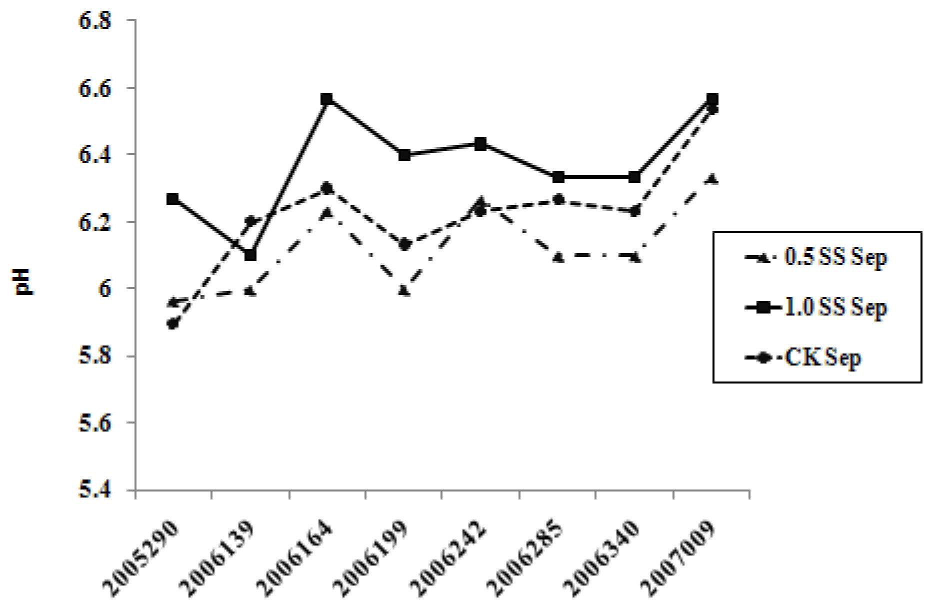

Figure 55. pH of soil at Sandhills plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Plots treated with both the inorganic fertilizer ($p<0.0001$) and 0.5% SuperSoil ($p=0.0082$) significantly increased in pH over the course of the study. However, there was no significant change in pH for the 1% SuperSoil treatment, due to a higher pH at establishment. Despite the changes in pH, there is overall no significant difference between the treatments.

OCTOBER

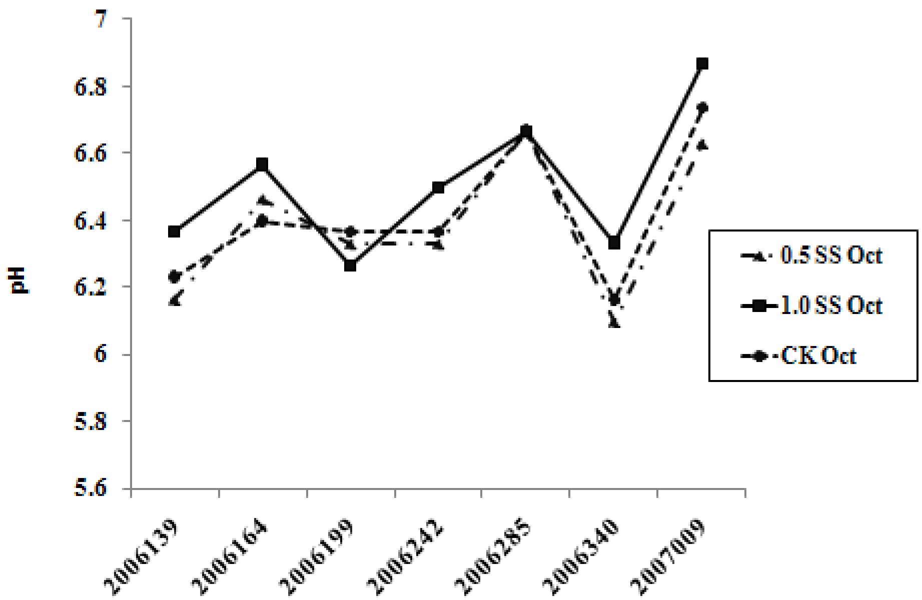

Figure 56. pH of soil at Sandhills plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

All three treatments increased significantly over the course of the study ($p<0.0008$).

However, the pH in the plots of the three treatments is not significantly different.

NOVEMBER

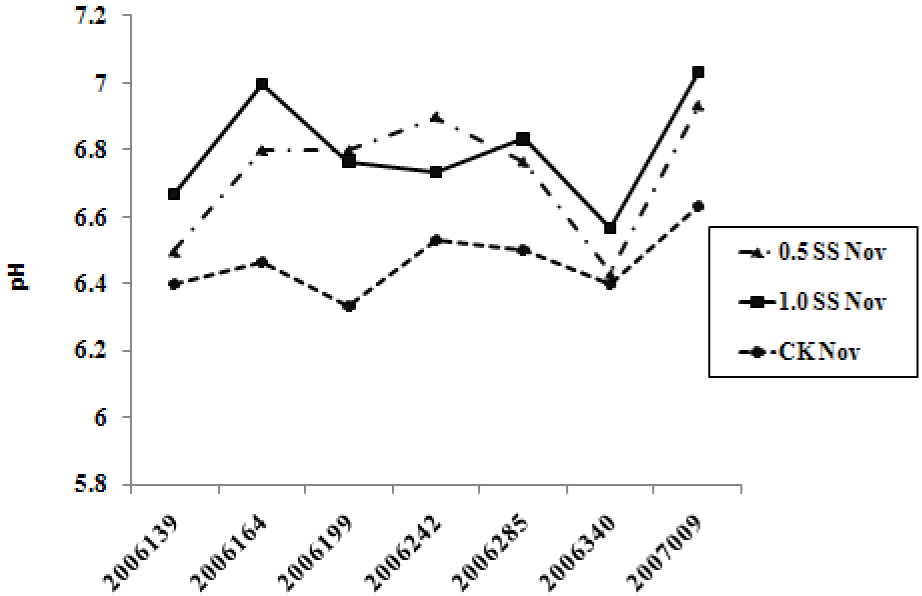

Figure 57. pH of soil at Sandhills plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Plots treated with both SuperSoil treatments ($p<0.0082$) significantly increased in pH over the course of the study. However, there was no significant change in pH in the plots treated with the inorganic fertilizer. Additionally, the plots treated with 1% SuperSoil have a significantly higher pH than the plots treated with the inorganic fertilizer ($p<0.01$). However, the pH in the plots treated with 0.5% SuperSoil is not significantly different from either of the other treatments.

Sandhills Conclusions

When examined over all the establishment dates, the pH in plots treated with 1% SuperSoil is significantly higher than the pH in plots treated with either the 0.5% SuperSoil or the inorganic fertilizer. There is a significant increase in pH for all the treatments over the course of the study.

Lake Wheeler

Overall, there is a significant effect on the pH amount in the soil depending on which month the plot was established. There is a highly significant change on the level of pH due to date of establishment in plots planted in March ($p<0.0001$), September ($p<0.0001$), and October ($p<0.0001$). Plots established in November, 2005 have a significantly higher pH than the plots established in any other month. Therefore it is important to look at the treatment effect within an establishment month in order to analyze the treatment effect.

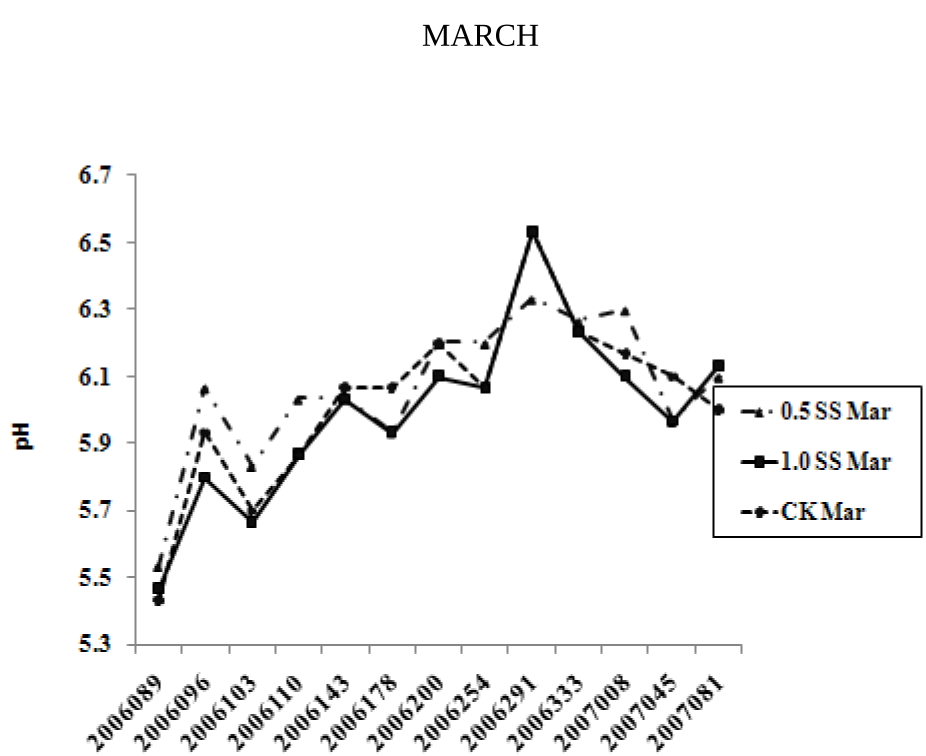

Figure 58. pH of soil at Lake Wheeler plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

All three treatments increased significantly over the course of the study ($p<0.0001$). However, the pH in the plots of the three treatments is not significantly different.

APRIL

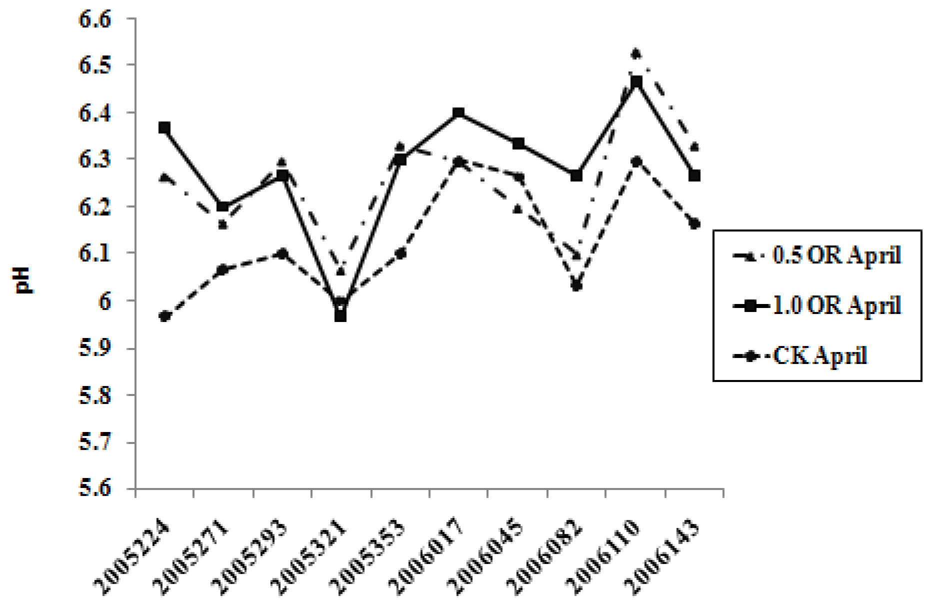

Figure 59. pH of soil at Lake Wheeler plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the pH in any of the treatments. Additionally, there is no significant difference between the treatments ($p>0.01$).

MAY

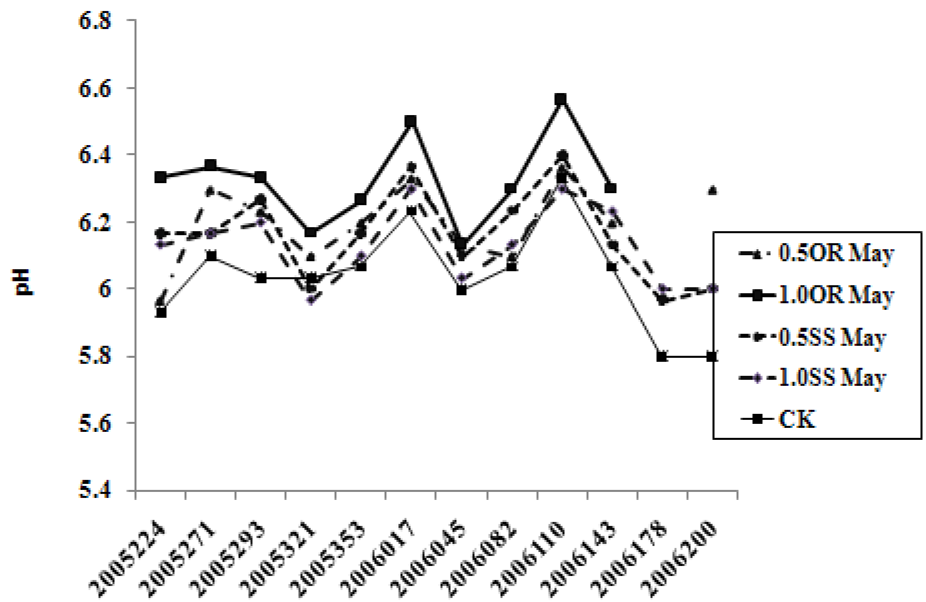

Figure 60. pH of soil at Lake Wheeler plots established in May, 2005. The treatment legend indicates the amount of Orbit (OR) or SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the pH in any of the treatments for plots established in May, 2005 (p>0.01). Additionally, there is no significant difference between the treatments (p>0.01).

SEPTEMBER

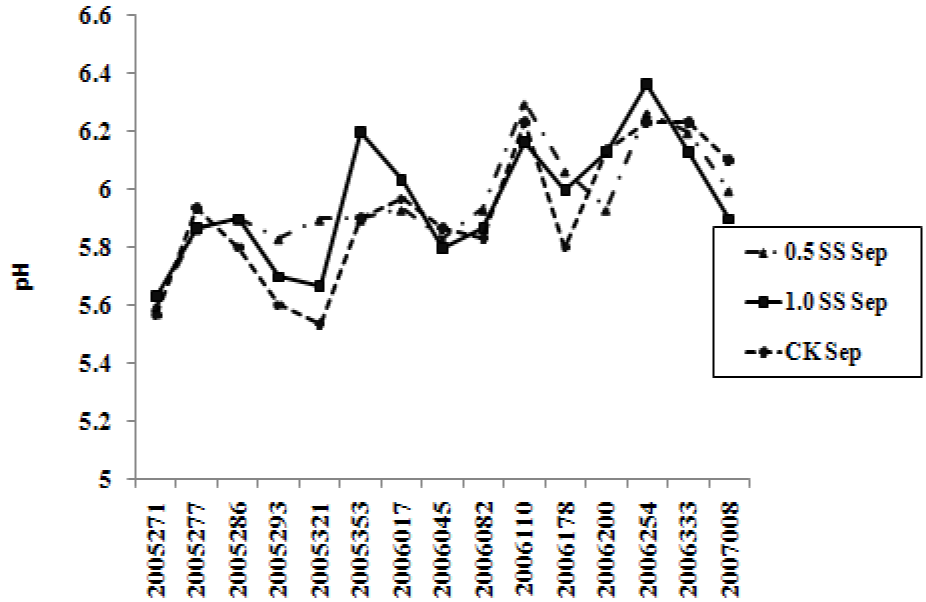

Figure 61. pH of soil at Lake Wheeler plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

There is a significant increase in the pH for plots treated with the inorganic fertilizer (p=0.001), however the pH in plots of either of the SuperSoil treatments did not significantly change over the course of the study. Despite the change in the pH in inorganic fertilizer treated plots, the pH in the plots of the three treatments is not significantly different.

OCTOBER

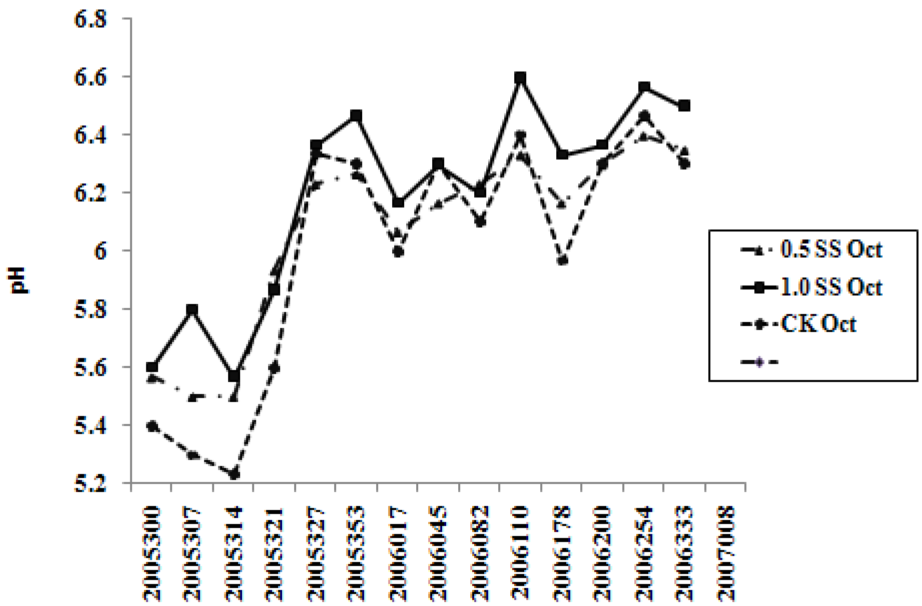

Figure 62. pH of soil at Lake Wheeler plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

All three treatments increased significantly over the course of the study ($p<0.0001$).

However, the pH in the plots of the three treatments is not significantly different.

NOVEMBER

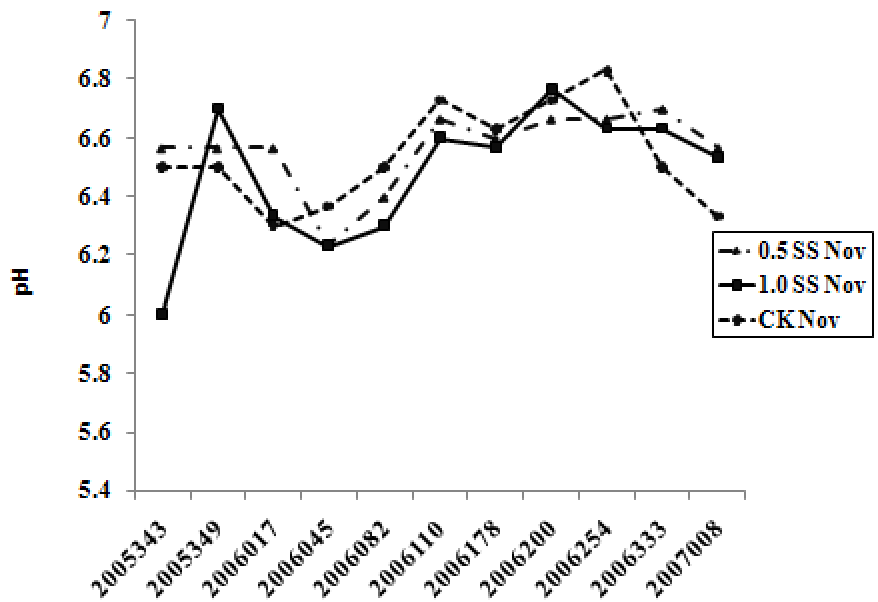

Figure 63. pH of soil at Lake Wheeler plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the pH in any of the treatments for plots established in November, 2005 ($p>0.01$). Additionally, there is no significant difference between the treatments ($p>0.01$).

Lake Wheeler Conclusions

When examined over all the establishment dates, there is no significant difference between any of the treatment. However, there is a significant increase in pH for all the treatments over the course of the study. This increase in pH is not statistically different from any of the treatments. Therefore the pH for plots treated with SuperSoil is not statistically different from plots treated with inorganic fertilizer.

Fletcher

Overall there is a significant effect on the pH amount in the soil depending on which month the plot was established. There is a highly significant change in pH due to date of establishment in plots planted in September ($p<0.0001$) and October ($p<0.0001$). However there is no significant difference in the pH between plots with different establishment months. However, it is still useful to look at the treatment effect within an establishment month in order to better analyze the treatment effect.

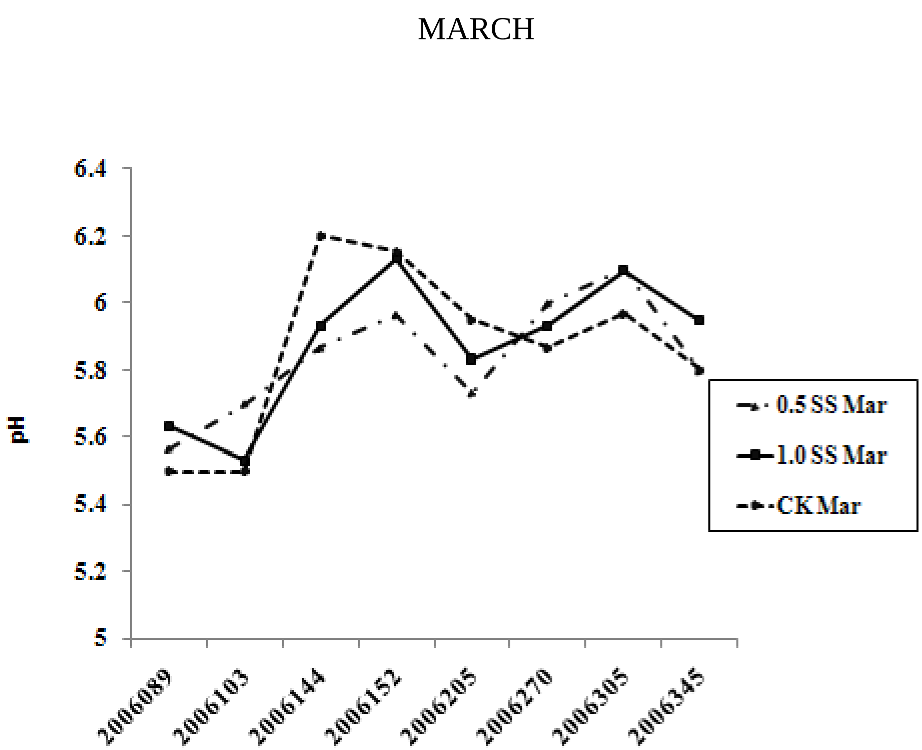

Figure 64. pH of soil at Fletcher plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the pH in any of the treatments for plots established in March, 2006 ($p>0.01$). Additionally, there is no significant difference between the treatments ($p>0.01$).

APRIL

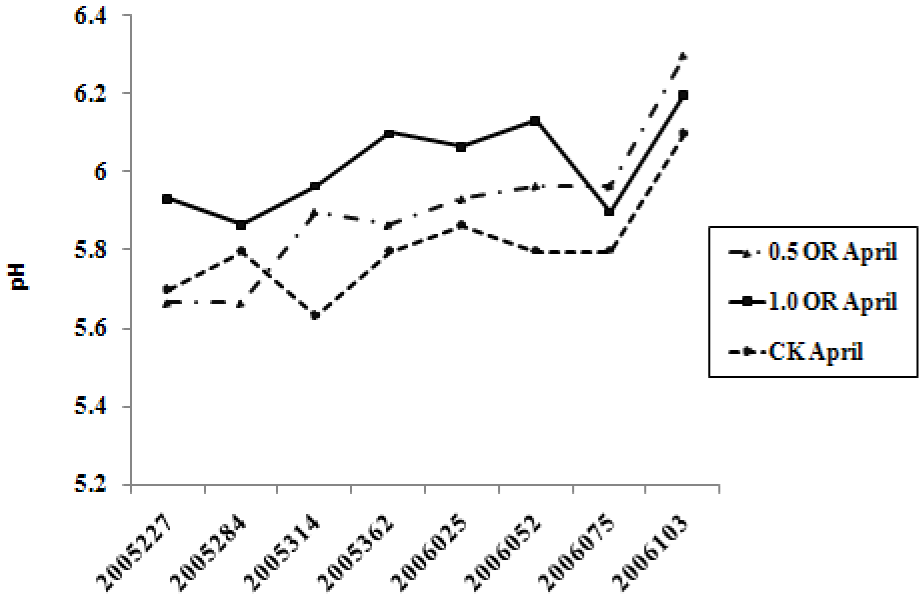

Figure 65. pH of soil at Fletcher plots established in April, 2005. The treatment legend indicates the amount of Orbit (OR) material incorporated on a volume basis either as 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

All three treatments increased significantly over the course of the study ($p<0.01$). However, the pH in the plots of the three treatments is not significantly different.

MAY

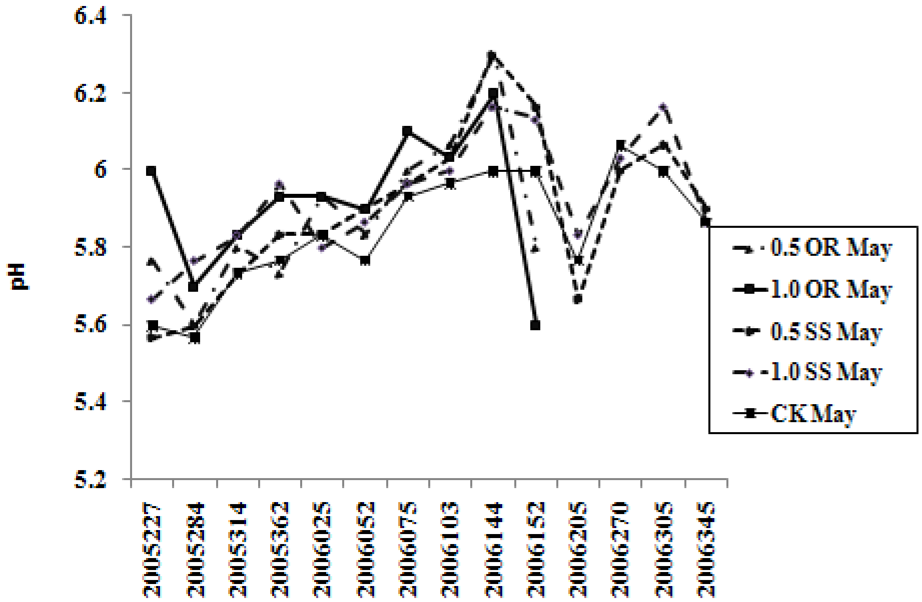

Figure 66. pH of soil at Fletcher plots established in May, 2005. The treatment legend indicates the amount of Orbit (OR) or SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the pH in any of the treatments for plots established in May, 2005 ($p>0.01$). Additionally, there is no significant difference between the treatments ($p>0.01$).

SEPTEMBER

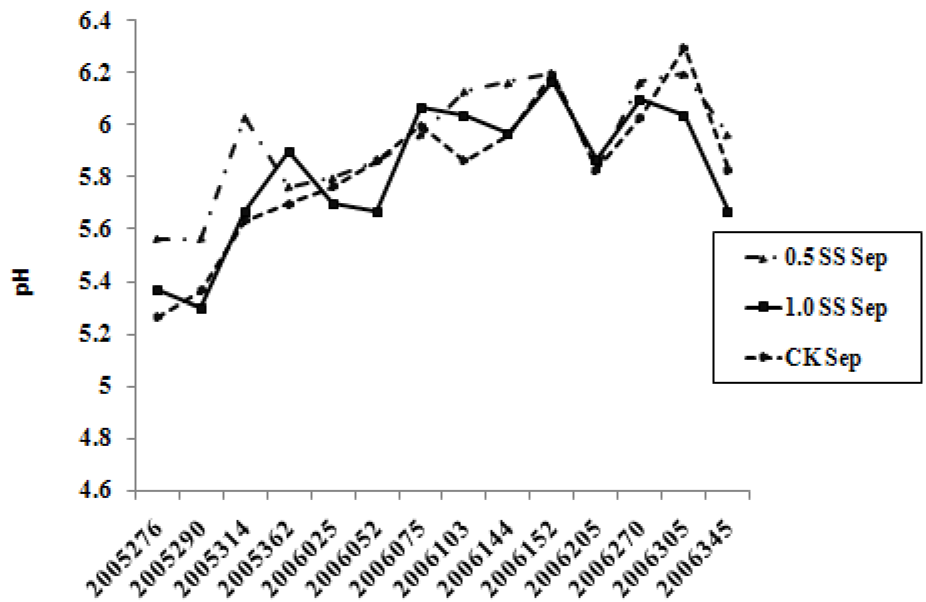

Figure 67. pH of soil at Fletcher plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

The pH in plots treated with 0.5% SuperSoil or the inorganic fertilizer significantly increased over the course of the study. The pH in plots treated with 1% SuperSoil did not significantly change over time due to a higher pH at establishment. Despite the change in pH of the two treatments, there is no significant difference between the treatments ($p>0.01$).

OCTOBER

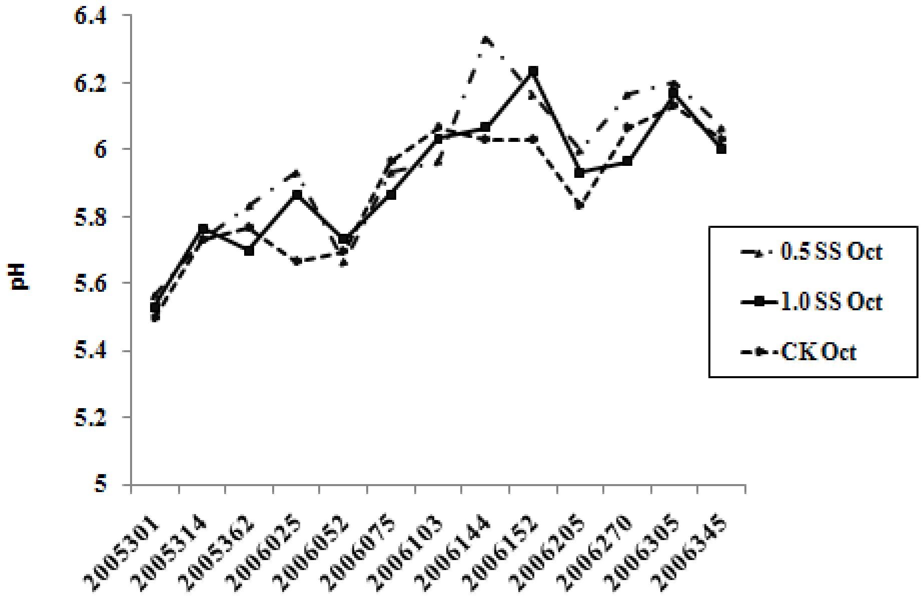

Figure 68. pH of soil at Fletcher plots established in October, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

All three treatments increased significantly over the course of the study ($p<0.0008$).

However, the pH in the plots of the three treatments is not significantly different.

NOVEMBER

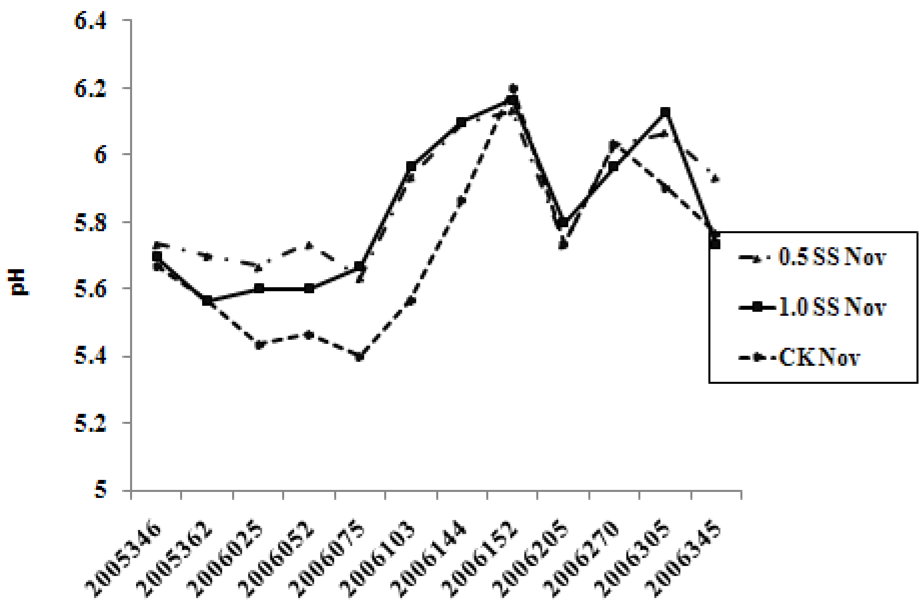

Figure 69. pH of soil at Fletcher plots established in November, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

Over the course of the study, there is no significant change in the pH in any of the treatments for plots established in November, 2005 ($p>0.01$). Additionally, there is no significant difference between the treatments ($p>0.01$).

Fletcher Conclusions

When examined over all the establishment dates, there is no significant difference between any of the treatments. However, there is a significant increase in pH for all the treatments over the course of the study. This increase in pH is not statistically different between any of the treatments. Therefore the pH for plots treated with SuperSoil is not statistically different from plots treated with inorganic fertilizer.

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CHAPTER 2: NUTRIENT RUNOFF FROM ORGANIC AND INORGANIC FERTILIZERS ON TURFGRASS

ABSTRACT

The use of organic fertilizers in a nutrient management program has shown many benefits, such as improved plant growth compared to inorganic materials. However, the use of organic fertilizers in addition to other fertilizers may increase the total nitrogen accumulation and lead to excess nitrogen runoff into ground and surface water. Additionally, since fertilizers are mostly applied based on the nitrogen content, phosphorus can build up at a faster rate than nitrogen, which may lead to phosphorus runoff into surface water. This study looked at both nitrogen and phosphorus concentration in runoff from turfgrass plots where a single fertilizer application was made in order to determine the potential for contamination of surface water. Twenty-four plots were constructed at the Lake Wheeler Turfgrass Field Lab in Raleigh North Carolina specifically to collect surface runoff. Two types of fertilizer were applied to the plots -- an organic fertilizer, SuperSoil (4% N, 0.88% P, 2.5% K) and an inorganic fertilizer (10% N, 8.8% P, 16.6% K), referred to in this study as standard. Additionally, non treated plots were used as a check. Both a linear regression test and an analysis of variance using Least Squared Means found that there was no significant difference in nitrogen or phosphorus concentrations in runoff depending on type of fertilizer and the control. Therefore, this study concludes that there is no greater environmental threat from runoff from organic fertilizers than from inorganic fertilizers or unfertilized areas.

INTRODUCTION

Soil modification with the use of organic materials can often improve physical and chemical conditions in the soil and enhance turfgrass establishment (Chand et al., 2006; Eghball, 2002). The use of bio-solids has been shown to improve plant growth and subsequently decrease soil erosion (Meyer et al., 2004). Therefore, organic fertilizers should produce minimal nutrient loss in runoff. However, due to the use of organic fertilizers in addition to standard fertilizer, the total nitrogen accumulation can be high and therefore nitrogen runoff could be a problem. Additionally, since fertilizers are mostly applied based on the nitrogen content, phosphorus can build up since it is often overlooked when determining fertilizer application rates. This study looks at both nitrogen and phosphorus runoff on turfgrass plots with a single organic fertilizer application in order to determine the potential for contamination of surface water.

Nitrogen

Of the nutrients generally found in commercial fertilizers, nitrogen is often found in the highest concentration since it is generally the limiting agent for plant growth (Easton and Petrovic, 2004; Watschke et al., 2000). Nitrogen is an important fertilizer component, because it aids plant growth, but nitrogen accumulation due to fertilizer application can vary. Nitrate levels were found to decrease rapidly and evenly independent of application rate and bio-solid source – swine effluent or compost suggesting that potential nitrogen runoff from organic fertilizers is slow and steady (Wright et al., 2007). In fact, runoff of NO_3^-N in turf plots may be as low as <1% of applied fertilizer, indicating that only a small percentage of the nitrogen in fertilizers is likely to become an environmental threat (Gross et al., 1990).) The highest concentration of nitrogen loss likely occurs during the first 20 weeks of turf establishment (Easton and Petrovic, 2004). Therefore runoff and potential contamination may only be a problem during establishment due to a higher rate of erosion during that period. While there are several studies that show soil nitrogen accumulation and suggest potential theories for nitrogen runoff, little experimental data pertains directly to nitrogen runoff from rain with respect to organic fertilizer treatments.

Phosphorus

Phosphorus is important for the establishment and rooting of plants and therefore is a key component of both organic and non-organic fertilizers. Logically, fertilizers that contain higher phosphorus levels have a potentially higher rate of phosphorus loss in soils (Easton and Petrovic, 2004). Increases in fertilizer phosphorous do not result in increases in the amount of phosphorus recovered from plant material, indicating that once the levels of phosphorus required for healthy plants are reached the plant does not uptake more phosphorus, even if it is available in the soil. In most soils, phosphorus moves very little, but it may leach into ground water through very sandy or organic soils (Sparks, 1995). Because phosphorus is generally attracted to soil particles, most phosphorus movement occurs when sediment erodes from disturbed soils. Therefore, water-soluble forms of phosphorus will run off into surface water sources, but are not likely to leach into ground water. When phosphorus gets to surface waters, it can cause undesirable algal blooms and abnormal aquatic plant growth (Bush and Austin, 2001). Much of the phosphorus that accumulates in swine lagoons will attach to particles and accumulate in lagoon sludge (Safley et al., 1993). One study showed that when applied to turf, phosphorus is already bound to cations and phosphorus loss over time is minimal. While phosphorus leaching into groundwater has been shown to be minimal, the amount of surface phosphorus runoff from a surface applied organic fertilizer is has not been well documented.

Despite the benefits of increased nutrient availably, and the evidence of nutrient stability in most soil systems, some studies have shown that repeated use of biosolids can lead to excess build up of nutrients in the soil and can lead to leaching and runoff loss (Gross et al., 1990; Vietor et al., 2002). Nutrient loss can be up to five times higher during turf establishment when the surface of the soil is the most exposed (Easton and Petrovic, 2004). Therefore, in order to minimize initial high levels of nutrient runoff, established plots were used to determine the concentrations of NH_4-N, NO_3-N and PO_4-P in runoff that occurs with organic fertilizers, inorganic fertilizers and non-treated plots.

METHODS and MATERIALS

Two types of fertilizer were used in this study, an organic fertilizer, SuperSoil, and an inorganic, 10% N, 8.8% P and 16.6% K fertilizer, referred to in this study as Standard. SuperSoil is composed of swine lagoon sludge composted with cotton gin residues and contains < 5% moisture. This bio-solid has a nutrient composition of 4% N, 0.88% P and 2.5% K. Both fertilizers came ready-to-use and therefore did not undergo any additional treatment prior to turf application.

Twenty-four plots with runoff collection construction located at the Lake Wheeler Turfgrass Field Lab in Raleigh North Carolina were used. The plots were placed on the middle of an incline hill (6 to 10% slope), in order to influence the direction of rain runoff on the plots. A trench was dug around each plot and wooden runners were placed along the vertical edge and the top of the plots in order to focus the rain water down the longitudinal surface of the plot. In the gutter at the soil surface, large galvanized trash cans were placed in holes at the base of each plot and a PVC pipe was inserted which focused the rainwater from the gutter into the trash can. Large plastic buckets were inserted into the trash can under the polyvinyl chloride (PVC) pipe in order to catch the runoff. The lids were placed on the trash can in order to keep out contaminants and direct rain, which risked diluting the runoff.

The plots were established in spring 2005 with a 32% bermudagrass, 63% tall fescue, and 5% centipedegrass mixture seeded at a rate of 9.5g /m^2 and all had a minimum of 90% vegetative cover when fertilization treatments were initiated. One topdressing application of SuperSoil (4-0.88-2.5) and the standard fertilizer (10-8.8-16.6) were applied to designated plots at a rate of 4.8 g N/m^2 in July 2006. An unfertilized treatment served as the control. Each treatment was replicated eight times.

April Plots

CK	STD	SS	CK	STD	SS	CK	STD	SS

May Plots

CK	STD	SS	CK	STD	SS	CK	STD	SS	CK	STD	SS	CK	STD	SS

Diagram 1. Plot plan for study at Lake Wheeler. “April Plots” had been planted in April 2005 and “May Plots” were planted in May 2005. Abbreviations are: Untreated control plots (CK), SuperSoil (SS) and standard fertilizer (STD) treatments.

Data collection occurred weekly after rainfall events for a total of 16 weeks. Long periods of rainfall or increases in soil moisture have been shown to cause loss of nutrients due to runoff (Linde and Watschke, 1997; Easton and Petrovic, 2004). Therefore, data collected included rainfall amounts, total runoff volume, and sub-samples of runoff solution from individual plots.

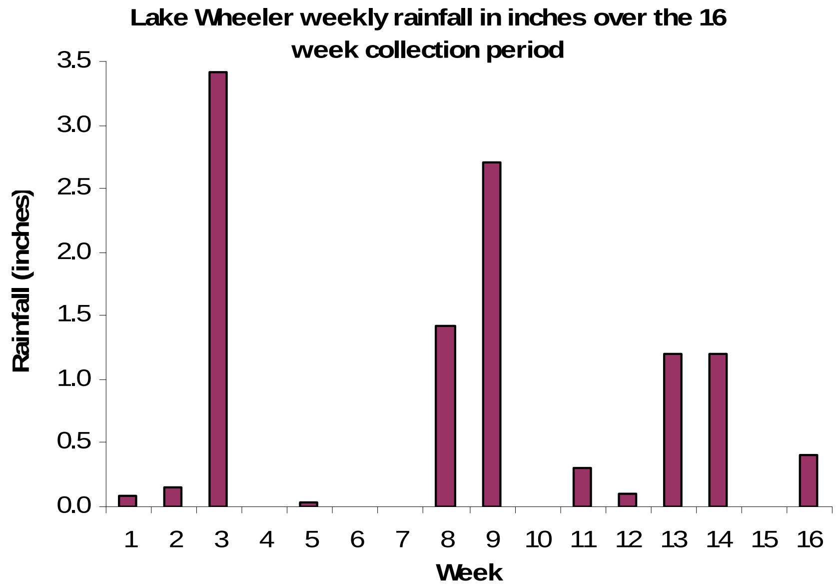

Figure 1. Weekly rainfall for Lake Wheeler Turfgrass Field Lab from July 10-Oct. 30, 2006. Data taken from Lake Wheeler weather station, when available and the adjacent Yates Mill Pond weather station when data was not available for Lake Wheeler.

Runoff samples were analyzed for nitrate, ammonium, and phosphate by the soil analysis lab in the Soil Science department at North Carolina State University. The quantitative data of mg of nutrient per liter of sample was transformed using LSMeans to normalize the data and the subsequent data set was analyzed using ANOVA in SAS to determine if there was a significant difference between treatments at a single time point ($p<0.05$). Linear regression was performed on all data points.

Several complications arose in respect to sample collection. Several times, researchers found that the collection bucket had either overflowed, which made determining how much runoff water was collected difficult, or the bucket had overturned completely. The trashcans that contained the collection buckets were found to leak at times of heavy rainfall, which meant that subsurface water from outside the plot area may have entered the collection bucket. The higher elevation plots were unfertilized, so contamination was minimal. Samples known to be contaminated or for which there was concern about the validity of the content were discarded from the dataset for analysis.

RESULTS and DISCUSSION

Phosphorus

Over the collection period, phosphate concentrations varied depending on the treatment (Figure 2). Overall, the concentration of phosphorus in runoff showed no significant change over time in either of the treatments or in the control. However, both the standard fertilizer and the SuperSoil fertilizer showed slight decreases in overall concentrations of P in the runoff samples. More importantly, neither of the fertilizer treatments showed increased concentration of phosphorus in the runoff samples, indicating that treating with fertilizer does not increase the risk of phosphorus runoff. In fact, the final concentrations of runoff from both fertilizers were significantly lower than the phosphorus concentrations in the unfertilized control. Interestingly, the initial concentrations of phosphorus in the runoff samples was similar for both fertilizers, but the organic SuperSoil maintained a more constant phosphorus level over time, where the inorganic fertilizer phosphorus concentration in runoff decreased over time. This may indicate that the concentration of phosphorus in the soil is maintained at a more constant level with the organic fertilizer than with the inorganic fertilizer due to long-term mineralization. While this information is useful to determine the overall trends in phosphorus runoff from the fertilizers, all three trend lines have low coefficient of determination values (r^2 <0.2), and therefore the data may be better analyzed using analysis of variance using LSMeans in order to take into account some missing values in the data.

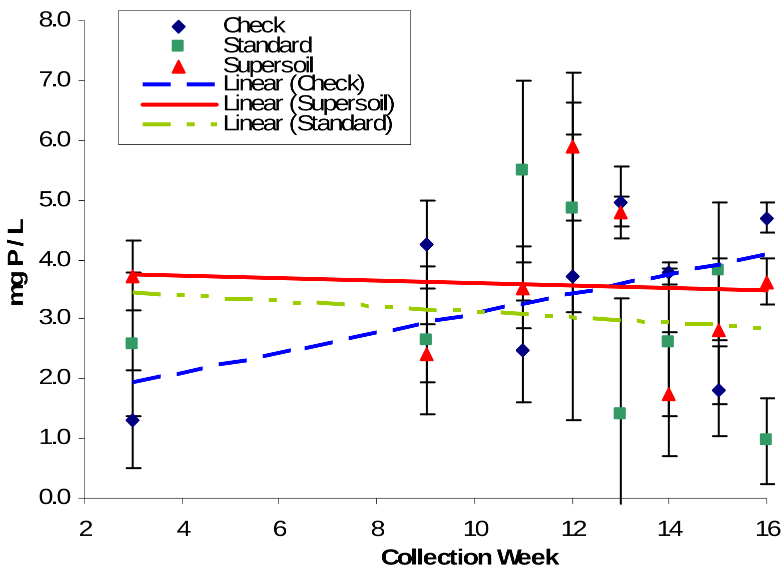

Figure 2. Mean values for PO4-P concentrations. Linear regression, best fit line, for total P concentration of PO_4-P in runoff for all fertilizers treatments. Error bars represent the standard error of the population for each mean. Overall, there is no significant difference between the concentrations of PO_4-P over all treatments.

Due to the skewed normality of the data, the data were analyzed using Least Squared Means in an analysis of variance (ANOVA). The ANOVA results showed the runoff from the organic fertilizer, SuperSoil, was not significantly different from the inorganic fertilizer and neither of the fertilizers showed significantly more phosphorus runoff than the untreated control plots. The similarity between the runoff from the two fertilizers is probably due to the attraction of phosphorus to other particles in the soil, and therefore significant phosphorus runoff is unlikely in cases of minimal erosion. These results support the results of the linear regression and suggest that neither organic nor inorganic fertilizers contribute significantly to increased phosphorus concentrations in rainwater runoff from fertilized turf plots. Therefore, organic fertilizers such as SuperSoil, do not pose a greater environmental threat to surface water than areas not recently treated with fertilizer.

Ammonium-Nitrogen

Both fertilizer treatments and the control showed slight decreases in nitrogen concentration from NH_4-N over the collection period (Figure 3). However, the decreases do not differ significantly from each other. Similar to the results with phosphorus, the organic fertilizer maintained a more constant nitrogen concentration in the runoff during the collection period. This may be due to the slow release properties of nitrogen in organic fertilizers. The r^2 values showed a better relationship between the best fit line and the data than in the phosphorus regression with values of 0.8, 0.3, and 0.2 for standard fertilizer, check and SuperSoil fertilizer respectively. However, it is also useful to analyze the data using ANOVA.

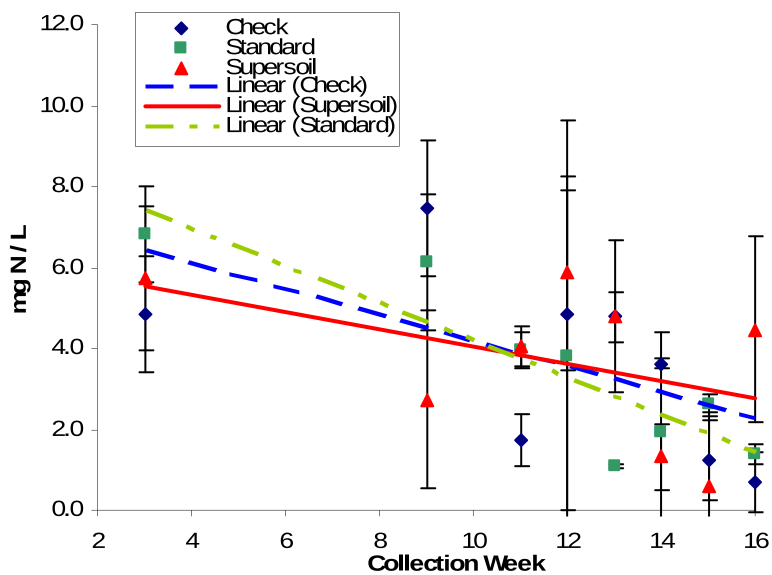

Figure 3. Mean values for NH_4-N concentrations. Linear regression, best fit line, for the total NH_4-N concentration runoff for all fertilizers treatments. Error bars represent the standard error of the population for each mean. Overall, there is no significant difference between the concentrations of NH_4-N over all treatments except on week 13.

When a one-way ANOVA test was run on the data the concentration of NH_4-N in runoff from the control, the organic fertilizer, SuperSoil or the inorganic fertilizer did not differ significantly except on one collection date, week 13 (Oct. 10, 2006). On that particular date, the SuperSoil fertilizer showed significantly higher concentrations of nitrogen than either the standard fertilizer or the control. In fact, the concentration of nitrogen in the SuperSoil from that collection period was the highest recorded from any of the samples, across all collection dates. However, the concentration of nitrogen from the SuperSoil fertilizer on week 13 was not considered an outlier during the ANOVA analysis since it was not outside of the normal range. This high nitrogen data point may be due to contamination of the collected runoff by a high nitrogen source. Therefore it can still be concluded that overall the differences in nitrogen concentrations from NH_4-N did not differ significantly over time for any of the treatments. This is consistent with the results from the linear analysis which showed no significant changes in nitrogen concentrations in the runoff over the collection period.

Overall, nitrogen runoff of NH_4-N also did not vary significantly between the organic fertilizer, SuperSoil, and the inorganic standard fertilizer. Neither of these treatments showed significant difference in concentrations of nitrogen runoff from NH_4-N when compared to non-treated turf plots. Therefore, it can be concluded that the potential of environmental contamination from nitrogen (NH_4-N) from fertilizer treated plots, either using an organic or inorganic fertilizer is the same as the threat of nitrogen runoff from untreated turf plots.

Nitrate-Nitrogen

The trend in nitrogen concentrations in runoff samples was also analyzed from NO_3-N (Figure 4). The trend over time showed slight increases in NO_3-N levels in runoff from both treatment plots and a decrease in nitrate concentrations in the control plots. Similar to the linear regression with phosphate, the coefficient of determination values were also low (r^2<0.14) in nitrates and therefore the data would also benefit from an ANOVA test. On week 13, the SuperSoil mean appears significantly higher than the other two treatments; however the ANOVA analysis shows that it is not significantly different. Similarly, the standard fertilizer mean for week 15 appears significantly higher than either of the other treatments, however using an ANOVA test, it appears that this value is also not significantly different from the other treatments. The variation in nitrogen concentrations was analyzed from NO_3-N at each collection date using ANOVA. The trend of the two treatments and the control are not significantly different. These findings are consistent with the overall analysis using the linear regression model when initial and final concentrations were summed. Therefore it can be concluded that overall, there was no significant difference in the nitrogen concentrations from NO_3-N in the runoff for either of the two treatments or the control.

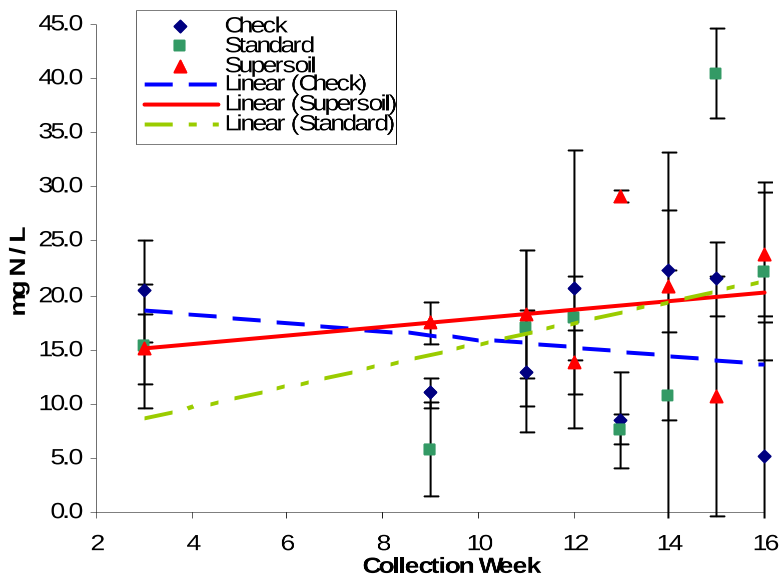

Figure 4. Mean values for NO_3-N concentrations. Linear regression, best fit line, for the concentration of NO_3-N in runoff for all fertilizer treatments. Error bars represent the standard error of the population for each mean. Overall, there is no significant difference between the concentrations of NO_3-N over all treatments.

Nitrogen from nitrates showed similar results to nitrogen from ammonium. The organic fertilizer treated plots did not show significantly more runoff of nitrogen than the plots treated with inorganic fertilizer or the untreated control plots. Therefore, we conclude that environmental nitrogen contamination from organic and inorganic fertilizer treated turf areas is similar to untreated turf plots.

Since the trends for all three nutrients did not significantly vary for any of the nutrients, it can be concluded that there is a similar amount of nutrient loss due to rain for both treated and untreated turf plots. Treated plots do not pose a greater environmental contamination threat than untreated turf areas. Specifically, SuperSoil, the organic fertilizer, poses no greater contamination risk to surface water than non-treated areas or areas treated with a standard (10%N-8.8%P-16.6%K) fertilizer.

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CHAPTER 3: NITROGEN MINERALIZATION STUDY

ABSTRACT

Soil modification with organic materials, such as bio-solids, is becoming an increasingly popular soil treatment since it can often improve physical and chemical conditions and enhance the performance of turf grass establishment. Two nitrogen mineralization experiments were conducted using a Cecil Sandy Loam soil from the Lake Wheeler Turfgrass Field Lab in Raleigh and a Wakulla soil from Sandhills Research Station in Jackson Springs, North Carolina. One hundred grams of each soil type was divided into plastic bags and separately amended with either nothing (control), Orbit or SuperSoil bio-solids at 1% by volume and stored in an incubator at 25°C. Soil extractions over a 10 week time period and a second experiment over a 3 week period. Starting on the second week and continuing every two weeks for ten weeks or weekly in the second experiment, five bags of each treatment were removed from the incubator. All samples were subjected to a 1:10 standard KCl extraction. Extracted samples were frozen and then analyzed for ammonium and nitrate. Both experiments had similar results. This study found that Wakulla soil has about three times less NH_4^+ -N than the Cecil soil. Since Wakulla Sand soil does not have as high a capacity to bind ammonium in the soil as Cecil soil, as evident by a lower CEC, the overall extractable ammonium concentrations in the Wakulla Sand soil are much lower than those in the Cecil soil. Since Wakulla soil is excessively well-drained, even in the controlled conditions, evaporation and condensation may cause redox reactions and therefore would promote faster nitrification of NH_4^+ to NO_3^-. The denser Cecil soil is less aerobic than the Wakulla soil, and has a greater CEC, so the NH_4^+ would likely be bound in the soil and undergoes nitrification at a slower rate. The Orbit treatment seems to bind nitrogen in both Cecil and Wakulla soils so that is not accessible for mineralization or plant nutrient uptake. The SuperSoil treatment has a similar effect. In fact, in Wakulla soil, the SuperSoil treatment provides more accessible nitrogen than untreated soil. However, in the Cecil soil the SuperSoil treatment also seems to bind nitrogen in inaccessible plant forms. Therefore using either the Orbit or the SuperSoil treatments does not appear to contribute additional nitrogen in accessible forms for plant uptake.

INTRODUCTION

Nitrogen is the limiting factor in plant growth and therefore most fertilizers are applied on a per nitrogen basis. Therefore, turfgrass managers pay close attention to the rate and amount of nitrogen applied to the soil in order to prevent excess nitrogen buildup (Easton and Petrovic, 2004; Watschke et al, 2000). The rate of fertilizer application depends on local, state and industry recommendations, as well as climate, soil type and turf species. Application of organic fertilizers, such as SuperSoil or Orbit, may raise the amount of nitrogen in the soil. However, it is unclear how much of a nitrogen increase may occur with organic fertilizers.

Soil modification with organic materials, such as bio-solids, is becoming an increasingly popular soil treatment since it can often improve physical and chemical conditions and enhance the performance of turf grass establishment (Eghball, 2002).
In fact, the use of bio-solids can improve plant growth and subsequently decreases the loss of soil due to erosion. The increase in plant growth occurs within the first year of application, possibly due to increases in carbon and nitrogen availability and therefore provides the desired results in a timely manner (Meyer et al, 2004). In some cases, when nutrient availability is low, use of organic fertilizers help sustain the nitrogen availability in soils (Chand et al, 2006). Organic sources of nitrogen that are composed of large amounts of proteins (blood meal) have been shown to release more nitrogen compared to materials that have gone through previous digestion wastes, such as animal manure. However, the rate of nitrification in soils amended with organic sources of nitrogen is largely unknown and may be important for developing application rates of organic fertilizers.

Nitrogen mineralization obeys the theories of first order kinetics: the first stage of nitrogen mineralization is ammonification where the nitrogen is converted to ammonium. Ammonification occurs independently from many external factors, such as aerobic or anaerobic conditions, and soil moisture content (Myrold, 1998). The process of ammonium turning to nitrate occurs within weeks of ammonification and depends on aerobic conditions in the soil.

Location and Soil Type

The Sandhills Research station is located near Jackson Springs, NC and has a soil type of Wakulla Sand. Wakulla Sand soil is coarse textured, sandy, siliceous soil and has a classification of Psammentic Hapludults. The Lake Wheeler Research Station is located in Raleigh, NC and contains Cecil Sandy Loam soil. This sample location has a 6-10% slope that ends at a water reservoir. Due to the slope, much of the area is eroded, giving the soil a higher clay percentage than typical Cecil soil. Cecil soil is a fine, kaolinitic and relatively acidic soil that is well drained. The Cecil soil at Lake Wheeler has higher clay content than the Wakulla Sand and therefore is likely to hold more nutrients, as evident by the CEC measurements of the two soils (Table 1).

Table 1. Soil Characteristics

Soil Type	Classification	% Sand	% Silt	% Clay	% Organic Matter	CEC	pH
Wakulla Sand	Psammentic Hapludults	94%	4%	2%	0.6%	1-2	5.8
Cecil Sandy Loam	Typic Kanhapludults	~80%	~5%	15%	0.5-1.0%	1-5	4.5-6.5

Data from Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW].

MATERIALS and METHODS

Previous nitrogen mineralization studies have conflicting results, which depend highly on the experimental environment, since soil nitrogen mineralization rates are directly correlated by temperature in field systems (Stanford et al, 1973). Using controlled conditions may limit some of the variation in previous nitrogen mineralization studies. Two nitrogen mineralization extractions were conducted, the first was over a 10 week time period, and then a second experiment was conducted two years later, with the same fertilizers and the same methods, over a 3 week period. Both experiments had similar results.

Site Location

This study was conducted, in the spring of 2005, on a Cecil Sandy Loam soil from the Lake Wheeler Turfgrass Field Lab in Raleigh and in a Wakulla soil from Sandhills Research Station in Jackson Springs, North Carolina.

Medium Preparation and Temperature Treatment

This experiment was designed using a Randomized Complete Block Design. One hundred grams of each soil type was divided into Ziploc bags and separately amended with either nothing (control), Orbit or SuperSoil bio-solids at 1% by volume and stored in an incubator at 25°C.

Sample Collection and Treatment

Starting on the second week and continuing every two weeks for ten weeks, five bags of each treatment were removed from the incubator. All samples were subjected to a 1:10 standard KCl extraction. Extracted samples were frozen and then analyzed for ammonium and nitrate.

Statistical Analysis

Statistical analysis was run with SAS with the help of the Statistics department at NC State University. Ammonium concentrations were log transformed in order to satisfy normality. ANOVA was run with both Bonferroni and Tukey to adjust error levels. Contrast analyses were performed on all possible variable comparisons. Where indicated, least-squared means were used when missing data created an unbalance design.

RESULTS and DISCUSSION

Ammonium-Nitrogen Concentrations

A contrast analysis with log-transformed values for ammonium showed that the two soil types Cecil vs. Wakulla are significantly different. The Wakulla soil shows 3.2 times less ammonium than the Cecil soil (figure 1). Even so, both soil types show similar slopes (b=0.02) indicating that NH_4^+-N concentrations are increasing slightly in the soils at the same rate.

The contrast analysis also shows that there is wide variability within a sample date, except for week 4, which shows little variability. Weeks 6 and 8 show less variability than weeks 1 and 5, which have the highest variability. A quadratic fitting for the sample dates is significant (df=4), but neither the linear nor the cubic fitting showed significance.

Using both Bonferroni and Tukey to adjust the error level, the treatments, Orbit, SuperSoil and the control, do not differ significantly in relation to ammonium concentrations ($p<0.01$). However, there are individual sample dates that show some significant differences between the log-transformed least squared mean for ammonium concentrations. The overall trend for both soil types show that SuperSoil decreases over time, while the Orbit treatment and the control decrease between the first two sample dates and then increase over the course of the study.

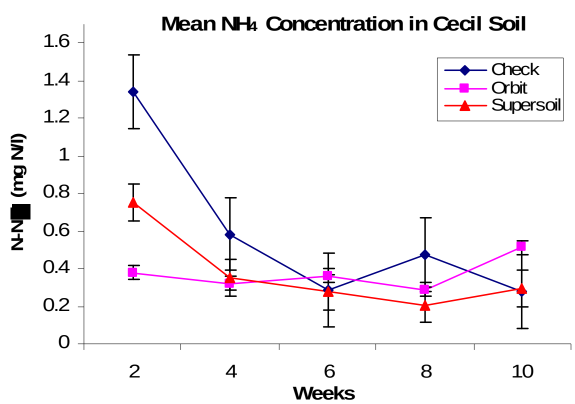

Figure 1. Mean nitrogen concentration from ammonium in Cecil soil over a ten week period.

The check, un-treated, sample showed significantly higher ammonium concentration at the first sample period (week 2), however, there was no significant difference between the control and the Orbit treatment for the remainder of the study. At week 8, the control has a slightly higher ammonium concentration as compared to the SuperSoil treatment where the ammonium concentration in the control increased from the previous sample period, but remained almost the same for the SuperSoil treatment. The Orbit treatment had a significantly lower ammonium concentration initially, as compared to either the control or the SuperSoil treatment, however it increases slightly by the end of the study ($p<0.01$).

Overall, the trend for the concentration of ammonium in both the control and the SuperSoil treatment decrease over time, although the ammonium concentration in the control decreases at a faster rate (b=-0.11) than the SuperSoil treatment (b=-0.05). The ammonium concentration in the Orbit treatment, however, increases slightly over time (b=0.01).

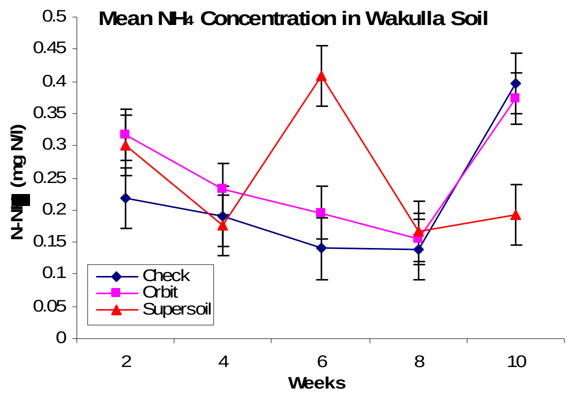

Figure 2. Mean nitrogen concentration from ammonium in Wakulla Sand soil over a ten week period.

Over the course of the study, the Orbit treatment did not significantly vary in ammonium concentration from the control, where the SuperSoil treatment did significantly differ from the control at two collection dates ($p<0.01$). Neither the SuperSoil nor the Orbit treatments have significantly different ammonium concentrations than the control on the on first two sample dates ($p<0.01$). However, on the sixth week, the SuperSoil treatment had significantly higher ammonium concentrations than either the Orbit treatment or the control, which are not significantly different ($p<0.01$). On the final sample date, the SuperSoil treatment was significantly lower than either the orbit treatment or the control ($p<0.01$).

Over the sample period, the trend for the control increases, (b= 0.01), while SuperSoil treatment decreases (b=-0.01). The Orbit does not show a significant change over time, except on the last collection date (b=0.004).

Nitrate-Nitrogen Concentrations

The SuperSoil and check samples show significantly more ($p<0.0001$), about 20 times greater, NO_3-N concentrations in the Wakulla soil than in the Cecil soil (figure 3 and 4).

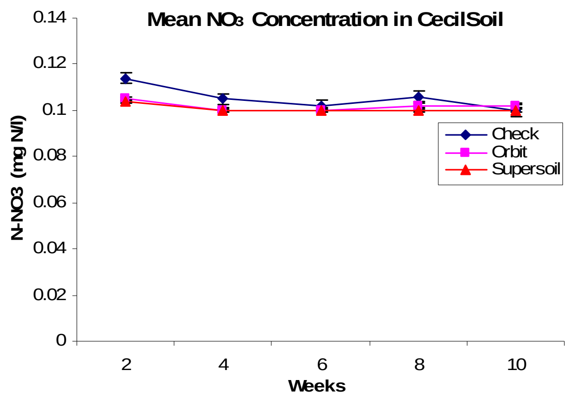

Figure 3. Mean nitrogen concentration from nitrate in Cecil soil over a ten week incubation period.

The initial nitrogen concentration for the Orbit treatment is slightly higher than either the SuperSoil treatment ($p<0.01$) or the control, both of which do not differ significantly from each other. However, after the initial sample point, the Orbit treatment and the SuperSoil treatment do not differ significantly nor do they differ significantly from the control.

Both of the treatments and the control show similar trend lines, since they did not differ from each other significantly. Linear regression models this data well ($r^2>0.5$).

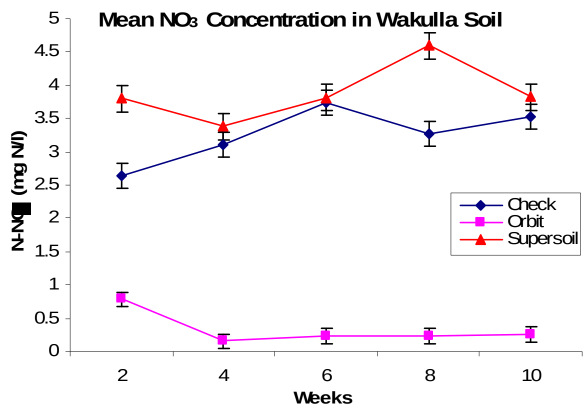

Figure 4. Mean nitrogen concentration from nitrate in Wakulla Sand soil over a ten week period.

The Orbit treatment is significantly lower in nitrate concentration than either the control or the SuperSoil treatment at all time periods ($p<0.0001$). The SuperSoil treatment only differs significantly from the control at week 2 and week 8, where SuperSoil has a significantly higher mean nitrogen concentration from the control ($p<0.01$).
The SuperSoil treatment and the control increase slightly in nitrogen concentration at similar rates; the slope (b) for SuperSoil is 0.06 and 0.09 for the control. The Orbit treatment decreases slightly over the course of the study (b=-0.05).

Total Nitrogen

The total amount of nitrogen (NO_3-N and NH_4-N combined) in the Wakulla soil samples was significantly higher than the total amount of nitrogen in the Cecil soil samples ($p<0.0001$). The SuperSoil treatment in Wakulla soil shows the highest nitrogen content, while the Orbit treatment in the Cecil soil shows the lowest nitrogen content. The untreated samples are significantly higher in nitrogen than the treated samples ($p<0.01$), for each soil type, except for the Wakulla SuperSoil treatment, mentioned earlier.

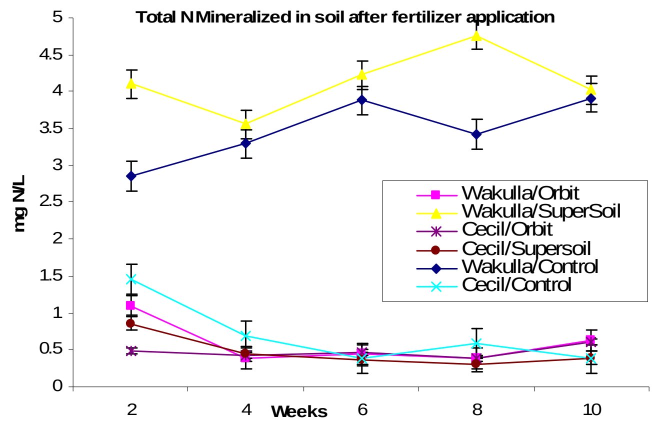

Figure 5. Combined NO_3 and NH_4 concentrations for each treatment and soil type.

Percent of Nitrogen Mineralized

Both treatments decreased in the percent of nitrogen in the soil over the 10 week period. The SuperSoil treatment has an r^2 of 0.1, and the Orbit treatment has an r^2 of 0.6, therefore both show linear decreasing trends. The SuperSoil treatment has a significantly higher percent of nitrogen than the Orbit treatment due to the high concentration of NO_3 in Wakulla soil ($p<0.0001$).

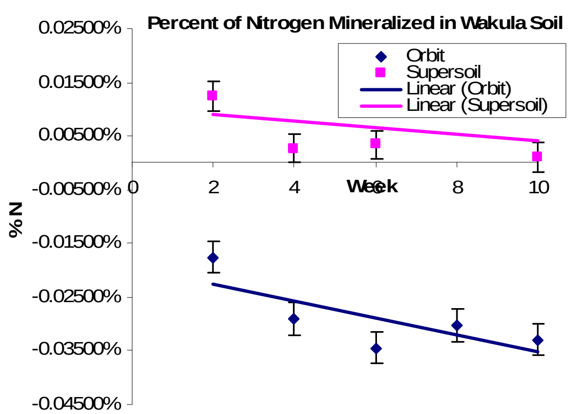

Figure 6. Percent of nitrogen in Wakulla soil. Percent of nitrogen was calculated from subtracting the total amount of nitrogen in the treatment from the total amount of nitrogen in the control, divided by the amount of nitrogen added.

Both treatments increased over the ten week study in Cecil soil. The Orbit treatment increased at a faster rate (b= 0.00001) than the SuperSoil treatment (b=0.000006). Both treatments followed a linear increase; the r^2 for Orbit is 0.7 and the r^2 for SuperSoil is 0.6, showing that both trends are highly linear. The two treatments are not significantly different in the percent of nitrogen found in the soil.

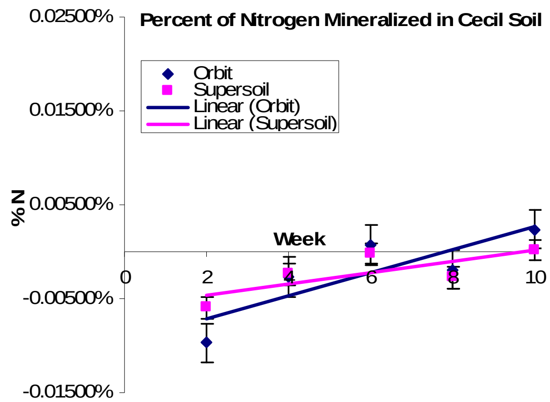

Figure 7. Percent of nitrogen mineralized in Cecil soil. Percent of nitrogen was calculated from subtracting the total amount of nitrogen in the treatment from the total amount of nitrogen in the control, divided by the amount of nitrogen added.

The SuperSoil treatment in Wakulla soil was the only treatment that increased the amount of nitrogen mineralized over the course of the study. In contrast, the Orbit treatment in the same soil type dramatically decreased the amount of nitrogen mineralized. Both the Orbit and SuperSoil treatments equally decreased the amount of nitrogen mineralized in the Cecil soil over the course of the study.

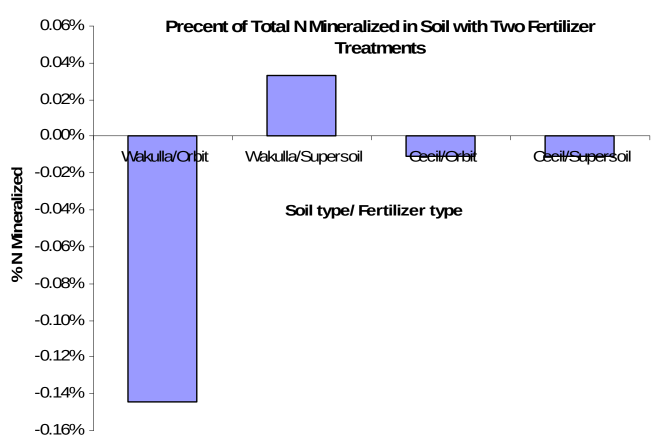

Figure 8. Percent of nitrogen mineralized in Cecil soil. Percent of nitrogen was calculated from subtracting the total amount of nitrogen in the treatment from the total amount of nitrogen in the control, divided by the amount of nitrogen added.

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FINDINGS AND CONCLUSIONS

Overall, the nutrient and pH results in the soil treated with 0.5% SuperSoil are not different from the soil treated with an inorganic fertilizer. However the 1% SuperSoil treatment consistently showed higher nutrient concentrations and higher pH than the other two treatments. The mountain location, however, showed the least change in nutrients or pH due to any fertilizer augmentation.

Phosphorus

At Castle Hayne, the phosphorus concentration in the 1% SuperSoil treated plots was significantly higher for both bahiagrass and bermudagrass plots. However, there was no significant change in phosphorus concentrations at Castle Hayne, irrespective of treatment or grass type. At the Sandhills location, while the 1% SuperSoil treatment had significantly higher concentrations than the other treatments, none of the treatments showed a significant change in phosphorus concentration over the course of the study. At the Lake Wheeler location the plots treated with 1% SuperSoil showed significantly higher phosphorus concentrations and also had a significantly greater increase in phosphorus concentration over time, than the other treatments. Overall there is a significant increase in phosphorus concentration at Fletcher; however, none of the treatments are significantly different from each other.

Potassium

At the Castle Hayne location, the 1% SuperSoil treatment had the greatest effect on the potassium concentrations and showed the greatest change in potassium level over the course of the study for both grass types. At the Sandhills location, the plots treated with 1% SuperSoil had both a significantly greater potassium concentration than the other treatments and significantly increased in potassium concentration over time; however, the 0.5% SuperSoil treatment plots and the inorganic fertilizer treatment plots were statistically similar. Similar to the Sandhills, Lake Wheeler plots treated with 1% SuperSoil had the greatest significant increase in potassium concentration as well as significantly more potassium than the other treatments, which were not statistically different. Unlike the other location, Fletcher plots showed no significant change in potassium concentration for any of the treatments over time, nor were any of the treatments significantly different.

pH

At Castle Hayne, the pH for plots treated with SuperSoil was not statistically different from plots treated with inorganic fertilizer. In plots at the Sandhills, the pH was greatest in plots treated with 1% SuperSoil, however, there was a significant increase in pH for all the treatments over the course of the study. At Lake Wheeler and at Fletcher, all treatments showed a significant increase in pH over the course of the study, but none of the treatments were statistically different.

Runoff data

From the study which looked at nutrient loss in runoff, this study found that there is no greater environmental threat from runoff from organic fertilizers than from inorganic fertilizers and that organic fertilizers show a slow initial release of nutrients where inorganic fertilizers have a higher initial release of nutrients into runoff. However, over the long term, the nutrient release of organic and inorganic fertilizers from runoff concentrations is not significantly different.

These plots were only treated twice with each fertilizer, once as preplant incorporation and once with a topdressing application in the second year. Additional studies where plots are treated with more applications of fertilizer in order to induce higher levels of soil nutrients and show the interplay of accumulation and runoff would help to explain the benefits and risks of using organic fertilizers over long periods of time.

Mineralization data

This study found that the Wakulla soil has about three times less NH_4^+ -N than the Cecil soil. Since the Wakulla sandy soil does not have as high a capacity to bind ammonium in the soil as the Cecil soil, as evident by a lower CEC, the overall extractable ammonium concentrations in the Wakulla sandy soil are much lower than those in the Cecil soil.

Since the Wakulla sandy soil is excessively well-drained, even in the controlled conditions, evaporation and condensation may cause redox reactions and therefore would promote faster nitrification of NH_4^+ to NO_3^-. The thicker, Cecil soil is less aerobic than the Wakulla soil, and has a greater CEC, so the NH_4^+ would likely be bound in the soil and undergoes nitrification at a slower rate.

The Orbit treatment seems to bind nitrogen in both Cecil and Wakulla soils so that is not accessible for mineralization or plant nutrient uptake. The SuperSoil treatment has a similar effect, but not as dramatic. In fact, in the Wakulla soil, the SuperSoil treatment provides more accessible nitrogen than untreated soil. However, in the Cecil soil the SuperSoil treatment also seems to bind nitrogen in inaccessible plant forms. Therefore using either the Orbit or the SuperSoil treatments does not appear to contribute additional nitrogen in accessible forms for plant uptake.

RECOMMENDATIONS

Concerns have been raised in North Carolina and other states about the use of both inorganic and organic fertilizers which contain a high ratio of phosphorus in proportion to nitrogen. The main issue has been contamination of water with excess phosphorus resulting in eutrophication conditions which precipitate deterioration in water quality conditions. Organic fertilizers have been especially targeted as a potential source of phosphorus because of their higher phosphorus to nitrogen ratio which in many cases approaches 1:1.

The nitrogen mineralization studies indicated a minimal contribution to the short term available nitrogen pool from the use of the organic materials. This should be considered where there is a need for immediate to short term nitrogen availability for grass establishment. These materials could be used in combination with inorganic fertilizers.

This study addressed the long term soil stability and nutrient runoff from the use of organic materials for preplant and topdressing of roadside plots. Based on the results of these studies, there is no greater risk of nutrient loss using an organic fertilizer source than there is from an inorganic material.

Based on these results, organic materials are recommended for use as both preplant soil incorporated fertilizers or topdressing fertilizers for roadside grass establishment.