ECONOMICS AND IMPACT OF MANURE AND COMPOSTED MANURE ON SOIL QUALITY AND YIELD COMPARED TO CHEMICAL FERTILIZER AMONG POTENTIAL BIO-FUEL CROPS

By

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Bachelor of Science in Plant and Soil Science

Oklahoma State University

Stillwater, OK

2010

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2010

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ACKNOWLEDGMENTS

Over the past two years I have come to greatly appreciate the people around me as they make the entire academic system work and are the reason that I have the opportunity to be here and complete my degree. My experience over the last few years have been an excellent experience as I was allowed to grow not only academically but personally as I was allowed and expected to maintain and pursue my own degree and research goals.

Starting off I would like to thank Dr. Chad Penn for all the time and effort he put into me and my project. I am grateful for the trust and opportunity he gave to me, by offering me this assistantship. Through these last two I have come to appreciate even more the role that professors play in student's academic careers and the great and long effects they will have for years to come.

I also want to thank Dr. Godsey and his crew for all the help in harvesting and planting my crops. I greatly appreciated the time he took to answer my many questions and for offering the most practical advice when it came time to make tough decisions.

Lastly I need to thank Dr. Penn's lab crew for all their many hours of service on my project. Most importantly of this crew is Lisa Fultz as without her I'd probably still be in the lab running samples. Her advice and expertise will always be appreciated and never forgotten. Also in this group I would like to thank Patrick Bell and Dustin Stoner for their help. In addition I need to thanks the Eastern Oklahoma Research Station crew for all their help and cooperation.

My time here at Oklahoma State University is a time that I will never forgot as the skills I've learned here will continue to guide and aid me for the rest of my life. Again I would like to thank and show the greatest respect to those that have helped me reached this point and this respect will never be forgotten.

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INTRODUCTION

According to the United States 2007 Census of Agriculture there are roughly 180,000 poultry farms producing over 9 billion birds a year with broiler and layer poultry numbers combined (Natl. Agric. Stat. Serv., 2007). Arkansas and Oklahoma combined produced over 1.4 billion broilers for sale in 2007 alone, with Arkansas producing over ninety-five percent of these birds (Natl. Agric. Stat. Serv., 2007). With each bird producing on average 1.1 kg of waste a year (Malone et a., 1992), that results in roughly 1.54 million Mg of poultry broiler litter to be disposed of each year in Arkansas and Oklahoma alone. The majority of poultry production in Oklahoma occurs in eight counties located in far eastern Oklahoma along the Arkansas border (Britton and Bullard, 1998) and a large portion of Arkansas production occurs in the northwestern part of Arkansas. These areas in northeastern Oklahoma and northwestern Arkansas are host to multiple river and water systems that are facing problematic issues caused by decades of application of animal waste to pasture and cropland above crop removal. Two of the most discussed watersheds affected in these areas are the Eucha/Spavinaw Watershed and the Illinois River Watershed (Moore and Edwards, 2005). As a whole the country has seen the number of poultry operations cut by over half while production has continued to increase to meet demand through use of

Confined Animal Feeding Operations (CAFOs) over the last forty years (Centner, 2003).

The application of poultry litter to the lands surrounding poultry operations has led to phosphorous (P) saturation beyond both crop requirements and soil P capacity creating a risk for offsite movement to nearby streams. This P movement can have a negative impact on water quality producing effects such as eutrophication, foul odor, and poor taste (Moore and Edwards, 2005). Soil P saturation has occurred as result of years of application of litter on an nitrogen (N) basis alone; not taking into account the plant's lower P requirements and the concentration in litter. One solution to this problem is the transportation of litter to areas outside of these watersheds. The poor quality soils that cover a large area of Oklahoma are an exceptional area to dispose of litter and add to the already strong case for the justification of litter transport out of these watersheds. Yet, Oklahoma poultry litter use is somewhat limited as a fertilizer source outside of these local areas even though this nutrient source for farmers has been an option for many years. The under utilization of this resource can be associated with poultry litter misconceptions held by the public, including farmers, about its value as an alternative fertilizer to inorganic fertilizers and its much published negative effects on the environment.

Economics also play a huge role as high fuel and transportation cost diminish the economic value of litter and inhibit the ability to move this litter farther from the effected watersheds. Production and environmental misconceptions can be overcome by showing the positive effects of litter on Oklahoma soils and crops compared to conventional methods of fertilization.

Efficiency of litter transport can also be improved through use of better storage techniques to enhance degradation of poultry litter, which in turn will increase the monetary value by increasing nutrient density. Not only will increased production in these areas brought on by the use of poultry litter lead to increased economic returns, but it will also better prepare Oklahoma for a possible future in bio-fuel crop production.

Literature Review

Phosphorus background

Phosphorus is one of major macro nutrients essential for plant growth and a variety of important life functions in plant systems. Phosphorus plays a vital role in all biological systems affecting both organism growth and energy transfer at the cellular level through its role in cellular structure and adenosine tri phosphate (ATP) (Brady and Weil, 2007 and Pierrou, 1976). Phosphorus importance is “second only to nitrogen (N) in its impact on health and production of both terrestrial and aquatic ecosystems” (Brady and Weil, 2007). Phosphorous in adequate levels enhances root formation, N fixation, flowering, quality of fruit, forage and grain products, water use efficiency and plant maturation (Brady and Weil, 2007). The cycle that governs P availability is quite different than the N cycle as P is for the most part a non-mobile element. Phosphorous has no gaseous state and exists in soil predominately in insoluble forms (Bowman and Vigil, 2002). All P originates from sedimentary and to a smaller extent igneous rock in the primary mineral apatite and other forms (Lindsay et al., 1962). Weathering of these apatite minerals is the primary way in which phosphate becomes plant available in the inorganic free orthophosphate ion HPO_4^{2-} or $H_2PO_4^-$. Yet, these free ions rarely exist more than on short term basis as they are quickly immobilized by iron and aluminum or even calcium (Pierrou, 1976). The degree of weathering of a soil system can greatly affect the P cycle as a highly weathered soil results in lower concentrations of base cations such as Ca and lower soil pH. These results of weathering shift the precipitation of P to the more abundant minerals left by the weathering process, producing aluminum and iron phosphates as the primary source of P.

Addition of P to soil is based on results of soil test P extractions and by the yield goal of a desired crop. Phosphorus fertilizer can come in two forms; inorganic and organic, with inorganic as the most commonly used form. The source of inorganic P is from highly insoluble phosphate rock deposits found in various locations scattered across the world (Bowman, 2002). This insoluble phosphate rock must be submitted to extreme heat or acid treatment to be converted into a soluble product that is highly soluble and therefore plant available. Some problems associated with mining phosphate rock are the cost of mining and the fact that it is not a renewable resource with some estimates predicting the largest mines to be depleted in the next 100 years, with lower quality, smaller mines to last another 400 years (Berg, 2005).

The background and uses of poultry litter

Poultry litter is a mixture of both poultry manure and bedding materials, usually rice hulls or woods chips (Edwards, 1992). Poultry are reared directly on the floor on top of these bedding materials in large open houses. The mixture is produced by the re-use of the bedding material for multiple flocks and is usually removed after one year of poultry production in the production house (Moore, 1998). Broiler litter is a another common term used from poultry litter as litter produced in this way is predominately produced by broiler poultry as laying poultry are usually kept in elevated cages and produce only poultry manure without bedding material (Moore, 1998). A typical broiler poultry house produces four to five flocks per year in this manner with the top layer of hardened manure removed between each new flock of poultry in a process called decaking.

Poultry litter contains essential plant nutrients consisting of macro (N, P, K), secondary macro (Ca S, Mg) and micro (Cu, Mn, Mo, Zn, Fe, B, Cl, Ni) nutrients (Sharpley et al, 2009; Perkins and Parker, 1971; Edwards, 1992; Wilkinson, 1979). It also has been known to contain less desirable nutrients such as arsenic and lead in smaller quantities (Jackson et al. 2003). Poultry litter is considered to be the most valuable of all animal waste for application as a soil amendment with its diverse and more importantly, high concentration of nutrients (Wilkinson, 1979; Moore et al. 1995). Nutrient content of poultry litter can vary considerably from year to year as function of bird type, handling and storage, feed ration and other supplements, and time between house cleanings (Sims and Wolf, 1994; Evers, 1998). The average N, P, and K fertilizer value of poultry litter produced in Oklahoma is expected to be around 29, 28, and 23 kg Mg^{-1} (Zhang and Raun, 2006). Other nutrients listed above are found in much smaller concentrations as can be seen in Table 1.

Numerous studies have been completed showing the effects of litter application on soil and crop production. Wood et al. (1993) found that using poultry litter as fertilizer for bermudagrass to be “an excellent sustainable agricultural practice” with residual effects on yield and crude protein continuing into the second year. Zhang et al. (2009a) found the percentage of N fertilizer available from litter application to range from 50-70 percent in the first year, 15 in the second, and 6 percent in the third year if surface applied, while soil incorporation resulted in a 10 percent increase in first year plant available N. Other studies concluded that 60 to 65 percent of N is available the first year when surface applied, while 15 percent is available for the following year (Cabrera and Cordillo, 1995; Payne and Donald, 1995). Both Cabrera and Cordillo (1995) and Payne and Donald (1995) concluded that the 20 to 30 percent loss of total N is due to the volatilization of ammonia. Yet, almost entirely all P and K are plant available from litter as would be expected from the same commercial fertilizer application rate at time of application (Wilkinson, 1979; Zhang, 2009b). When soils fertilized with organic fertilizers (manure) are compared to those using inorganic fertilizers in long term studies they have been shown to have "higher contents of organic matter and numbers of microfauna", be "more enriched in P, K, Ca and Mg in topsoils and NO_3^-, Ca and Mg in subsoils"; they also posses lower bulk density and higher porosity, improved hydraulic conductivity, and aggregate stability, while showing no difference in yield between fertilizer type (Edmeades, 2003). Moore and Edwards (2005) showed that both normal and alum treated litter applied to soils resulted in an increase in pH when compared to the control, while the ammonium-nitrate treated soils showed a decrease in pH over a long-term study. These results prompted them to suggest pasture application of poultry litter as a fertilizer as more sustainable practice than using ammonium-nitrate.

The use of manures long-term have been shown to increase soil concentrations of P, K, Ca, Mg, Cu, and Ni when compared to inorganic fertilized pastures (Kingery et al., 1993; Sharpley et al., 1993; Nyakatawa et al., 2001; Mitchell and Tu, 2006). Soil P increases are the most prominent and studied area as increases in P concentrations can lead to well-known water quality problems previously discussed. Increases in P and other nutrient concentrations in soil is due to an over application of these nutrients relative to the actual plant uptake and removal, which is due to application based on N needs alone. Poultry litter produced in United States usually possesses an average N-P-K ratio of 3-3-2.5 (Zhang et al., 2009a), but this ratio can very quite a bit depending on multiple factors such as age of birds, diet and moisture content of litter (Mitchell and Donald, 1995). Average forage N-P-K uptake ratio of Bermudagrass with a typical yield of 11.2 Mg ha^{-1} is 280-67-242 kg ha^{-1} (Zhang et al., 2009b). When litter is applied at this ratio to meet N requirements it requires that three times as much P must be applied than is required. Years of over application lead to the decreased ability of soil to retain applied P, leading to reduced P holding capacity and creation of a source of P to sensitive watershed environments.

Traditional composting of poultry litter has been shown to produce many positive effects. Sweeten (1980) found that composting animal manures results in reduced volume, weight, weed seed viability, and odor. Dao (1999) showed total mass reduction of manures by as much as 50 percent on a weight basis. It has also been shown that during composting pathogens in the manure can be eliminated by the heat produced by the process. Composting of manures and waste immobilizes N and produces a more humified substance that is a better soil amendment and works as a natural slow release fertilizer (Paul and Clark, 1996). Tyson and Cabrera (1993) revealed that N release from composted poultry manure is less available, making the composted litter less of environmental threat from nitrate leaching and ammonia volatilization. Preusch et al. (2002) found that composting produced an end product with a more consistent N mineralization rate between litters even though those same litters applied fresh had significantly different mineralization rates. Traditional composting incorporates the use of bulking agents (C source) to increase the C:N ratio increasing microbe activity.

Some problems associated with traditional composting of litter are the loss of N, additional mass of added bulking agents, and the resulting decrease in N/P ratio, which adds to the application/ plant use problem of P. Delaune et al. (2006) found composting poultry litter without the addition of bulking agents and the addition of alum resulted in more retained N and less soluble forms of P in litter and runoff compared to traditional composting. Alum accomplishes these processes by the following mechanisms (adapted from Moore et al., 1999):

$$Al_2(SO_4)_3 \cdot 14\ H_2O + 2\ H_3PO_4 \rightarrow 2\ AlPO_4 + 6\ H^+ + 3\ SO_4^{2-} + 14\ H_2O \quad [1]$$

$$6\ NH_3 + 6\ H^+ \rightarrow 6NH_{4+} \quad [2]$$

$$6\ NH_{4+} + 3\ SO_4^{2-} \rightarrow 3(NH_4)_2SO_4 \quad [3]$$

Alum first acts by reacting with phosphoric acid and producing aluminum phosphates and 6 M of H^+, increasing the acidity of the litter. With this increase in acidy comes promotion of the formation of ammonium from ammonia present in litter in a free gaseous state. The ammonia is then able to form even more stable ammonium sulfate.

Alum additions to poultry litter have been identified to have no effect on poultry litter decomposition in soils (Gilmour et al., 2004). Non-composted alum-treated poultry litter was found to produce 6 percent higher yields in fescue than normal treated litter applied on equal basis due to higher N concentrations (Moore and Edwards, 2005).

The use of aluminum sulfate (alum) in litter treatment prior to land application has produced very successful results in reducing water-soluble P in runoff from pasture applications (Moore and Miller, 1994; Sims and Luka-McCafferty, 2002). Warren et al. (2008) found that the addition of alum to poultry litter transformed 30 percent of the organic P in the 1.0 mol L^{-1} HCL extractable form (calcium phosphate) to the 0.1 mol L^{-1} NaOH extractable form (Fe and Al phosphates) in a sequential litter P-fractionation. When these litters were incubated in soils they resulted in a more recalcitrant P that persisted in the environment as a less soluble P form. The mechanisms by which alum effects poultry litter through reduced P solubility is still not entirely understood as early work suggest it is the formation of Al-P compounds and more recent work suggest that reduction occurs through a lower occurrence of organic P mineralization into water soluble P compounds (Warren et al., 2008).

Economic basis for moving litter

The most significant factor affecting the use of poultry litter in agronomic production systems today is the cost of transportation and application of these materials from production houses to agricultural fields. Based on fertilizer prices obtained in April 2010, the economic value of poultry litter (wet basis) as fertilizer when compared to inorganic commercial fertilizer cost is about \$76.70 Mg^{-1} assuming a conservative level of nutrients in the litter. The number above assumes the nutrient ratio of $N-P_2O_5-K_2O$ in the litter to be 3-3-2.5 (30-30-25) kg Mg^{-1}. These calculations are based on each pound of nutrient in the litter to hold equal economic value to the comparable inorganic commercial fertilizer source as demonstrated below:

Nitrogen (urea)

46 – 0 – 0 = 46% N

46% of 1 Mg = 460 kg of N/ton

\$452 Mg / 460 kg Mg^{-1} = \$0.98 kg^{-1} of N

Phosphorus (di-ammonium phosphate)

18 – 46 – 0 = 18% N & 46% P_2O_5

18% of 1 Mg = 180 kg of N Mg^{-1}

46% of 1 Mg = 460 kg of P_2O_5 Mg^{-1}

180 kg N x \$0.99 kg^{-1} = \$178 worth of N

\$573 total cost - \$178 N value = \$395 P_2O_5 cost

\$395 Mg^{-1} / 460 kg Mg^{-1} = \$0.86 kg^{-1} of P_2O_5

Potassium (potash)

0 – 0 – 60 = 60% K_2O

60% of 1 Mg = 600 kg K_2O Mg^{-1}

\$519 Mg^{-1} / 600 kg Mg-1 = \$0.86 kg^{-1} of K_2O

Now assuming from above that the poultry litter has nutrient content of 60-60-50:

N= 30 x \$0.98 kg^{-1} x 0.5 (% N available)	= \$29.4
P = 30 x \$0.86 kg^{-1}	= \$25.8
K = 25 x \$0.86 kg^{-1}	= \$21.5
Total	= \$76.7 Mg^{-1}

Value of the litter could also be increased due to micronutrient contents (Wilkinson, 1979), yet you rarely seen an economic value assigned to such nutrients. Using the calculations above one can greatly see the economic benefits of degrading litter and making it more nutrient dense as just a ten percent increase in P and K concentration with N levels holding steady (assuming minimal volatilization loss) the value of the litter can increase by \$4.73 Mg^{-1}. This results in the average semitrailer-load of manure that carries roughly 27 Mg litter increasing in value by \$127.71 a load, which greatly expands its economical transportation range.

Bio fuel crops

As the United States continues to take a harder look at becoming energy independent, the use of bio fuel crops becomes more important. The production of cellulosic ethanol from high forage/biomass yielding crops is one that is gaining a lot of attention. Preliminary research has shown that future ethanol production from cellulosic fermentation will be more energy efficient, cost effective, and environmentally beneficial than corn grain based ethanol production (Solomon et al., 2007). As these technologies are being advanced and developed it becomes apparent that production of these bio fuels sources must be researched and advanced to meet their potential future need. Multiple sources of materials for bio fuel production are available and have been considered such as trees (willow, hybrid popular, sliver maple and black locust), wood byproducts (sawdust and wood chips), construction and municipal byproducts, and paper and sewage sludge (Solomon et al., 2007). Agricultural products that have potential includes anything that can produce biomass efficiently and economically such corn stover, corn and sugarcane processing residues, cereal straws, and grasses (switch grass, bermudagrass, sweet sorghum, sorghum, miscanthus, and reed canary grass) (Solomon et al., 2007; Chen et al., 2007). The use of grasses as source for bio-fuel production makes even greater sense as over 150 million tons of hay and silage are already produced yearly for livestock feed and could easily be transitioned to the focus of a dual purpose crop (Chen et al., 2007).

Bermudagrasses (*Cynodon dactylon L.)* is one of the most widely adapted and produced C4 perennial forage crop grown in the southeastern United States and other temperate regions (Anderson, 2007 and Muir, 2009). There are already over 4 million ha of bermudagrass grown in the United States today (Sanderson et al., 2008) Bermudagrass has the ability to produce high yields and maintains itself as a very durable forage (Ball et al 1991). Bermudagrass has showed a linear yield response to N fertilizer application at an N rate as high as 560 kg ha^{-1} producing yields up to 1200 kg ha^{-1} as a quadratic function (Wilkinson and Langdale, 1974). Maximum yields were estimated by Wikinson and Langdale (1974) to be around 29 Mg ha^{-1} at around 1230 kg N ha^{-1}. In Oklahoma it is roughly assumed that for every 57 kg N applied per ha of bermudagrass results in 2.3 metric ton ha^{-1} of forage production up to 400 kg N ha^{-1} (Zhang et al., 2009c). Many varieties of bermudagrass are already available that were bred for increased ruminant digestibility, meaning increased efficiency of bioconversion to ethanol (Anderson et al., 2007). Anderson et al. (2007) found bermudagrass to be a superior feedstock for the conversion of ethanol via saccharification and fermentation. Use of bermudagrass as bio-fuel feedstock could also offer producers another opportunity to utilize their forage crops, especially in years of low quality production as feedstock nutrient quality has no effects on bio-fuel production (Anderson et al., 2007). For these reasons it is accepted as one of the prevalent crops looking to be a source of biomass for cellulosic ethanol production.

Sweet sorghum (*Sorghum bicolor (L.) Moench)* is another crop that has come to the forefront as an annual C4 grass with very high biomass production, sugar production, water logging resistance, salinity tolerance, and drought tolerance (Reddy et al., 2005; Mastrorilli et al., 1999). When sweet sorghum is compared to sugarcane it also possesses a much wider geographical range as it is adapted to both temperate and sub-tropical regions (Reddy et al., 2005). In all climates it is easily cultivated and grows rapidly. These attributes have earned sweet sorghum the nickname the 'camel' among the bio fuels community (Li., 1997). Sweet sorghum dry matter yields are only moderately affected by N application as shown by Buxton et al. (1999) with dry matter yields of 13.5, 16.1, 16.9, and 15.9 Mg ha^{-1} as result of the following N rates 0, 70, 140, and 280 kg ha^{-1} N. Geng et al. (1989) found that same amount of ethanol could be produced from sweet sorghum as corn, yet relying only on 36 percent of N used for corn production. These low N rate requirements favor sweet sorghum over grain crops for ethanol production (Wortmann et al., 2010). Sweet sorghum has the potential to produce juice or biomass alone, or both, for ethanol production making it an even more adaptable crop to bio fuel production.

Intense bio-fuel crop production will require large quantities of nutrients to maintain productivity in the future. Bio-fuel crop production is very similar to hay production where total biomass is removed from the field every year. Crops produced in this way require additional nutrient additions compared to traditional grazing and grain production systems. Complete removal of biomass leaves no nutrients to be recycled as animal waste or grain production residues in traditional systems. Not only does this removal affect soil N, P, and K concentrations but intense removal over sustained time periods can affect other nutrients rarely added back to soils. This is where poultry litter's ability to provide almost all essential plant nutrients in one application reaffirms its use in the world of bio-fuel production. This future will be even more secure through an increase in the ability to expand the economically limited transportation distance of poultry litter to future bio-fuel production areas across the state by a reduction in mass and increase in value per unit mass.

Objectives

The primary objectives of this study are to determine the value of poultry litter (both economic and physical) compared to inorganic commercial fertilizer when applied at equal rates to pasture and croplands for the purpose of producing biomass. Also, to evaluate the effectiveness of composting litter in a low input system and its ability to transform it into a more uniform product for use as a fertilizer in pasture and cropping systems.

The specific objectives of this research:

1. Quantify the changes in litter mass, density, and carbon and nitrogen content with a low input composting process with and without aluminum sulfate (alum) additions.

2. Compare forage production and nitrogen use efficiency for bio-fuel crops (sweet sorghum and Bermuda grass) of plots treated with several different application rates

of poultry litter, litter compost and chemical fertilizer among poor quality, nutrient deficient soils outside of intense poultry production watersheds.

3. Quantify changes in soil quality and fertility among litter and litter compost amended soils compared to control and commercial fertilizer treatments.

4. Use information gained from previous objectives for determining economic feasibility of using litter and litter compost as nutrient sources to poor quality soils.

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CHAPTER II

POULTRY LITTER CHARACTERISTICS AND EFFECTS OF AN IMPROVED STORAGE TECHNNQUE TO INCREASE VALUE

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ABSTRACT

Poultry litter is an excellent source of plant nutrients. However, continuous application of litter beyond crop phosphorus (P) requirements has resulted in the need for transporting litter outside of nutrient dense watersheds. Litter transport is somewhat limited due to the high cost of transportation, which is based on mass and mileage. This study was conducted to investigate an alternative litter storage technique for increasing litter degradation, humification, and nutrient density. The enhanced degradation storage process involved use of one ton fresh poultry litter piles constructed every year for three years in Haskell, OK in early spring and sampled prior to field application after eight weeks of degradation. Piles were turned once and brought up to 40 percent moisture; one treatment additionally received alum at a 10 percent rate (by weight). Total litter mass loss was calculated using P concentration as it is a non-gaseous, abundant and easily measured nutrient. Degradation resulted in a 19.6 to 26.9 % loss in mass during this 3 yr period. Nitrogen loss in the alum treated litter was significantly less when compared to regular degraded litter. Total P increased roughly 20 percent in both degraded litters, while water soluble P for the alum decreased over 32 percent compared to non-treated litter. Use of the enhanced degradation storage techniques, and especially the addition of

alum in this process, resulted in improved litter physical properties, increased nutrient density, and reduced mass which ultimately translates into decreased shipping costs per mass unit of nutrient.

INTRODUCTION

Poultry production in eastern Oklahoma plays a vital role in the economic viability of the rural areas located in this region. In 2009 alone Oklahoma produced over 226,000 broilers for meat production worth over 500 million dollars. (National Agricultural Statistics Service, 2010). Because the majority of Oklahoma poultry production occurs in only eight counties located in the far eastern half of state (Britton and Bullard, 1998), the economic impact of poultry production is even more pronounced. The majority of these poultry litter production operations are operated as Concentrated Animal Feeding Operation (CAFOs) that have come to be the norm for swine and poultry production in the U.S. Operations in Oklahoma are no different from other CAFOs around the U.S. as efficient and environmentally sound solutions to address their waste management issues are still desired.

The number of poultry operation in the U.S. has declined by half over the last 40 years while production of poultry has significantly increased to meet consumer demands through the use of CAFOs (Center, 2003). This system relies on the shipment of feedstocks to individual farms where an agricultural product is produced and then shipped off the farm. Yet, the majority of the nutrients shipped in as a feedstock are left behind as manure. The result of poultry production in this manner is poultry/broiler litter, a mixture of both poultry manure and bedding material usually rice hulls, woodchips, or sawdust (Edwards, 1992).

Poultry litter contains almost all the essential plant nutrients consisting of macro (N, P, K), secondary macro (Ca S, Mg) and micro (Cu, Mn, Mo, Zn, Fe, B, Cl, Ni) nutrients (Edwards, 1992; Wilkinson, 1979). Poultry litter is considered to be the most valuable of all animal waste for application as a soil amendment with its diverse and more importantly high concentration of nutrients (Wilkinson, 1979; Moore et al. 1995). The average N, P, and K fertilizer value of poultry litter produced in Oklahoma is expected to be around 29, 28, and 23 kg Mg^{-1} for N, P_2O_5, K_2O, respectively. (Zhang and Raun, 2006). The N-P-K ratio listed above shows the potential problem with long term poultry litter application to pasture and cropland soils. Poultry litter in the past has been applied based on plant available nitrogen (PAN) not taking into account the plant uptake of other nutrients (Read, 2007). Evers (1998) showed bermudagrass removed a much higher ratio of 10:1 N/P than was contained in the poultry litter with almost a 1/1 ratio.

When poultry litter is applied on PAN requirements only it results in buildup of excess P in soils (Sistani, 2004; Kingery et al. 1993). Continuous addition of poultry litter to soils has lead to soil test phosphorous (STP) values well in excess of proposed crop sufficiency of 32.5 mg kg^{-1} (Melich-III P) in Oklahoma. When soils exceed optimum STP, soil P-sorption capacity is reduced and P solubility increases, greatly increasing the risk of off-site movement of P through over land flow as dissolved P and particulate P into surrounding water bodies (Sharpley et al., 1994). As a result of these increased P losses comes the increase in occurrence of eutrophication in surface water bodies. Eutrophication of these water bodies results in a significant decrease of water quality as foul odor, poor taste, algal blooms or even fish kills produced by the depletion of dissolved oxygen through excess plant growth. These negative impacts that excess P can have on drinking water supplies are an ongoing problem throughout the U.S. and the poultry industry has continued to be the prime target of lawsuits aimed at compensating for them. The Eucha/Spavinaw watershed in northeastern Oklahoma is one example of excess P application negatively affecting water quality and the poultry industry being held accountable as the city of Tulsa sued the poultry industry and settled for millions (Moore, 2005).

The location of Oklahoma and Arkansas poultry production adds greatly to the problems as majority of the production takes place in areas with nutrient limited watersheds such as the Illinois River Watershed, Eucha/Spavinaw Watershed, and Wister Watershed. Within these geographical areas application of poultry liter has been banned when STP is in excess of 150 mg kg^{-1} are present. While, the rest of the state is limited to applying poultry litter at P plant removal rates when STP surpasses 200 mg kg^{-1}. These regulations result in poultry litter being moved out of these watersheds into P deficient soils elsewhere in the state.

The movement of litter out of these nutrient limited watersheds is the simplest and most practical way of eliminating the negative effects of the poultry litter application in these areas. Yet, the cost of transport of litter to P deficient soils is the limiting factor in regard to economic viability. Paudel et al. (2004) found in Northern Alabama that 29 surrounding counties could not utilize all the litter produced based on a P management basis and a maximum economic transport distance of 164 miles from the house. They also showed increased cost if movement of the litter out of the heavily surplus counties was the priority of their litter transport efforts.

The value of poultry litter is calculated assuming poultry litter nutrients hold the same economic value to farmers as commercial inorganic fertilizers. The value of poultry litter as of April 2010 based on a local farmers Coop granular fertilizer price quote is around \$77.00 Mg^{-1} with an average nutrient content of 30-30-25 (N-P_2O_5- K_2O) kg Mg^{-1}. Determination of the distance of economical transport or even application for farmers is always determined by this monetary value. The value is assumed based on the fact that the soils applied are deficient in N-P-K; otherwise they have no value to the farmer. In the past, others have suggested the use of composting to reduce the overall mass of the litter and increase its nutrient density resulting in a more valuable end product increasing economical shipping distance.

Traditional composting of poultry litter has been shown to produce many positive effects. Sweeten (1980) found that composting animal manures results in reduced volume, weight, weed seed viability, and odor. Dao (1999) showed total mass reduction of manures by as much as 50 percent on a weight basis. Composting of manures and waste reduces solubility of N and produces a more humified substance that is a better soil amendment and works as a natural slow release fertilizer (Paul and Clark, 1996). Some problems associated with composting of litter are the loss of N and the resulting decrease in N/P ratio, which adds to the application/ plant use problem of P. Others problems associated with traditional composting are the labor, energy, and time consumed, greatly reducing its appeal and economic gain. Another problem is the addition of a carbon source to increase the C/N ratio as this adds to the mass of litter exactly opposite of our ends goals. The use of a low input degradation system, one in which no additional carbon is added and energy inputs are keep to minimum should be a more attainable and economically viable than traditional composting.

Objectives of this experiment are to (i) determine the viability of an alternative low input litter carbon degradation process and its effects on litter properties both chemical and physical, (ii) determine the economic value of this process and ability to expand the transport of litter out of nutrient sensitive watersheds to P deficient soil throughout the state.

MATERIALS AND METHODS

A 3 year study was initiated in March of 2007 at the Eastern Research Station of Oklahoma State University located southeast of Haskell, OK The study consisted of two treatments of poultry litter to test the degradation process; an alum treated pile and an “as is” pile. Every March for three years, fresh broiler litter from the cleanout of broiler production houses in Eastern Oklahoma/Western Arkansas was transported to the research station where two 0.9 metric ton piles of broiler litter were constructed in a single open side covered shed. Based on results from our own small scale laboratory study, litter moisture content was brought up to 40% where the most significant mass reduction losses occurred. The natural litter pile was weighed out in 45 kg increments in a 132 L plastic trash can on a electronic postal scale where the proper amount of water was added to adjust moisture to 40 %, then mixed and dumped onto the ground. The alum treated litter was weighed out exactly the same way except with the addition of alum on a

10% by weight basis into the trash can prior to moisture adjustment. Both piles were constructed in a manner to produce a cone shaped pile that was then covered with a polyethylene tarp (5 mil thickness and 10 x 10 mesh) and staked flush to the ground. After 30 days of incubation both piles were mixed thoroughly by hand and recovered with the tarp for an additional 30 days of incubation; for a total incubation period of 60 days. Multiple litter samples were taken randomly from throughout the fresh poultry litter shipment and incubation piles prior to and after construction of the piles. Three subsamples were taken from the prior mixed samples for chemical analysis.

Litter Analysis

All poultry litter samples collected were analyzed to determine the effects of the degradation process on the chemical and physical properties of the poultry litter. Properties analyzed included nutrient concentration, nutrient solubility, mass reduction, and change in carbon forms. Nutrient concentrations were analyzed with air dried poultry litter for Total P, K, Mg, Ca, Na, Mn, Cl, Cu, Fe, Zn, Mo (EPA 3050 acid digestion method with solution analyzed by inductively coupled argon plasma analyzer (ICP-AES) Spectro Ciros, Mahwah, NJ) (Soil, Water, and Forage Analytical Laboratory, Oklahoma State University, Stillwater, OK) and wet litter for Total N and Total C (combustion method, Leco TruSpec St. Joseph, MI). Change in mass was calculated by a using non-volatile, stable element concentrations, in the case of this study P. The total concentration prior to and after completion of the degrading process was used to perform this mass degradation calculation as written below:

$$1-(1/\,({}^{\text{Post conc. P}}/{}_{\text{Pre-conc. P}}))$$

Water soluble phosphorous (WSP) was determined by shaking at a 1:100 (litter:water) ratio with de-ionized water for 1 hr then filtered with a Whatman #42 filter paper before P analysis by ICP-AES (Spectro Ciros, Mahwah, NJ). Ammonium and nitrate were extracted using a 1 *M* KCl solution followed by colorimetric flow-injection analyzer, Lachat (Lachat QuickChem 8000, Loveland, CO). Litter electrical conductivity (EC) and pH were measured using pH and EC probes with a solid:solution ratio of 1:5 and equilibration time of 45 minutes. A sequential phosphorus fractionation was performed using alkaline and acidic extractions from a method modified by Warren et al (2008) to separate and determine the organic and inorganic P concentrations and their solubility. Degree of humification of the litter carbon forms and their changes were analyzed following the method developed by Ciavatta et al. (1990).

Experiment data was analyzed as a Split Split Plot design with 3 replications and 2 treatments. Year was treated as the subplot while the main effect was treatment. Data were analyzed using PROC GLM in PC SAS Version 9.2 (SAS Institute, Cary.NC). Differences in treatments were determined with an LSMEANS statement and significance was determined at a $P \leq 0.05$ level.

RESULTS AND DISCUSSION

Fresh broiler litter collected and used for each year of the study were found to be within the typical range of broiler litters sampled in other studies and overall low variation between years (Table 1.1) (Sharpley et al. 2009). Properties found to be within these normal ranges include dry matter content, pH, E.C., TC, TN, P, K, Ca, Na, Mg, Mn, S, Fe, Cu, Zn, and WSP.

The use of an alternative low-input carbon degradation storage technique resulted in significant reductions in mass in both the normal and alum amended litters. Through this process an 18.1 to 26.9 percent mass loss was observed (Table 1.1) using P concentration as an indicator. The main driver for the change in mass can be attributed to microbial oxidation of the organic carbon pool to CO_2 that was lost through gas exchange. Averaged for each treatment, degradation resulted in a 19.6 and 23.0 percent mass loss for normal and alum degraded litters (Table 1.1). Warren et al. (2008) found very similar results in an incubation study with alum amended at the same rate and mass loss calculated on an actual weight basis. After 63 days they found a mass reduction of 17 and 30 percent for normal and alum degraded litters. They also reported total carbon (TC) losses after the same time period of 23 and 43 percent. Results of our study showed an average TC loss of 22 percent compared to the fresh litter (Table 1). Yet, between the normal and alum degraded litter there was no significant difference in TC losses. Delaune et al. (2006) noted similar losses when degrading animal waste without the use of bulking agents.

The difference in the percent mass loss between the two treatments could ultimately be traced back to the effects of pH change caused by the alum additions. Moore and Miller (1995) found the addition of alum to poultry litter initially lowered the pH of the litter from 7.3 to 5.7 when applied on a 10 percent by weight basis. This effect can be seen in Table 1.1 as the final pH of the alum degraded litter rebounded to around 8.0 but was still significantly lower than other litters. This effect on pH would have an effect on microbial populations as a shift to a more fungi dominated microbe population would occur as found by Rothrock et al. (2008). With this microbe shift comes an increase in lignin decomposition as fungi are known to be more efficient at C utilization than bacteria (Paul and Clark, 1996).This shift in microbe population could explain the difference of mass loss in our own and other experiments looking into alums effects on the litter composting process.

Degradation of the poultry litter resulted in similar N concentration as pre-degradation (Table 1.1). Yet, if the mass degradation is taken into account the losses of N in the degraded piles are appreciable ranging from 16 to 26 % loss of N. The N loss is assumed to occur entirely from N volatilization as the pile was covered and stored under a roof removing the opportunity for N leaching and runoff. DeLaune et al. (2006) found a 53 % N loss from untreated controls with less than 44% loss from alum amended litters. Other studies have also documented large N losses from manure in the composting process (Silva et al., 2009).The prior studies displayed higher rates of N loss due to the higher frequency of turnover/mixing and the fact that their piles were uncovered for the composting period allowing more chance for volatilized N to escape leading to more N volatilization.

Alum degraded litter resulted in N levels not significantly different than those of the fresh litter (Table 1.1). These results were somewhat expected through the use of the alum and its acidifying affects on the litter by preventing the deprotonation of ammonium to the volatile ammonia gas (Moore et al., 1996). Another effect of the alum addition to N concentration is ammonium levels as the fresh and normal degraded litters were not significantly different while the alum degraded litter retained over 40 percent more in the ammonium form (Table 1.1).

Increases in total concentration of non-volatile nutrients in the degraded litters were also observed as an end result of the degradation process and the overall mass loss of the degraded litter (Table 1.1).Warren et al. (2008) observed similar results as the total P concentration of normal and alum degraded litters increased from 17500 and 16300 to 23600 and 25300 mg kg^{-1}, respectively. The 26 % total P increase in the normal degraded litter is similar to our 19.6 % increase while the Warren et al.'s 36 % in total P for alum treated was higher than our 23 % increase. Differences in total P could be a result of different digestion methods used. Silva et al. (2009) also reported increases in P and other nutrients (Ca, Mg, and K) through a litter composting process. Moisture levels at the end of the composting process were not significantly different even though the degraded litters were initially brought up to 40% moisture to initiate the degradation process (Table 1.1).

Inorganic and organic P fractionation determined from the same P fractionation method as Warren et al. (2008) resulted in similar results especially for the H_20 and 0.5 mol $L^{-1}NaHCO_3$ extracts for both the organic and inorganic P based on shifts in P pools (Table 1.2). Addition of alum resulted in shifts in organic P fraction from the H_2O and 1.0 mol L^{-1} HCl extractable into the 0.5 mol $L^{-1}NaHCO_3$ and 0.1 mol L^{-1} NaOH fractions. Inorganic H_20 was dramatically lowered by the alum addition and again P shifted into the 0.5 mol $L^{-1}NaHCO_3$ and 0.1 mol L^{-1} NaHO fractions. Similar shifts were also found by Warren et al. (2008) and Dou et al. (2003). Untreated degraded litter showed a decrease in H_20 extractable P, which does not agree with our WSP data and other studies that show a significant increase in WSP or H_2O extractable P after degradation (Warren et al. 2008). Others parameters falling in line with previous studies suggests that contamination could have played a role in this occurrence. Extraction efficiency from the first 4 sequential fractionation ranged from 97 to 98 %, similar to McGrath et al. (2005) and Warren et al. (2008) extraction efficiencies.

Water soluble P of the poultry litter was significantly affected by the degradation process. Alum additions resulted in 32 % reduction in WSP over the initial fresh litter while normal degraded litter resulted in 31 % increase in WSP (Table 1.1). The degradation process had almost complete opposite effects on WSP depending on the treatment received. Warren et al. (2008) found similar results and with nuclear magnetic resonance (NMR) and sequential P fractionation they attributed the increase in WSP of the normal litter to the transformation of organic P in the form of phytic acid to the soluble P fraction through P mineralization. This transformation resulted in more than doubling of the soluble P pool after 63 day of incubation. As for the alum treated litter they attributed the reduction in WSP not only to a decrease in mineralization of phytic acid but also the absorption of P on newly formed amorphous Al oxides/hydroxides and precipitation of Al phosphate minerals as proven by Peak et al. (2002).

Along with C degradation there was also as shift in the C fractions as the degree of humification increased with litter degradation. This was evident by the decrease in the humification index as a lower humification index means a more recalcitrant C form (Table 1.3). As the fulvic and humic acid increased in concentration, the number of non-humic material decreased. Other research has also shown a decrease in humification index for composted poultry manure mixed with wood chips over a 35 d incubation period (Mondin et al. 1996). The resulting humification index number was very similar to those reported by Ciavatta et al. (1990) for urban compost and Govi et al (1993) for composted sewage sludge. With the increase in degree of humification came the loss of significant foul odors, a darker richer color and a more homogenous end product. The degradation process and the resulting humified end product should allow the litter to become less regulated as a fertilizer product and more as a soil amendment as the increased stability adds to the long term effects of the litter on soil properties.

Value of the poultry litter was significantly increased through degradation over the average value of the fresh poultry litter based on local Coop prices of N, P, and K as April 2010. Value of the natural degraded litter was increased on average by \$5.00 Mg^{-1} through the degradation process (Table 1.4). Addition of alum resulted in more retained N but alum's negative effect on the P concentration was not entirely regained as P value in normal degraded were higher by \$1.00 Mg^{-1}. This is explained by the fact that when you include the mass of alum added to the pile, the higher degree of mass loss of alum degraded litter is actually only a 15.3% mass loss. Also, when the cost of the alum addition is added to the equation the economic value decreases even more. With alum costing \$33.00 Mg^{-1} of fresh litter to treat, it reduces the value of litter far below the value of fresh litter (Table 1.4).

Based on the fact that a semi-load of poultry litter can carry roughly 24 Mg $load^{-1}$ and a fresh litter value of \$75.15 Mg^{-1}, one truck of litter can haul roughly \$1803of fresh poultry litter while \$1929of normal degraded could be hauled. The difference in value amounts to \$125 per truck of litter hauled. With this value increase, litter could be hauled an extra 24 miles in any direction away from the house and/or allow a producer to purchase even more litter with the same money.

CONCLUSION

Through the use of a low-input poultry litter degradation process a more uniform, consistent and more valuable end product was produced. Simplicity, ease, and more importantly cost of the proposed degradation system make it a simple choice over the conventional degradation systems as the only necessary tool required for degradation is the addition of water to 40 % moisture, construction of a cone shaped pile covered with a polyethylene tarp and mixing one time through the degradation process. The process significantly increased total nutrient content of litter and added to the value of the litter. The process also resulted in transformations of more soluble plant available P in the normal degraded litter while the alum treat resulted in less soluble forms of P reducing the chance of P runoff and increased in N retention. However, the cost of the alum addition removes it from economic competition with either fresh or normal degraded litter. The normal degraded litter without any amendments except moisture adjustment produced a $5.00 gain in value per Mg of degraded litter. This increase in value of natural degraded litter can greatly enhance the available market of the poultry litter and increase the litter's economic viability outside poultry production areas and the nutrient sensitive watersheds that surround them were P application has the capacity to be detrimental to ecosystem health and sustainability.

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Table 2.1: Results of Chemical and Physical Analysis (dry weight basis) of Poultry Litter Prior to and after degradation from 2007-2009 at Haskell, OK.

Litter Treatment	% DM[†]	% mass reduction[‡]	pH	TC[§]	TN[¶]	NH_4-N	NO_3-N	WSP[#]	HI[††]	P[§§]	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Bulk Density
				%	%	------ mg kg^{-1} -----				------------------------ mg kg^{-1} ----------------------										g cm^{-1}
2007																				
Pre-degraded	68.7	-	8.6	41.0	4.4	8976	1128	4078	1.49	17408	29897	30163	6583	9933	6723	388	381	261	576	0.29
Normal degraded	72.0	23.2	8.5	33.8	4.1	8307	371	4861	0.94	23801	36707	37460	5920	7643	11860	550	413	422	538	0.40
Alum degraded	73.0	26.9	8.0	35.3	4.3	14804	303	2049	0.89	22097	29673	36797	5180	6857	23537	592	481	510	737	0.42
2008																				
Pre-degraded	65.5	-	8.8	55.5	5.3	8879	2117	3536	1.50	17910	23710	35837	5210	8363	7307	217	381	228	542	0.32
Normal degraded	65.4	15.9	8.9	44.5	4.7	7882	439	5025	1.13	21193	24990	42867	6060	9833	8770	241	402	236	558	0.33
Alum degraded	64.6	18.1	8.1	40.6	5.2	14833	1031	2727	1.15	20118	24763	39276	5633	8993	21700	360	409	245	569	0.35
2009																				
Pre-degraded	64.5	-	8.4	33.2	4.4	10457	133	2184	1.53	17236	19013	34061	4783	6343	5813	592	277	179	593	0.30
Normal degraded	60.0	19.8	8.9	31.2	4.2	6938	139	3043	1.29	21629	22333	42150	5660	7327	6693	788	351	236	719	0.31
Alum degraded	69.4	24.1	8.0	26.8	4.3	15351	183	1375	1.35	18669	25067	45639	6140	8653	24247	1247	353	224	718	0.39

Averages

Pre-degraded	66.2	-	8.6	43.2	4.7	9437	1126	3266	1.51	17509	24207	33337	5526	8213	6614	399	347	223	571	0.30
Normal degraded	65.8	19.6	8.8	36.5	4.3	7709	316	4310	1.12	22197	28010	40805	5880	8268	9108	540	412	327	671	0.35
Alum degraded	69.0	23.0	8.0	34.3	4.6	14996	506	2050	1.13	20285	26501	40549	5651	8168	23161	719	392	297	608	0.38
LSD‡‡	ns	2.7	0.37	7.0	0.31	1796	ns	913	0.25	760	ns	3563	ns	ns	4000	ns	59	ns	ns	ns

† Percent dry matter

‡ Percent of the initial litter mass (not including added aluminum sulfate) that was degraded; calculated based on changes in concentration of a non-gaseous and recoverable element (phosphorus) after degradation

§ Total carbon

¶ Total nitrogen

Water soluble phosphorus

†† HI: humification index. non-humic carbon / (fulvic acid + humic acid). A lower index indicates a greater degree of humification.

‡‡ Least significant difference at P = 0.05. ns; not significant

§§ Total nutrient content (EPA 3051A acid digestion)

Table 2.2: Results of 2009 Phosphorous Fractionation of Poultry Litter Prior to and After Degradation Period of 60 Days.

		Inorganic Phosphorous					Organic Phosphorous						
		H_2O	0.5 mol L^{-1} $NaHCO_3$	0.1 mol L^{-1} NaOH	1.0 mol L^{-1} HCl	Residual HCl	H_2O	0.5 mol L^{-1} $NaHCO_3$	0.1 mol L^{-1} NaOH	1.0 mol L^{-1} HCl	Residual HCl	EPA 3051 Microwave Digestion	Cumulative Litter P
		mg g^{-1}											
Un-Treated Litter	0 weeks	9.3A†a‡	2.0Ab	1.5Aa	7.1Aa	0.16Aa	0.99Aa	1.2Ab	0.57Aa	0.5Aa	0.3Aa	0.09Aa	23.7Aa
	8 weeks	7.0Ab	6.2Aa	0.9Ab	7.4Aa	0.11Aa	0.96Aa	1.7Aa	0.75Aa	0.1Aa	0.3Aa	0.10Aa	26.6Aa
Alum-Treated Litter	0 weeks	1.6Bb	3.4Ba	1.5Aa	6.0Aa	0.12Aa	0.16Ba	1.0Aa	4. 9Ba	0.7Aa	0.3Aa	0.07Aa	19.8Ba
	8 weeks	4.1Ba	3.1Ba	1.1Ab	8.3Aa	0.07Aa	0.13Bb	1.1Ba	4.9Ba	0.2Aa	0.3Aa	0.05Aa	23.4Aa

†Means followed by the same upper case letters are not significantly different at the 0.05 alpha level between treatments and same degradation state.

‡Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between degradation states.

Table 2.3: Results of Degree of Humification on Poultry Litter pre-degraded, degraded, and alum amended degraded.

	LSD Between Treatments	Pre-degraded	Normal degraded	Alum degraded
2007		1.49	0.94	0.89
2008		1.5	1.13	1.15
2009		1.53	1.29	1.35
HI‡	0.25	1.51B†	1.12A	1.13A

†Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

‡ Humification Index: non-humic carbon / (fulvic acid + humic acid). A lower index indicates a greater degree of humification.

Table 2.4: Economic Value of Fresh, Natural Degraded, and Alum Degraded Litter based on Inorganic Commercial Fertilizer Value.

	Fresh Poultry Litter†	Natural Degraded Litter‡	Alum Degraded Litter§
Nitrogen Value ($ Mg^{-1})	29.94	24.04	25.71
Phosphorous Value ($ Mg^{-1})	22.76	28.86	26.37
Potassium Value ($ Mg^{-1})	22.45	27.48	27.31
Gross Value	75.15	80.38	79.39
Treatment Cost	-	-	-33.00
Total Net Value	75.15	80.38	46.39

† Fresh poultry litter has no amendment exactly as it comes out the production facility.
‡Natural degraded litter was adjusted in 40% moisture, turned once, and covered for 60 days under a barn.
§ Alum degraded litter was adjusted in 40% moisture, alum added on 10% by weight basis, turned once, and covered for 60 days under a barn.

CHAPTER III

EFFECTS OF INORGANIC FERTILIZER AND POULTRY LITTER AMENDMENTS ON THE SOIL CHEMICAL AND PHYSICAL PROPERTIES OF NUTRIENT DEFICIENT SOILS IN OKLAHOMA

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Abstract

Poultry litter additions to nutrient deficient soils are common practice for increasing soil quality and fertility for crop production. However, few studies compare inorganic commercial fertilizer and poultry litter applied at equal N, P and K rates to accurately interpret litter effects. The objectives of this study were to quantify changes in soil quality (chemical and physical) as impacted by the application of equal rates of inorganic commercial fertilizer, poultry litter, and degraded litter on potential bio-fuel crops. The effects of fertilizer type on soil qualities under bermudagrass [*Cynodon dactylon L.*] and sweet sorghum [*Sorghum bicolor (L.) Monech*] plots were investigated in Haskell, OK on Taloka silt loam and Woods County, OK on Eda loamy fine sand (sorghum only). After three years of application (Woods only 2 yr.) few significant differences in equally

applied nutrients were observed between fertilizer types for soils at all sites and crops. Soil test P for all rates except the lowest litter rate on sorghum resulted in concentrations exceeding recommended agronomic sufficiency level of 32 mg STP kg^{-1}. Water soluble P was not significantly affected by fertilizer types, only rate applied. Both degraded litters resulted in similar nutrient concentrations as higher applied fertilizer rates due to higher litter nutrient content. Alum treated degraded litter WSP concentrations were close to 50 percent less than similar P application rates, while no difference was observed between STP at equal rates. Litter treatments resulted in increased soil pH, whereas significant decreases resulted from inorganic application from the control. Increases in Mg, Ca, Cu, S, and Zn were observed in the top 5 cm soil profile from litter application to all sites. Poultry litter application produced all positive increases in soil quality as inorganic commercial fertilizer with the addition of other positive effects that increase long term sustainability of bio-fuel crop production.

INTRODUCTION

Arkansas and Oklahoma combined produced over 1.4 billion broilers for sale in 2007 alone, with Arkansas producing over ninety-five percent of these birds (Natl. Agric. Stat. Serv., 2007). With each bird producing on average 1.1 kg of waste a year (Malone et a., 1992), resulting in roughly 1.54 million Mg of poultry broiler litter to be disposed of each year in Arkansas and Oklahoma alone. The majority of poultry production in Oklahoma occurs in eight counties located in far eastern Oklahoma along the Arkansas border (Britton and Bullard, 1998) and a large portion of Arkansas production occurs in the northwestern part of Arkansas. These areas in northeastern Oklahoma and northwestern Arkansas are host to multiple river and water systems that are facing problematic results caused by the application of decades of animal waste to pasture and cropland. Two of the most discussed watersheds affected in these areas are the Eucha/Spavinaw Watershed and the Illinois River Watershed (Moore and Edwards, 2005). These problems are often attributed to the increasing concentration of confined animal feeding operations (CAFOs) in these areas that have occurred over the past few decades. The importing of large quantities of nutrient rich animal feed from outside the farms creates this problem as a majority of nutrients imported are left behind as animal waste to be land applied locally. Long-term manure applications have been show to increase soil concentrations of P, K, Ca, Mg, Cu, and Ni when compared to inorganic fertilized pastures (Kingery et al., 1993; Sharpley et al., 1993; Shuman and McCracken,;

1999; Nyakatawa et al., 2001; Mitchell and Tu, 2006). Increases in P and other nutrient concentrations in soil is due to an over application of these nutrients versus the actual plant uptake and removal, which is due to application based on nitrogen (N) needs alone. Poultry litter produced in the United States usually possesses an average N-P-K ratio of 3-3-2.5 (Zhang et al., 2009b). This ratio in comparison to most plant uptake ratios leads to soil P build up since as only a fraction of applied P is actually removed. Phosphorous build-up leads to the decreased ability of soil to retain applied P, resulting in more P loss and not only does soil lose P holding capacity but now the soil itself can become a source of P into the sensitive watershed environments.

The application of poultry litter based on plant available nitrogen (PAN) requirements to the lands surrounding these areas has led to increased soil test phosphorous (STP) beyond crop requirements and soil P capacity creating a risk for offsite movement to nearby streams resulting in eutrophication, thereby causing decreased water quality, foul odor, and poor taste (Moore and Edwards, 2005). One solution to this problem is the movement of the nutrient dense litter to areas outside of these watersheds. The nutrient deficient soils that cover a wide area of Oklahoma are an exceptional area to land apply poultry litter and add to the already strong case for the justification of movement of poultry litter out of these watersheds. Economics plays a dominant role in litter movement with cost of transport reducing viable transport distance. Composting of litter has been suggested as an option to reduce transportation cost by decreasing overall mass. Agricultural and environmental misconceptions that limit litter use can be overcome by showing the true effects of litter on Oklahoma soils and crops compared to the currently accepted methods of fertilization. Not only will increased production in these areas brought on by the use of poultry litter lead to increased economic returns but also better prepare Oklahoma for a possible future in bio-fuel crop production.

Poultry litter is a mixture of poultry manure and bedding materials, usually rice hulls or woods chips that is a by-product of poultry production (Edwards, 1992). The mixture is produced by the use of the same bedding material for multiple flocks and is usually removed after one year of production (Moore, 1998). Poultry litter contains essential plant nutrients consisting of macro (N, P, K), secondary macro (Ca, S, Mg) and micro (Cu, Mn, Mo, Zn, Fe, B, Cl, Ni) nutrients (Edwards, 1992; Wilkinson, 1979). Poultry litter is considered to be the most valuable of all animal waste for application as a soil amendment with its diverse and more importantly high concentration of nutrients (Wilkinson, 1979).

Wood et al. (1993) found that using poultry litter as fertilizer for bermudagrass to be “an excellent sustainable agricultural practice”. When soils fertilized with organic materials (manure) are compared to those using inorganic fertilizers in long term studies, they have been shown to increase organic matter, number of microfauna, P, K, Ca and Mg; lower bulk density, higher porosity, and increase aggregate stability, while showing no difference in yield between fertilizer type (Edmeades, 2003). Moore and Edwards (2005) showed that poultry litter applied to soils resulted in increased soil pH over the control, while inorganic N treated soils decreased in pH. The authors concluded that pasture application of poultry litter as a fertilizer source is more sustainable than using inorganic commercial fertilizer.

Composting of manures can potentially increase value (on per weight basis) by reducing mass and increasing nutrient density. Dao (1999) observed as much as 50 % mass loss through composting of manure. Sweeten (1980) found that composting animal manures results in reduced volume, weight, weed seed viability, and odor. Composting of manures and waste immobilizes N and produces a more humified substance that is a better soil amendment and works as a natural slow release fertilizer (Paul and Clark, 1996). Some problems associated with composting of litter are the loss of N and the resulting decrease in N/P ratio, which adds to the application/ plant use problem of P. Delaune et al. (2006) found composting poultry litter without the addition of bulking agents and the addition of alum results in more retained N compared to normal composting and less soluble forms of P in litter and runoff. Warren et al. (2008) found soils treated with alum amended litter to possess more P in a recalcitrant form that persists in the environment as a less soluble P form.

The primary objectives of this study are to (1) quantify changes in soil quality (chemical and physical) effected by the application of inorganic commercial fertilizer, poultry litter and degraded poultry litters at equal nutrient rates.

Material and Methods

Study location and treatments

A 3 year study was established at two locations in the spring of 2007 with two plots at Oklahoma State University's Eastern Oklahoma Research Station located south of Haskell, OK (35 44' 46" N, -95 38' 23"W) and 2 years (weather limited) of production from a plot located west of Aline, OK in Woods County (36 29' 25" N, -98 40' 24" W).

Plots were established on a Taloka fine mixed, active, thermic, mollic, Albaqualfs at Haskell and Eda mixed, thermic Lamellic Ustipsamments at Woods County. Taloka soils are described as very deep, somewhat poorly drained, very slowly permeable soils that formed in loamy and clayey material weathered from colluvium and alluvium over interbedded shales and sandstone. Eda soils consist of very deep, somewhat excessively drained, rapidly permeable soils that formed in sandy eolian deposits on dunes. The Haskell site has on average 215 growing days, average temperature of 15.5^{o}C, and 1130 mm of precipitation a year. Woods County site has on average 191 growing days, average temperature of 14.3^{o}C, and 683 mm of precipitation a year. These sites were chosen as background soil nutrient levels showed deficiencies of N, P, and K for crop production allowing for better interpretation of effects litter and commercial fertilizer affects on target nutrient deficient soils.

The experiments were designed as a completely randomized block design with 4 repetitions and 11 treatments. Plots were 3 m wide by 9 m in length with 3 m alleys between repetitions. The single site in Woods County and one of the sites in Haskell were planted to sweet sorghum (*Sorghum bicolor* (L.) Moench) using conventional tillage system with the variety Topper for all three years of the experiment, seeded at a seeding rate of 52,000 plants ha^{-1}, spaced on 76 cm rows. The other site at Haskell was an established bermudagrass (*Cynodon dactylon L.)* hay pasture. The 11 treatments consisted of fresh poultry litter, commercial fertilizers, degraded poultry litter, and a control for each repetition. Poultry litter and commercial fertilizer were amended at 4 different rates (A, B, C, D; Table 3.1-3.3) with equal N, P, and K addition. However, degraded litter was only applied at rate C (Table 3.1) due to limited quantities. Poultry litter was surface in the bermudagrass plots while the sweet sorghum was incorporated with field cultivator to a depth of 7.5 cm. Fertilizer source used for the commercial fertilizers included urea, di-ammonium phosphate and potash in granular form.

Fresh litter was started in a low-input degradation system 2 months prior to application of fertilizer. The degraded litter consisted of two degradation treatments both treated exactly the same way except for addition of alum on a 10% by weight basis, which is discussed in more detail in Chapter 2. When the degraded piles were initiated, fresh litter for later applications was collected, weighed out and refrigerated for 2 months prior to field application in the second week of May every year.

Weeds were controlled in the sweet sorghum with pre and post emergence application of atrazine (Atrazine 4L Makhteshium Agan, Inc. Raleigh, NC) depending on need at 1.1 kg ha^{-1} and a post emergence application of glyphosate (Round-up Power-Max, Monsanto , St. Louis, MO) at 200 g ha^{-1} with a backpack hooded sprayer when needed through the crop season. Accepted best management practices were used in bermudagrass plots to maintain the best weed free environment possible with these accepted practices (Redfearn et al. 2009)

Physical and Chemical Analysis

Soil samples were taken every fall within a month of the last biomass harvest. Soil samples were taken at three depths: 0-5 cm, 5-15cm, and 15-30 cm. Ten to twelve cores were taken with a 2.54 cm diameter soil probe from each plot, mixed thoroughly in a plastic bucket and a sub-sample removed for analysis. Sub-samples were then dried at 35 C° for 3 days and ground to pass through a 2 mm screen before extraction and analysis of plant available P, K, Mg, Ca, Na, Mn, Cl, Cu, Fe, Zn, Mo (Melich III extraction with solution analyzed by inductively coupled argon plasma analyzer (ICP-AES) Spectro Ciros, Mahwah, NJ) and total nitrogen (TN) and total carbon (TC) (combustion method, Leco TruSpec St. Joseph, MI, Oklahoma State University Soil, Water, and Forage Laboratory). Water soluble phosphorous (WSP) was determined by shaking at a 1:10 (soil:water) ratio with de-ionized water for 1 hour then filtered by a 0.45 um filter before P analysis by ICP-AES (Spectro Ciros, Mahwah, NJ). Ammonium and nitrate were extracted using a 1 *M* KCl solution followed by colorimetric flow-injection analyzer, Lachat (Lachat QuickChem 8000, Loveland, CO). Litter electrical conductivity (EC) and pH were measured using pH and EC probes with a solid:solution ratio of 1:2 and equilibration time of 45 minutes.

Aggregate stability samples were taken in the fall of 2009 by breaking loose, uncompressed soils from each plot with a shovel at 0-10 cm depth for wet-aggregate stability analysis (Yoder, 1936; Low, 1954). Before drying, these soils were sieved through a 8 mm sieve. After sieving they were allowed to air dry. After samples were known to be dry they were placed in wet-sieving apparatus that consisted of 5 sieves (4mm, 2mm, 1mm, 0.5 mm, and 0.25mm). Soil was pre-wetted for 10 minutes by lowering sieves into distilled water until water was just covering the soil on the upstroke. Soils were then wet sieved for 10 minutes at 30 rotations a minute. Afterwards the soil was removed, dried, and weighed out based on final sieve location. Results were reported as final soil mass in each individual sieve and geometric mean diameter (GMD; median particle size on a weight basis using the formula from Mazurak (1950).

Bulk density was also sampled in the fall of 2009 using the core method with 7.62 by 7.62 cm rings that were hammered into the ground with a rubber mallet. The inside soil was removed, bagged, and dried at 35°C for 3 days or until dry and weighed to calculate bulk density.

Experiment was analyzed as a Randomized Complete Block design with 4 replications and 11 treatments. Soil quality parameters were measured with years independent. Data were analyzed using PROC GLM in PC SAS Version 9.2 (SAS Institute, Cary.NC). Differences in treatments were assessed with an LSMEANS statement and significance was determined at a $P \leq 0.05$ level.

Results and Discussion

Soils collected and analyzed from plots prior to treatment application revealed typical soil properties for all three sites (Table 3.2). The sites all possessed nutrient deficiencies of soil test N and K with P deficiencies only present at Haskell sweet sorghum site when compared to Oklahoma State University optimum nutrient requirements for the proposed crops of 32.5 mg P kg^{-1} and 125 mg K kg^{-1}(Zhang and Raun, 2006). The low fertility status soils are likely to show a response to the various amendments tested.

Above average rainfall was recorded for the first two years at the Haskell site while the third year resulted in below average rainfall during the growing season (Figure 3.1). Rainfall during the growing season at Woods County in 2007 was above normal, while 2008 resulted in a lost crop due to insufficient rainfall (Figure 3.2). After the loss of the sweet sorghum crop, a winter wheat crop was planted in November of 2008 that was also lost due to insufficient moisture. For these reasons the use of this location was discontinued the final year. Soil samples for the second year were still taken and analyzed for the effects of treatment application.

Soil pH

Soil pH at all three sites increased or remained steady when compared to the control with the application of poultry litter in any form, while application of commercial fertilizer resulted in a significant reduction in final soil pH (Figures 3.3-3.5). Maintenance or increases in soil pH with the addition of litter agrees with numerous other studies conducted in other states/climates (Mitchell and Tu, 2006; Sharpley and Bain, 1993; Hue, 1992). High rates of inorganic commercial fertilization (urea) produced significant decreases in soil pH that agree with results of Moore and Edwards (2005). At the highest rate of urea application (rate D) at least a half unit decrease in pH was observed for all sites after 3 years (Table 3.5-3.7). The use of inorganic N sources are known to result in decreased pH through nitrification of ammonium. The most significant increases in pH were observed in the higher rates of poultry litter application. The increase in pH can be attributed to the addition of alkalinity ($CaCO_3$) and organic matter (OM) in poultry litter that have the ability to neutralize acidity, and complex Al. Hue (1992) found poultry litter to be as effective as $Ca(OH)_2$ in neutralizing the acidity of soils in Hawaii. The more significant increase in pH at the Woods site can be attributed to the sandy, poorly buffered soil, while the Haskell silt loam had a greater buffering capacity. The addition of degraded alum litter resulted in no significant change in pH at either site (Figure 3.3-3.5) as the result of the initial alum addition prior to the degradation process. Prior addition of alum resulted in decreased pH and neutralization of litter alkalinity which decreases liming potential of litter compared to fresh and degraded normal litter (Moore et al., 1999). Changes in pH at the lower soil depths were insignificant as a result of treatment for all sites with expected increases in pH as a function of depth (Table 3.5-3.7).

Soil Test Phosphorus

Haskell Bermudagrass

Three years of P fertilizer application resulted in significant increases (relative to the control) in P concentration at the 0-5 cm depth in every treatment of bermudagrass except the lowest litter application rate (Figure 3.6). The 0-5 cm STP increased from 33 mg kg^{-1} to over 120 mg kg^{-1} after 3 years of application of 268.6 kg P ha^{-1} of inorganic P. The use of poultry litter applied at the same rate was only increased to 120 mg STP kg^{-1} after 3 applications (Table 3.8). Increase of STP over 120 mg kg^{-1} is a very significant increase as this concentration is almost double the sufficiency value for STP suggested by OSU for bermudagrass production. Also all STP values are still well below the limits set by the NRCS for litter application in both nutrient limited and non-limited watersheds (NRCS, 2007). Soil test P for poultry litter applied at the highest rate at the 0-5 cm depth were significantly less than the inorganic fertilizer applied at the same rate (Table 3.8). The difference is likely a result of P availability of poultry litter compared to inorganic forms that are completely soluble when initially applied, while poultry litter is assumed to be 90% available at the most liberal estimates. When STP changes are compared to the McGrath et al. (2010) study that applied litter similar to our low application rates over 2 years, increases were very similar over the same time span and application rate.

Normal and alum degraded litters resulted in similar final STP concentration as fresh litters applied at the same rates (Table 3.8). Degraded alum treated litter resulted in no difference in STP versus fresh litter P agreeing with results of Warren et al (2006) showing no difference in P availability between alum and untreated litters applied to soils. Alum treatment inhibited the movement of P as less STP is found in the lower depths unlike the normal poultry litter (Table 3.8). Reduction in downward P movement in degraded alum treated litter is a result of alum treatment and the reduction in P availability through decreased P mineralization and formation of insoluble Al phosphates (Warren et al., 2008). Significant increases in P concentration relative to the un-amended control were seen at the 5-15 cm depth after the second year and an even greater difference after the third year of application, especially at the higher rates (Table 3.8). At the 15-30 cm depth, increases in P concentration relative to the un-amended control were not significant until the third year of fertilizer application (Table 3.8). The 5-15 and 15-30 cm depths in all treatments were not significantly different from each other while the 0-5 was significantly different from the lower depths (Table 3.8). Kingery et al. (1994) found similar amassing of P in the top 15 cm of soils in Alabama over decades of litter application in sandy soils. With given time and continued applications these soils should lead to a similar trend as the P will slowly leach from the top 0-5 cm into the lower profile.

Haskell Sweet Sorghum

Soil test P at the 0-5 cm depth significantly increased in concentration at the higher application rates over the control in all 3 years of the study (Figure 3.8). A final STP concentration of 90 mg kg^{-1} was reached at the highest application rate, 180 kg P ha^{-}

^{1} yr^{-1}, over the initial 8 mg STP kg^{-1}. Significant differences were not observed between organic and inorganic applied fertilizer, only rates applied. This differs from bermudagrass where organic applied fertilizer resulted in lower STP levels than inorganic at the higher rates. Also this could be a factor of the initially lower STP levels in the sweet sorghum plots at Haskell This difference could be a result of error in analysis of litter and over application of P in the inorganic form. But with smaller increases in bermudagrass STP at the 0-5 cm depth this reasoning loses validly and suggests the possibility of P loss due to runoff in the un-incorporated bermudagrass plots. Increases in STP concentration at lower depths were seen in sweet sorghum compared to the bermudagrass. It is reasonable to assume the increased STP concentrations at the lower depths in the sorghum plots are due to the mixing action of a conventional tillage crop production system.

Degraded litter followed similar trends found in bermudagrass application (Table 3.9). Like the bermudagrass plots the 5-15 and 15-30 cm depths in all treatments were not significantly different from each other while the 0-5 cm were significantly different from the lower depths (Figure 3.8).

Woods Sweet Sorghum

Soil test P after 2 years was significantly increased as a result of P application (Figure 3.9). Final STP after 2 years of application were raised 85 mg kg^{-1} over the initial concentration of 34 mg kg^{-1}, at the highest rate of application (Table 3.10). Significant differences were observed between inorganic and organic amendments at the same application rate with inorganic applications resulting in higher STP concentrations.

This can again be attributed the difference in P availability of organic fertilizer. Applications resulted in at least a doubling of STP over the control in every treatment after 2 years of application. Degraded normal litter was not statistically different than the high rate of inorganic application (Figure 3.9). Degraded alum litter resulted in slightly less STP after 3 years of application but was still statistically the same as the highest rate of fresh litter applied. Soil test P increases were more pronounced in the 5-15 soil depth in the Woods sites than Haskell (Figure 3.9). High levels of STP at lower depths in the Woods sites over Haskell sites can be attributed to the difference in soil type (sandy loam vs. silt loam) and the corresponding P buffer capacity and susceptibility to leaching.

After three years, every application rate of poultry litter and commercial fertilizer STP for all sites increased above the agronomic sufficiency level of 32.5 mg STP kg^{-1} accepted for most crop production in Oklahoma, except for the lowest litter application rate at Haskell sweet sorghum (Zhang and Raun, 2009). With no difference in P availability between the two sources, environmental concerns for poultry litter can be given no more criticism than inorganic P fertilizer sources. Continuous application at the highest rate should not be necessary when agronomic sufficiency levels for P and K can be obtained after only 2 years of application with NL-D rate for sweet sorghum or lower rates for bermudagrass. Once these sufficiencies are reached it makes sense to switch to an inorganic N oriented fertilizer system without excess application of P and K until deficiencies return, especially in nutrient sensitive environments.

Water Soluble Phosphorus

Haskell Bermudagrass

Water soluble P at the 0-5 cm depth showed a significant linear increase with fertilizer application rate (Figure 3.10). Both the organic and inorganic P fertilizers applied at the highest rate, 268.6 kg P ha^{-1} yr^{-1}, resulted in 17.9 mg WSP kg^{-1} after 3 years of application (Table 3.11). Increases in WSP at the lower application rate were similar to McGrath et al. (2010) as they reported an increase from 2.9 mg kg^{-1} to 10.3 mg kg^{-1} over two years of application of 51 kg ha^{-1} of poultry litter P a year. At a concentration of 17.9 mg kg^{-1} these soils are well above the environmental threshold suggested by Maguire and Sims (2002) of 8.6 mg WSP kg^{-1}. Few significant differences between fertilizer types were observed after the first year of application and then almost doubling of soluble P for the following 2 years after application in most treatments (Figure 3.10). Poultry litter and inorganic fertilizer were not significantly different when compared at equal P application rate. Degraded normal litter plots WSP concentrations were similar to the highest rates of fertilizer application (Figure 3.10). Degraded alum treated (CAL) litter plots displayed WSP concentrations at 0-5 cm depth similar to P applied at half the rate (Figure 3.10). At even lower depths degraded litter had WSP concentration similar to the control. Again this is due to the same chemical function as alum on STP. Over 3 years of application increases in WSP in the 5-15 cm depth were observed at the higher rates, especially degraded normal litter (Table 3.11). Increase in WSP at lower depths at higher rates is expected as the soil becomes saturated at higher depths and P has a greater chance of leaching. Overall WSP between depths is not significantly different between the 2 lower depths while the 0-5 cm depth is higher (Table 3.11).

<u>Haskell Sweet Sorghum</u>

In the first year of application a significant difference between the control and P application treatments was only observed for the two highest P application rates and the CNL (Figure 3.12). The second year results showed further increase in the difference between the control as the two lowest inorganic and organic P rate were the only rates that were not significantly different from the control. The final year of application resulted in all treatments significantly different from the control except the lowest P rates for both fertilizer types (Figure 3.13). Concentrations of WSP for the highest application rate were increased from 3 mg kg^{-1} to 12 mg kg^{-1} with 3 applications (Table 3.12). There were no significant differences in WSP concentrations between P sources (Figure 3.12). Warren et al. (2006) also found no differences in WSP between litter and inorganic P sources applied at the same rates. Water soluble P for the degraded alum treated litter (CAL) was again similar to the lower rates of P application (Table 3.12). Greater numerical increases in WSP concentrations were observed for sweet sorghum over the bermudagrass the 5-15 cm depth (Table 3.12). Sweet sorghum also produced increase in WSP at the 15-30 depth in all treatments over the control, except for the alum degraded litter and lower rates of P application (Table 3.12).Greater increases in WSP concentration for sweet sorghum over bermudagrass can be assumed a result of the mixing of the soil by tillage as P was physically moved into the lower profile. Water soluble P between the two lower depths was not significantly different while the 0-5 cm depth was different from the lower depths, over double for most rates (Table 3.12).

Woods Sweet Sorghum

After the first year of application, P applied at highest rates resulted in significant increases in WSP over the control (Figure 3.14). Water soluble P increased from 5 mg kg^{-}

^{1} to 14 mg kg^{-1} after 2 applications at the highest rate (Table 3.13). A significant difference between organic and inorganic P sources was not present (Figure 3.14). In year two all treatments resulted in significant increases over the control. This difference from the Haskell sites is expected as the sandier soil at Woods has less ability to absorb P and more chance for P movement through the soil as was seen in STP results above. Again the degraded alum (CAL) treated litter resulted in solubility similar to the lower rates of applied P (Figure 3.14). Increased WSP distribution over all depths and especially the lower depths in Woods over both sweet sorghum and higher P application rates of the bermudagrass sites in Haskell reaffirm the lower P sorption capacity of sandy soil and as a result a clear P leaching trend is present (Figure 3.15). The use of degraded alum treated litter (CAL) could be useful in nutrient sensitive areas by reducing P movement and allowing for more economical higher rate of application to meet plant requirements.

Increases in WSP for all treatments at the 0-5 cm depth were observed after 3 years of application leading to increased risk of offsite movement of P. There was no significant difference between poultry litter and inorganic phosphate effects on WSP. The above results assure that neither fertilizer is safer than the other for use in environmentally sensitive areas and proper precautions must be taken for application of either fertilizer source.

Potassium

<u>Haskell Bermudagrass</u>

Increase in soil test K was not significantly different between treatments and the un-amended control for the first 2 years of study (Figure 3.16). Only after 3 years of application was there a significant difference from the control produced in the high litter rate applications (Figure 3.16). The highest increase in K concentration was seen for the CNL with a final concentration of 142 mg kg^{-1} compared to the control of 78 mg kg^{-1} (Figure 3.16). Degraded normal litter increasing the most in K was not unexpected as the degradation process increased the concentration of litter nutrients above the other sources as it was applied on N content only. Our increase in K agrees with other studies that utilized poultry litter (Reddy et al., 2008), yet the reason behind the lack of change in inorganic application is not entirely understood. The inorganic applications do increase over time with increasing application rate but they lack a significant trend that should be present. Explanation of this could be assumed from a loss of nutrients into the lower profiles below our sampling depths or the higher crop yields resulting in more nutrient removal. Another explanation could be an underestimation of K in the litter and unequal rate applications. Reddy et al. (2008) produced a significant increase in K of composted litter over the fresh application when applied on an N basis. The current study also resulted in similar increases just not on a statistical basis. Greater increases in degraded litter were expected as K concentration increased in litter due to the degradation process while the N level remained relatively steady, which dictated application rate. No significant differences in soil test K were seen at the lower depths.

<u>Haskell Sweet Sorghum</u>

Results of Haskell sweet sorghum displayed a clear trend in K increase at 0-5 cm depth with application rate (Figure 3.17). Like bermudagrass, K increases were still more significant for poultry litter applications and even greater for the degraded litters. Difference between fertilizer type K increases can be assumed from higher biomass yields and more plant removal of K. No significant differences in soil test K were seen at the lower depths between the control and fertilizer treatments.

Woods Sweet Sorghum

Woods sweet sorghum differed greatly from the Haskell sites as both organic and inorganic K sources increased in relationship to fertilizer application rates (Figure 3.18). No difference in K concentration as a factor of fertilizer type for Woods can reassure the plant removal reasoning for the lower K concentration in Haskell sites treated with inorganic K additions. Plant removal at Woods was significantly less and no crop was removed for the final year. Meaning less K was taken up and removed from the site explaining the higher concentration in the soil for both treatments. More evidence for this reasoning is the lack of apparent movement of K in the Woods sandy soil. No significant differences in soil test K were seen at the lower depths between the control and fertilizer treatments.

Calcium, Magnesium, Sulfur, Copper, Zinc

Calcium, Magnesium, Sulfur, Copper, and Zinc concentration were significantly increased at each site when poultry litter was applied compared to the control and inorganic fertilizer applications (Figures 3.19-3.33). Increases in these nutrients were expected due to litter composition. Results agree with Mitchell and Tu (2006) as they reported significant increases in the same nutrients on both a 3 and 10 year study of poultry litter application to a cotton and corn production system. Adeli et al. (2009) also saw increase in Melich III extractable Mg, Cu, K, and Zn after 3 years of application. No significant differences in these nutrients were seen at the lower depths. Significant changes in Ni, Mn, TN, and TC concentrations were not present.

Iron

Increases in Melich III extractable Fe were greatest for the inorganic commercial fertilizer application (Figure 3.34-3.36). Increases in Fe concentration among litter applications were for the most part insignificant when compared to the control except for high rates applied on Haskell sweet sorghum. Increases in Fe concentration of urea applied plots are most likely the result of the reduction in pH by nitrification of ammonium. Decreases in pH are known to increase solubility of Fe. No significant differences in soil test Fe were seen at the lower depths.

Aggregate Stability and Bulk Density

Aggregate stability plays a critical role in water availability, root growth, and resistance to erosion. Soils possessing greater aggregate stability at the "surface are more resistant to water erosion than other soils, both because soil particles are less likely to be detached and because the rate of water infiltration tends to be higher on well aggregated soils" (NRCS, 2001). Aggregate stability was only analyzed for the Haskell sites. Haskell sites were analyzed on the basis that they posed a greater chance of displaying a change in aggregate stability with 3 years of litter applications. The Haskell bermudagrass site showed relatively few statistical differences in aggregate stability between treatments (Figure 3.37). The treatment with the highest aggregate stability geometric mean diameter (GMD) was the CNL treatment. These results are not unexpected as the addition of degraded litter with its greater degree of stable carbon forms has the greatest ability to increase total carbon which holds a strong relation to aggregate stability (Haynes et al., 1991).

Sweet sorghum litter application results showed a significant increase in aggregate stability with litter treatment over inorganic fertilizer (Figure 3.38). The higher rates of fresh litter and CNL produced the greatest increase in aggregate stability. Increase in aggregate stability can be attributed to the added organic matter of the litter. The higher rates of inorganic fertilizer application produced a trend of decreasing stability when compared to the control, although not significant (Figure 3.38). Adeli et al. (2009) reported litter application to corn-cotton cropping systems resulting in increased aggregate stability while inorganic application resulted in no change from the control over 3 yrs.

Bermudagrass and sweet sorghum GMDs were different with almost 3 times the average size for the bermudagrass over the sweet sorghum. Control treatment of the sweet sorghum averaged a GMD of 0.35 while the bermudagrass had a value above 1.0. This difference would be expected as the conventional tillage used in our sweet sorghum production is known to decrease aggregate stability (Brady and Weil, 2008).

Haskell bermudagrass showed a numerical decrease in bulk density with poultry litter additions compared to inorganic additions (Figure 3.39). However, none of these increases were statistically significant (Figure 3.51). CNL and NL-A showed the greatest decrease in BD over inorganic application. This lack of any trend in the above results may be due to the pasture cropping systems as grasses produce more stable carbon forms and more plant matter was returned (soil organic carbon is closely related to BD) than the sweet sorghum plots as root matter and continued plant growth (Haynes et al., 1998).

Haskell sweet sorghum plots showed only a numerical decrease in BD with increasing rate of litter application (Figure 3.40). Brye et al. (2009) and Adeli et al. (2009) found similar results from the application of litter to row crop systems, a decrease in BD but with no statistically significant trend. Comparison of actual BD results between crops was as expected since BD for sweet sorghum was 0.15 g cm^{-3} greater than the bermudagrass. Conventional tillage is known to increase bulk density of soil through loss of structure and organic matter (Brady and Weil, 1998). As these trends are just starting to emerge it would be expected that in a few more years of applications these differences would become significant.

Conclusion

The addition of poultry litter and commercial fertilizer at identical P and K rates resulted in very similar soil test concentrations of the applied nutrients. Soil test P was increased above the recommend agronomic sufficiency level (32 mg STP kg^{-1}) after only two years of application for the two highest rates. After three years of application all rates surpassed the sufficiency level for P, except the lowest litter application in sweet sorghum. The use of poultry litter also produced a more sustainable effect on soil pH when compared to inorganic N as pH increased with litter additions. These results are opposite of the negative decreasing effects of inorganic N application, which can lead to the need for lime additions to correct the decreased pH. Increases in other soil nutrients (Mg, Ca, Cu, S, Zn) in Oklahoma soils produced results very similar to others studies conducted throughout the United States. Increase in these secondary macro and micro nutrients will hold more value in a future bio-fuels production systems as complete removal of biomass will lead to long-term depletions of nutrients. Water soluble P was not significantly affected by the type of P applied, only rate applied. Results from this study assure that neither fertilizer is safer than the other for use in environmentally sensitive areas and proper precautions must be taken for application of either fertilizer source, especially in nutrient sensitive areas. Degraded natural litter resulted in soil nutrient increases similar or higher than fresh litter or inorganic fertilizer applications at the same or higher rates. Both the normal degraded and alum degraded litter reported similar soil nutrient contents as the other treatments as result of increased nutrient density due to the degradation process. The use of degraded alum litter reduced the chance of offsite P movement while still supplying equally sufficient levels of soil test P compared to equally applied P rates. Use of this technique could be very useful in nutrient sensitive areas where P deficiencies are present and the cost warranted due to the risk and potential reduction of environmental contamination.

Soil physical properties were positively affected by addition of poultry litter in all forms. Both bulk density and aggregate stability showed improvement in quality over the commercial fertilizer. The effects were not significant but the trends were starting to appear and continued application will most likely result in significant trends appearing.

The above results demonstrate the usefulness of poultry litter application to soils found throughout the state of Oklahoma. Poultry litter application should be added to every farmers list of available sources for crop nutrients and seriously considered for supplying farmers long term non-N needs.

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Figure 3.1: 2007-2009 Haskell Mesonet Station Monthly Rainfall Data Compared to the 30 Year Average.

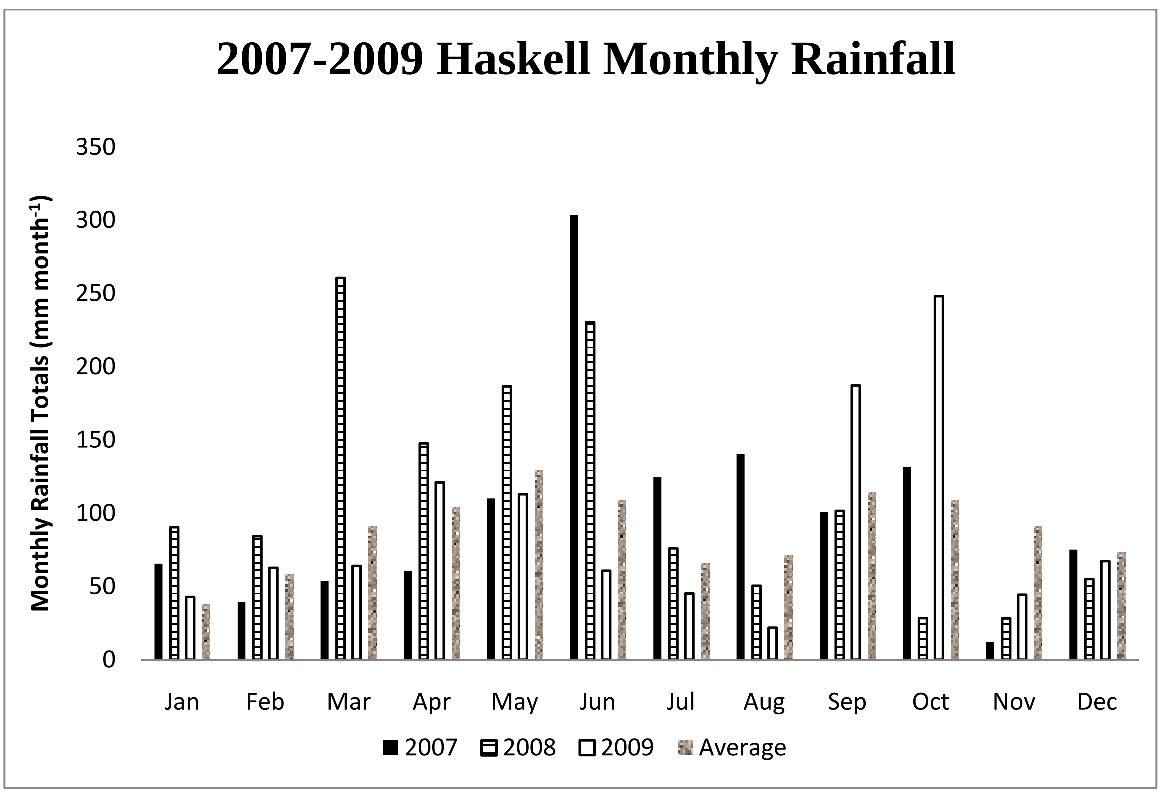

Figure 3.2: 2007-2008 Woods County Monthly Rainfall Data taken from the Cherokee, OK Mesonet Station Compared to the 30 Year Average

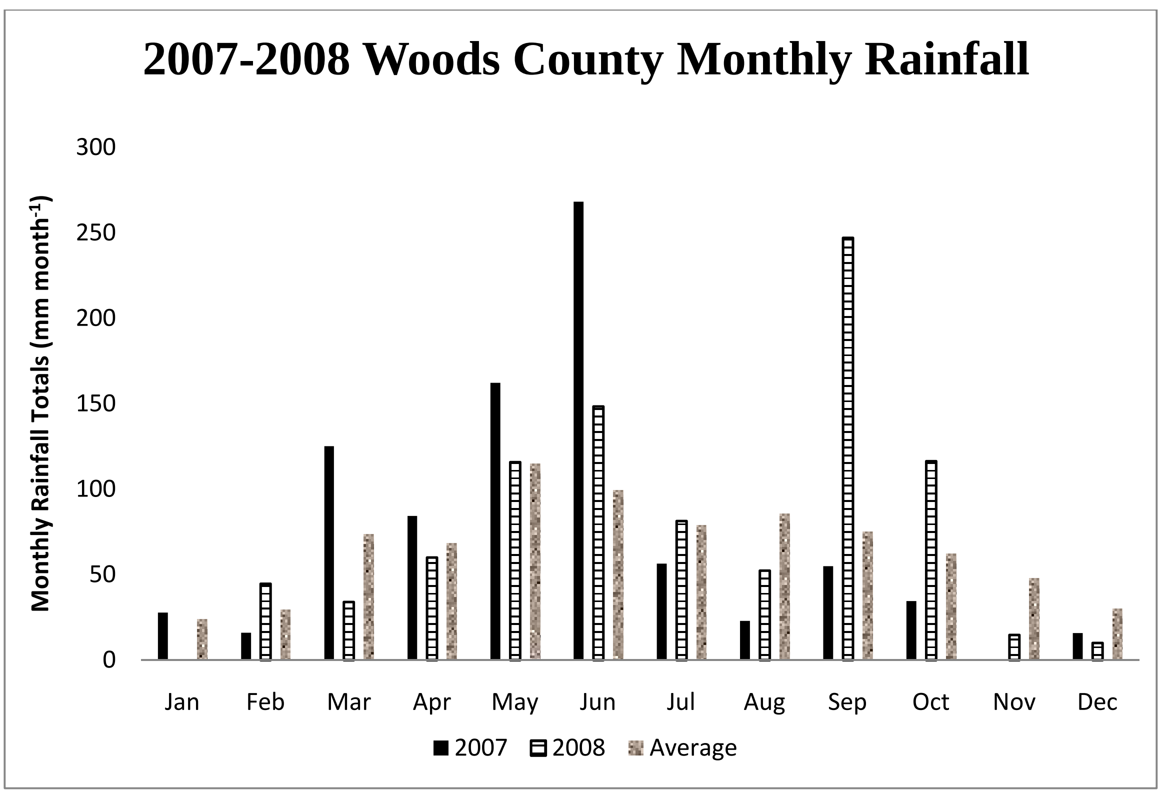

Figure 3.3: Final pH results of the 0-5 cm soil depth after 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

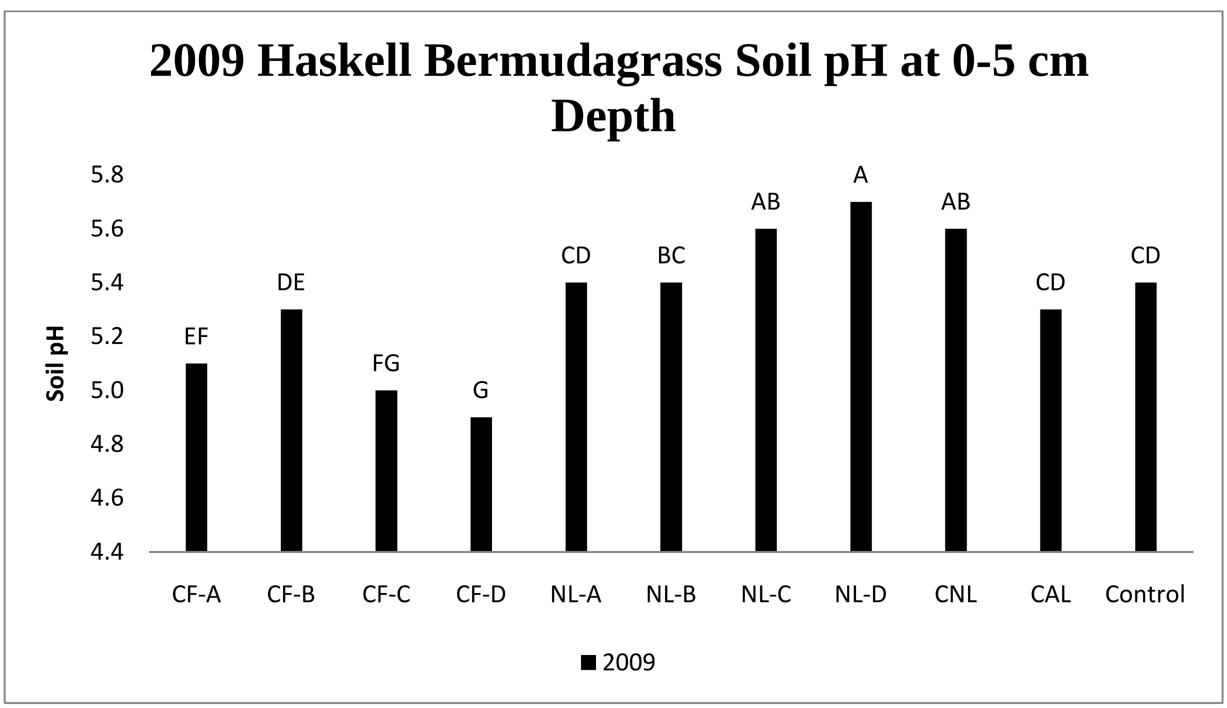

Figure 3.4: Final pH results of the 0-5 cm soil depth after 3 years of poultry litter and inorganic commercial fertilizer application to sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

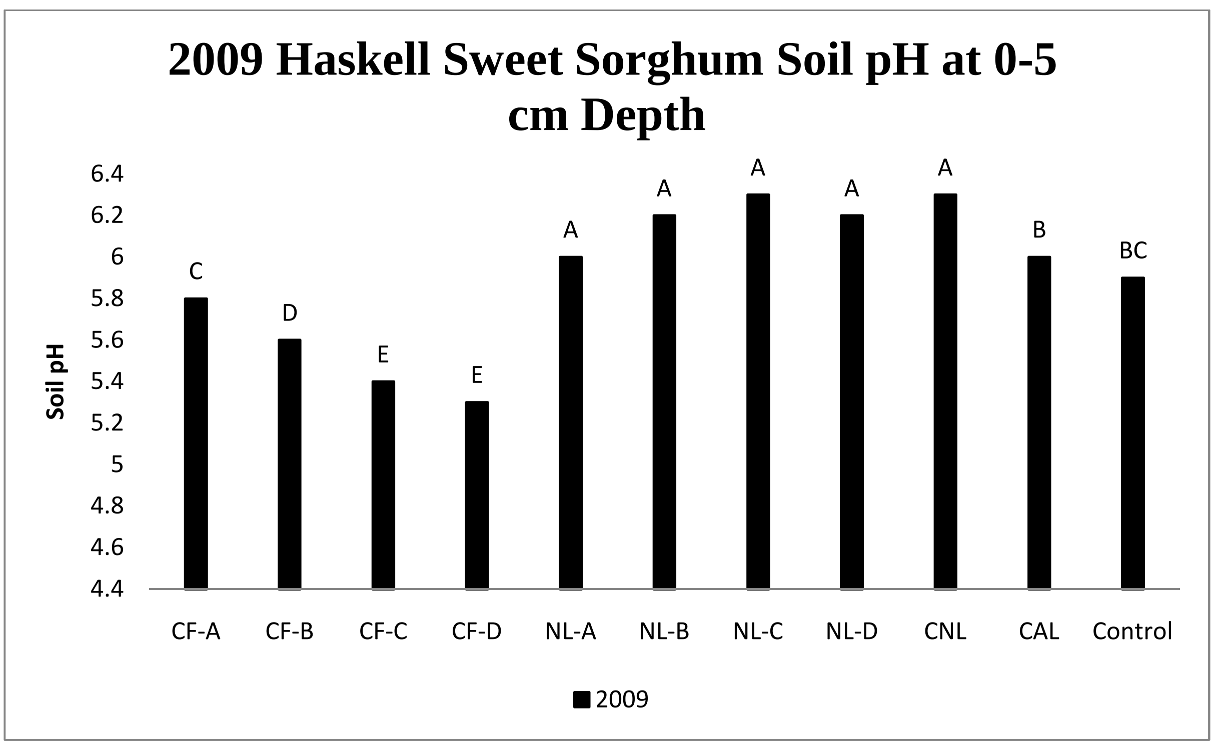

Figure 3.5: Results of pH at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on $N\text{-}P_2O_5\text{-}K_2O$ basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Upper case letters above bars represent LSD at $P \leq 0.05$ between various treatments within years.

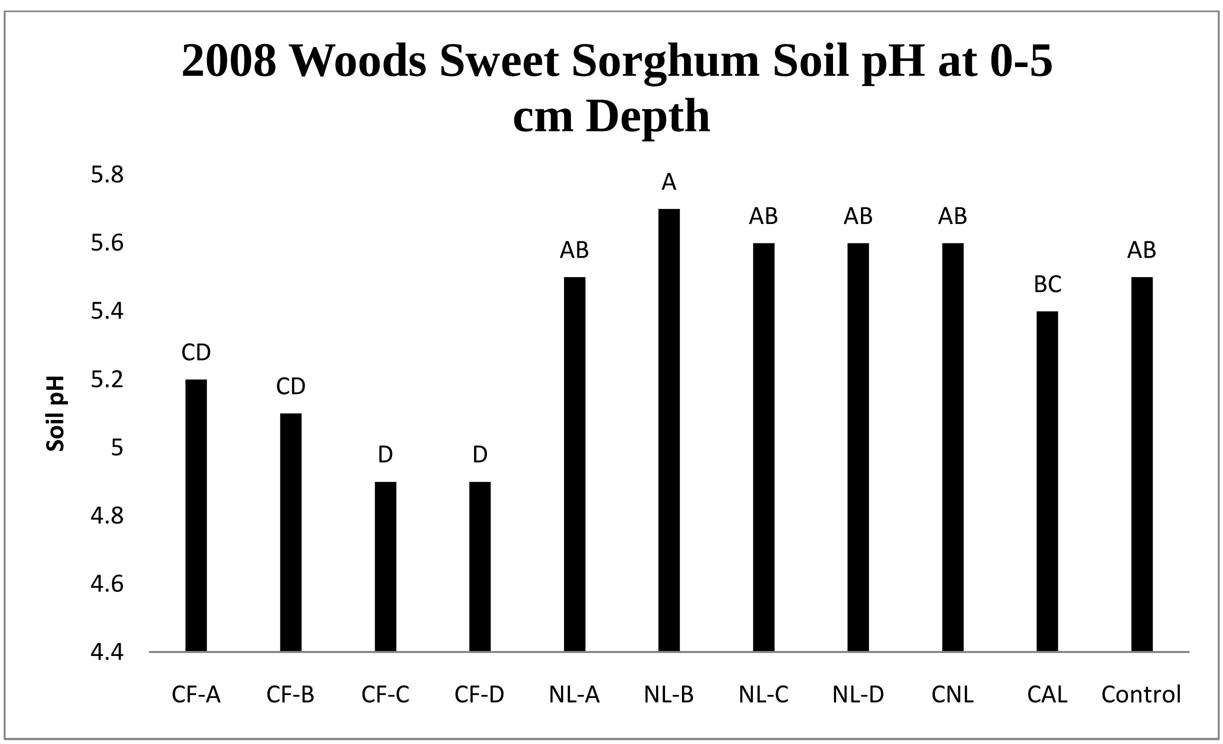

Figure 3.6: Results of soil test P at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

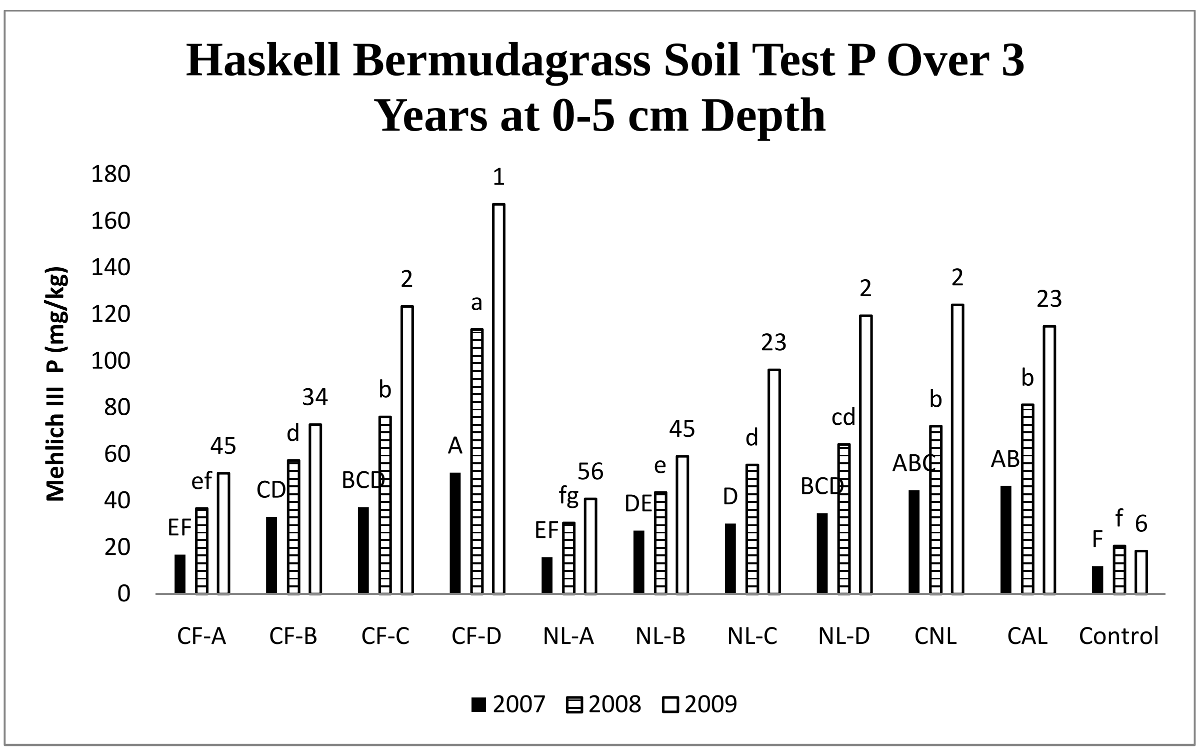

Figure 3.7: Results of soil test P at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treats within years.

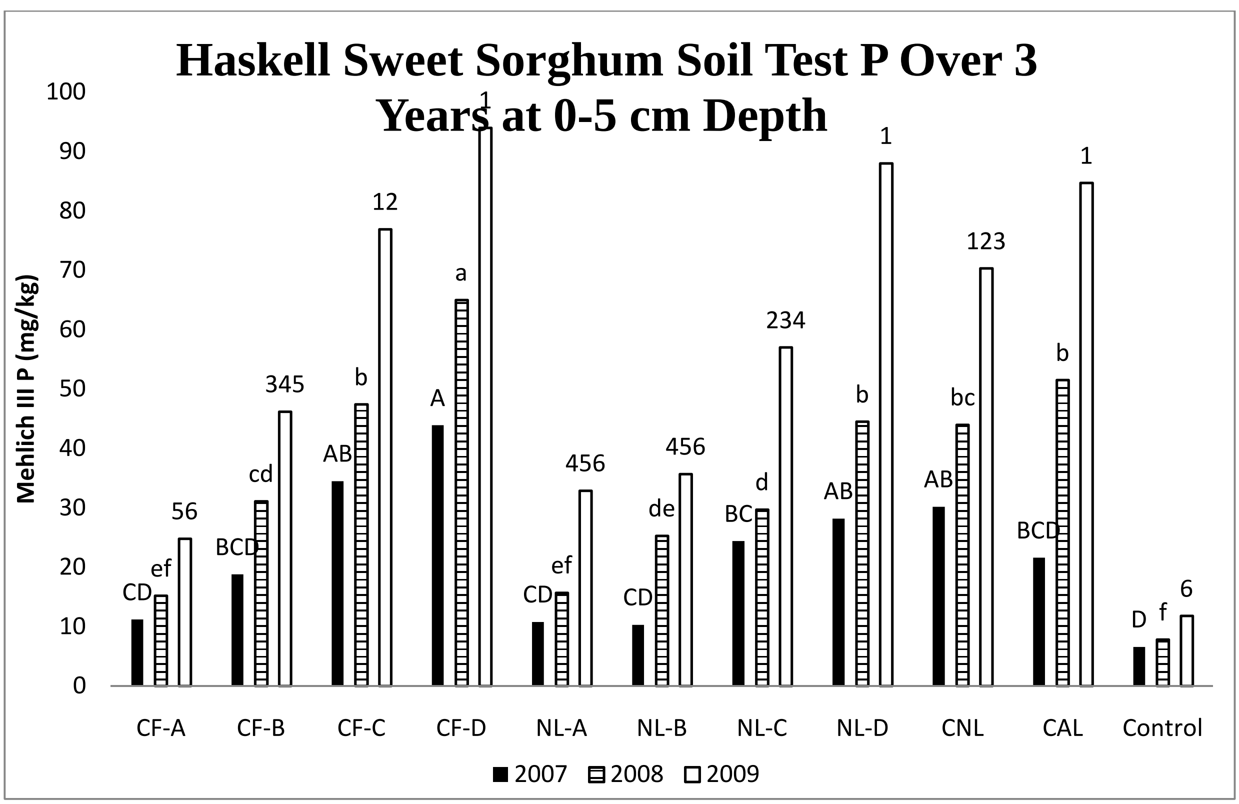

Figure 3.8: Results of soil test P over 3 soil depths after 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Upper case letters above bars represent LSD at P $\leq$ 0.05 between various depths for each treatment.

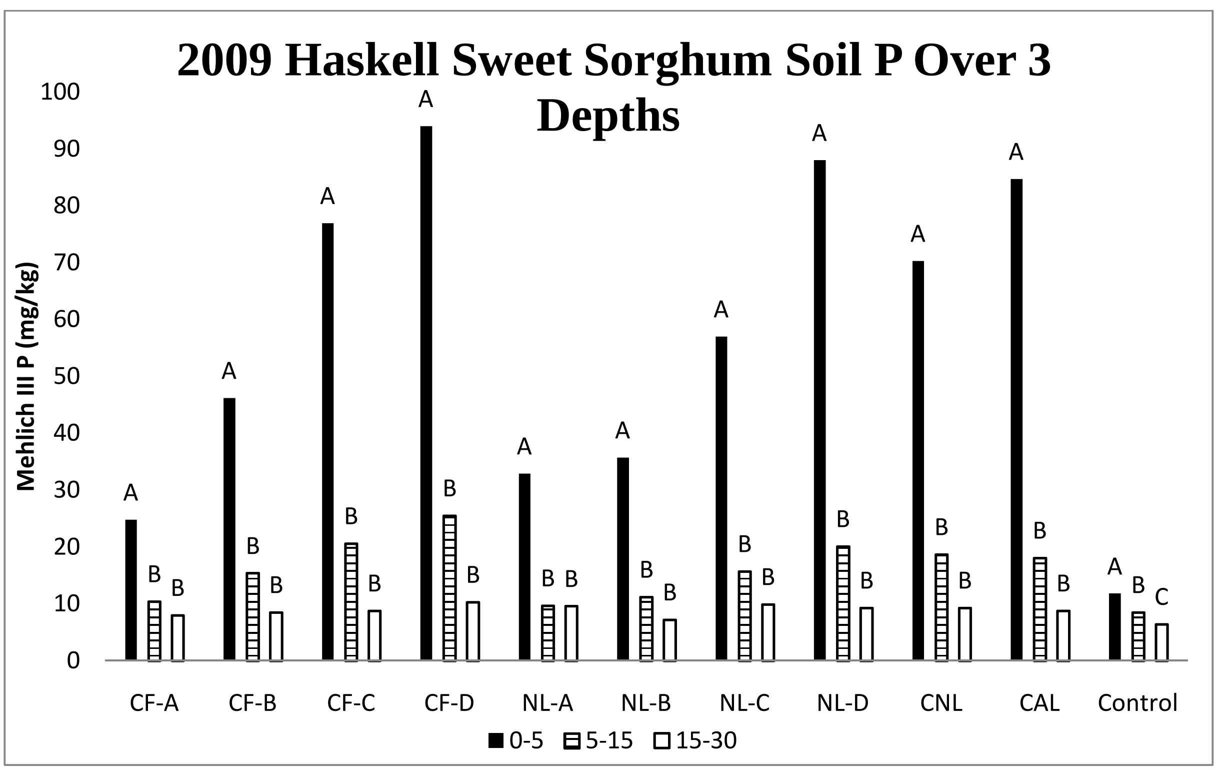

Figure 3.9: Results of soil test P at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treats within years.

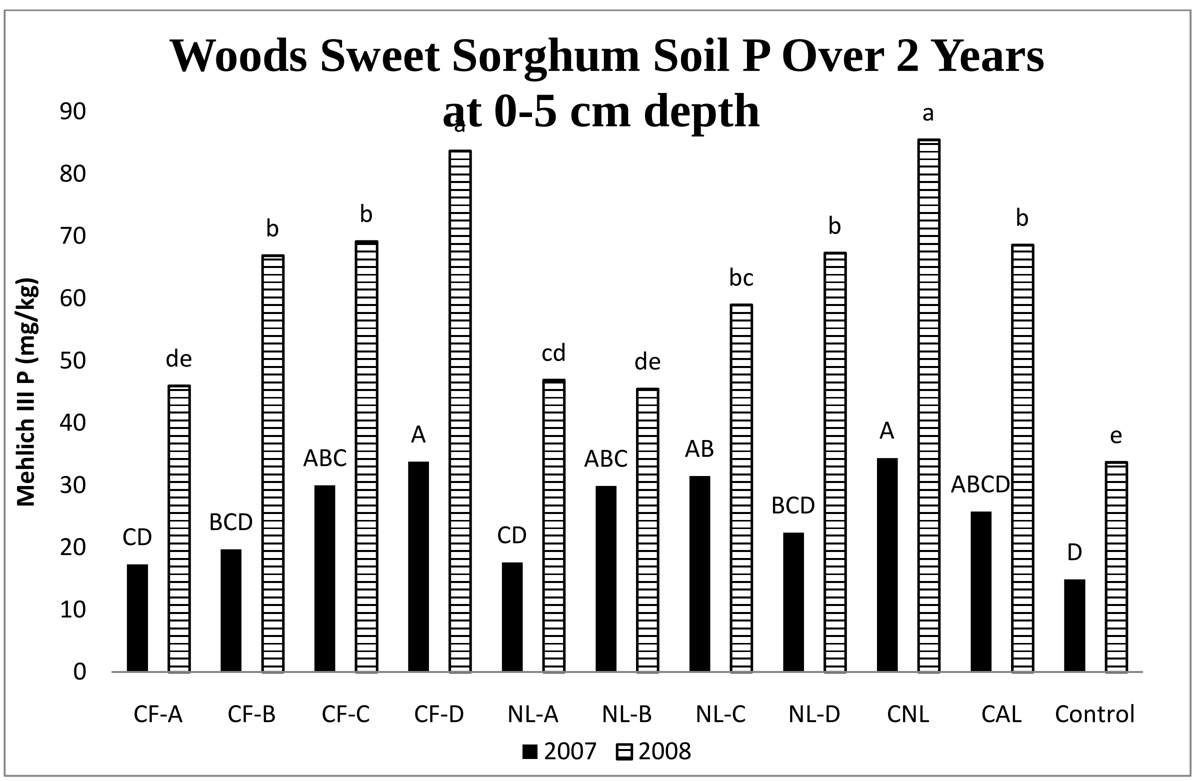

Figure 3.10: Results of water soluble P at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

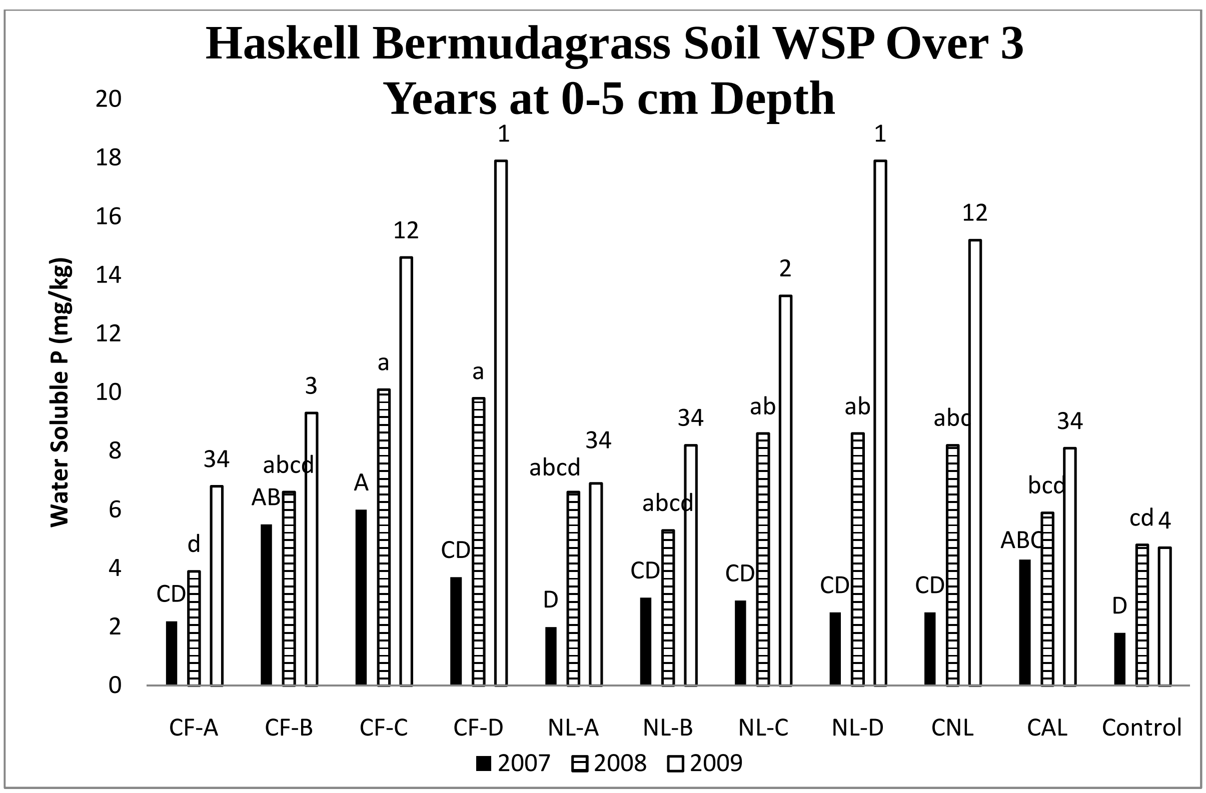

Figure 3.11: Results of water soluble P at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

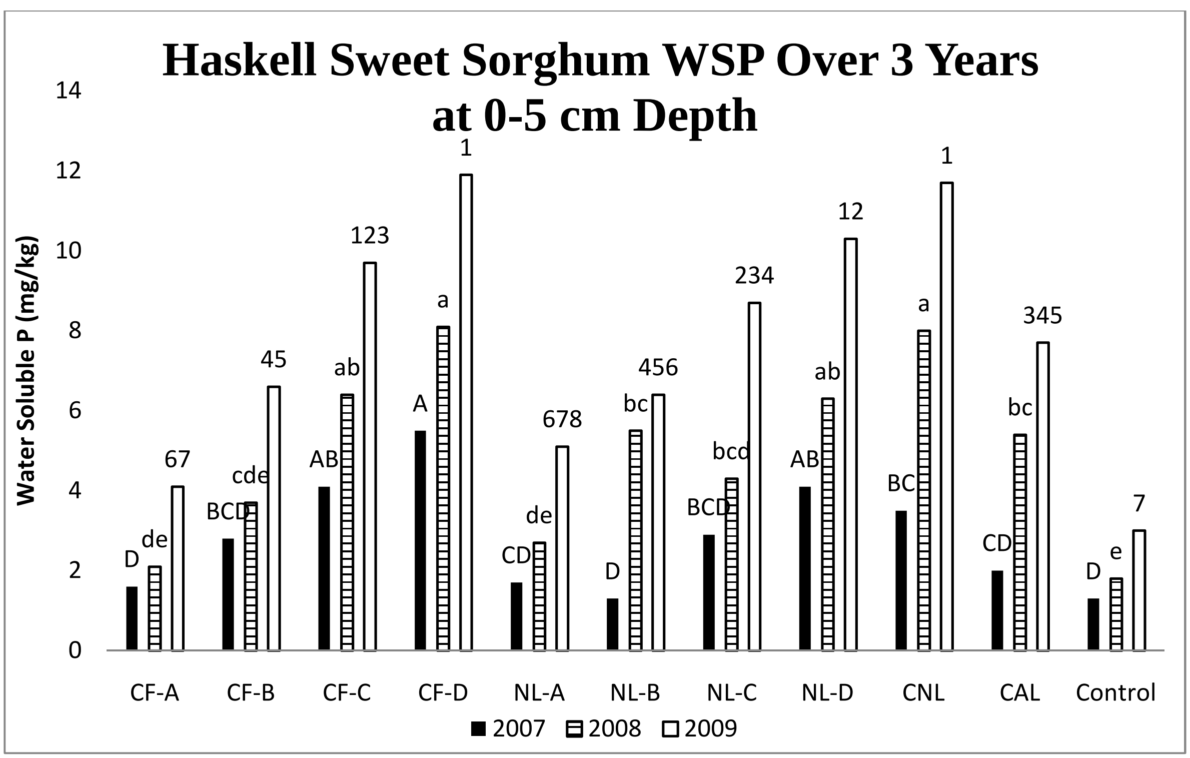

Figure 3.12: Results of water soluble P at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

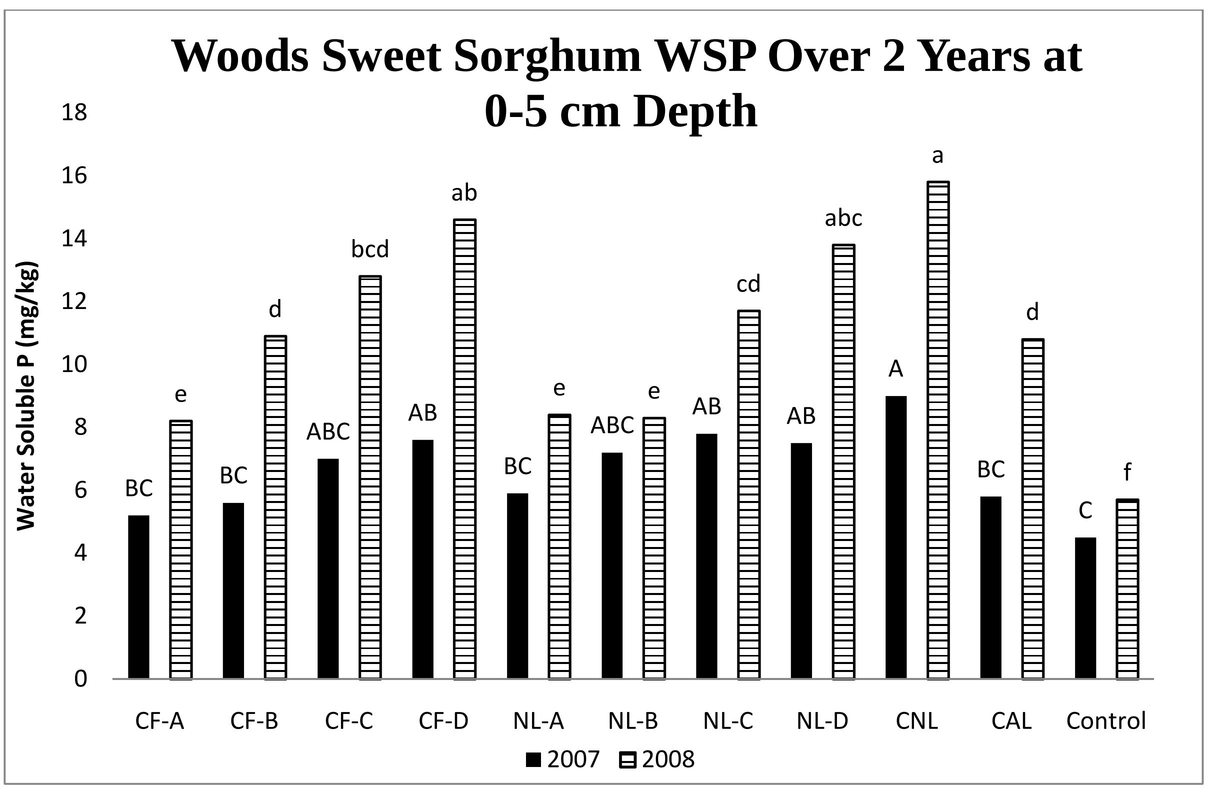

Figure 3.13: Results of soil test K at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

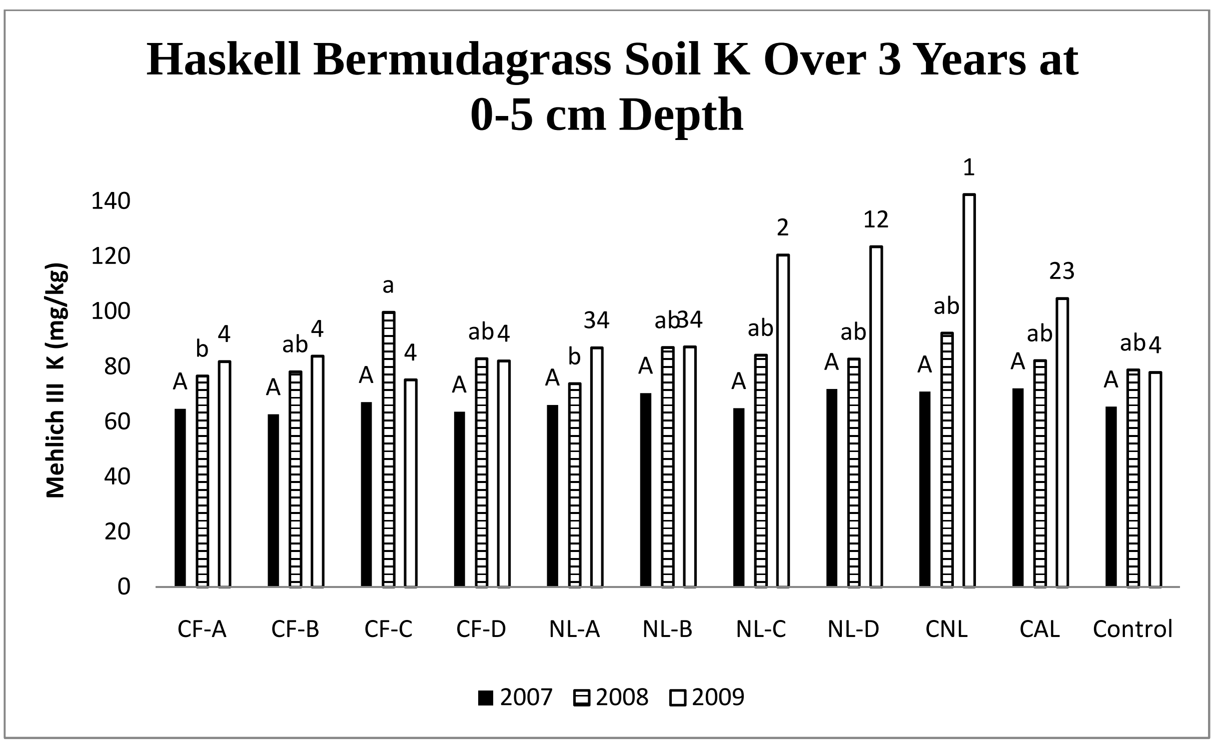

Figure 3.14: Results of soil test K at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

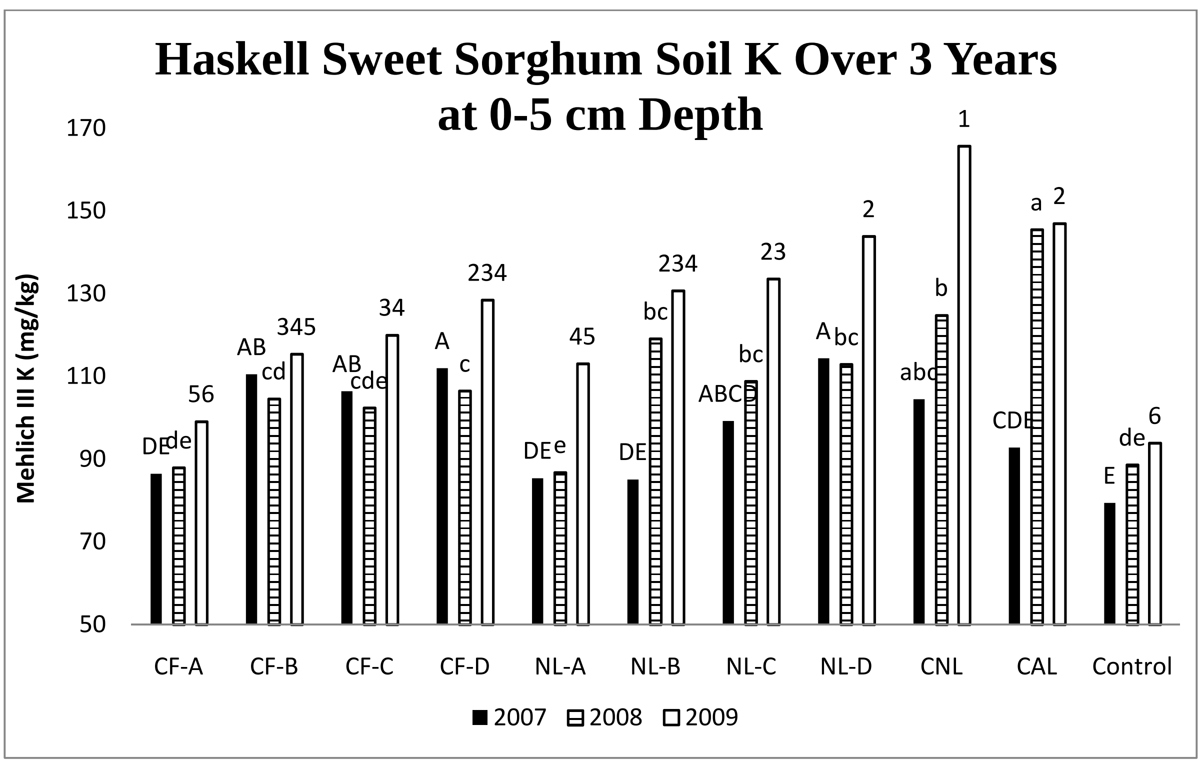

Figure 3.15: Results of soil test K at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

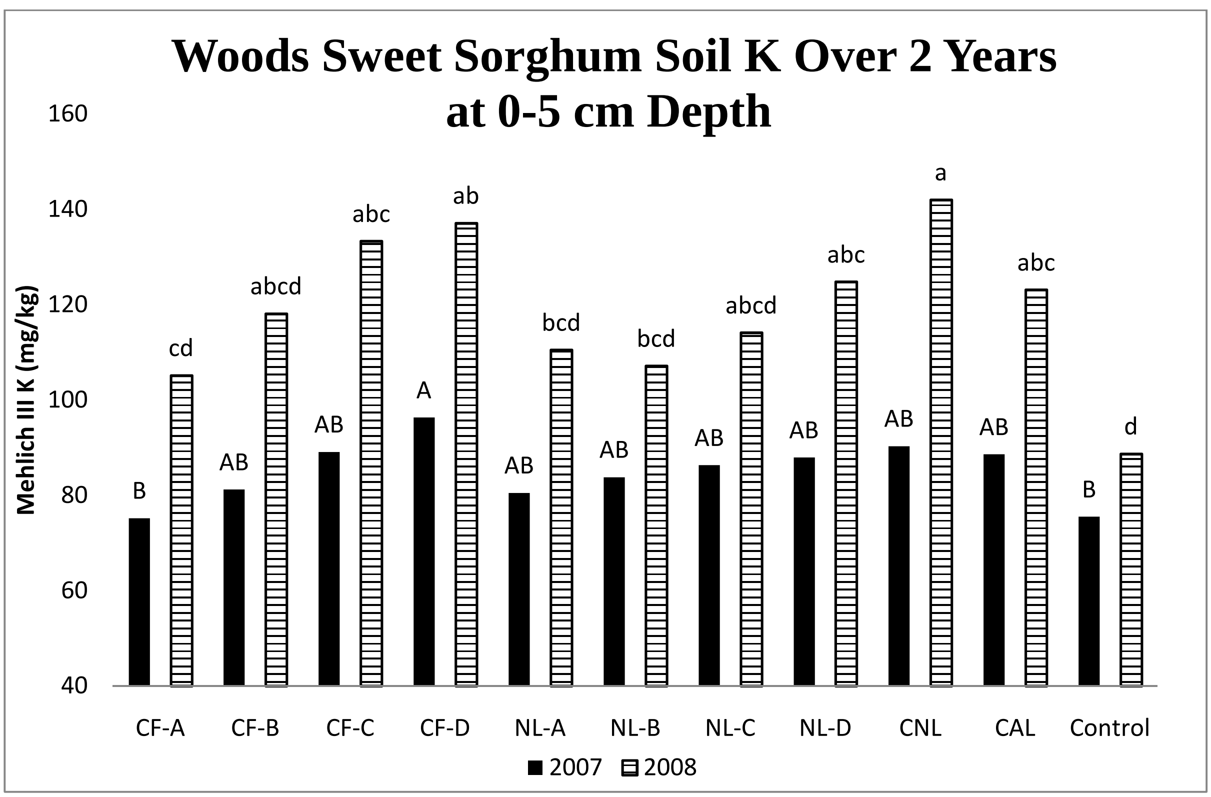

Figure 3.16: Results of soil test Ca at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

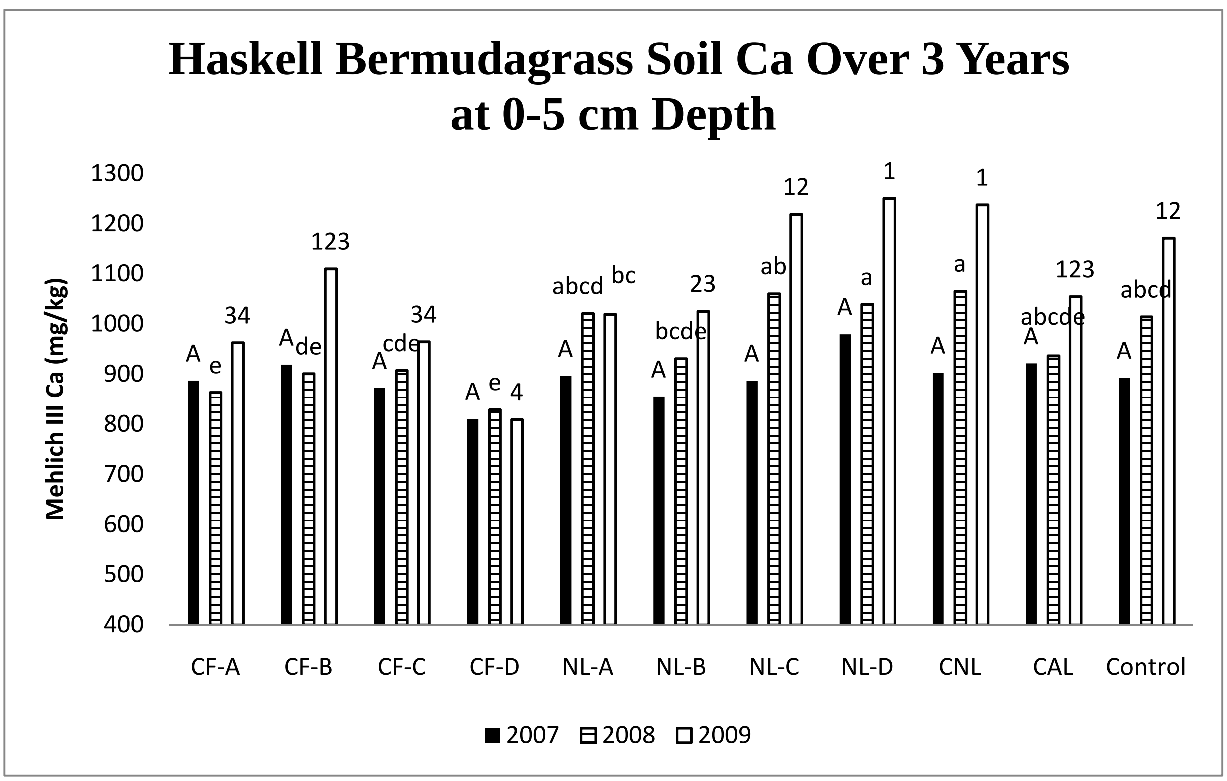

Figure 3.17: Results of soil test Ca at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

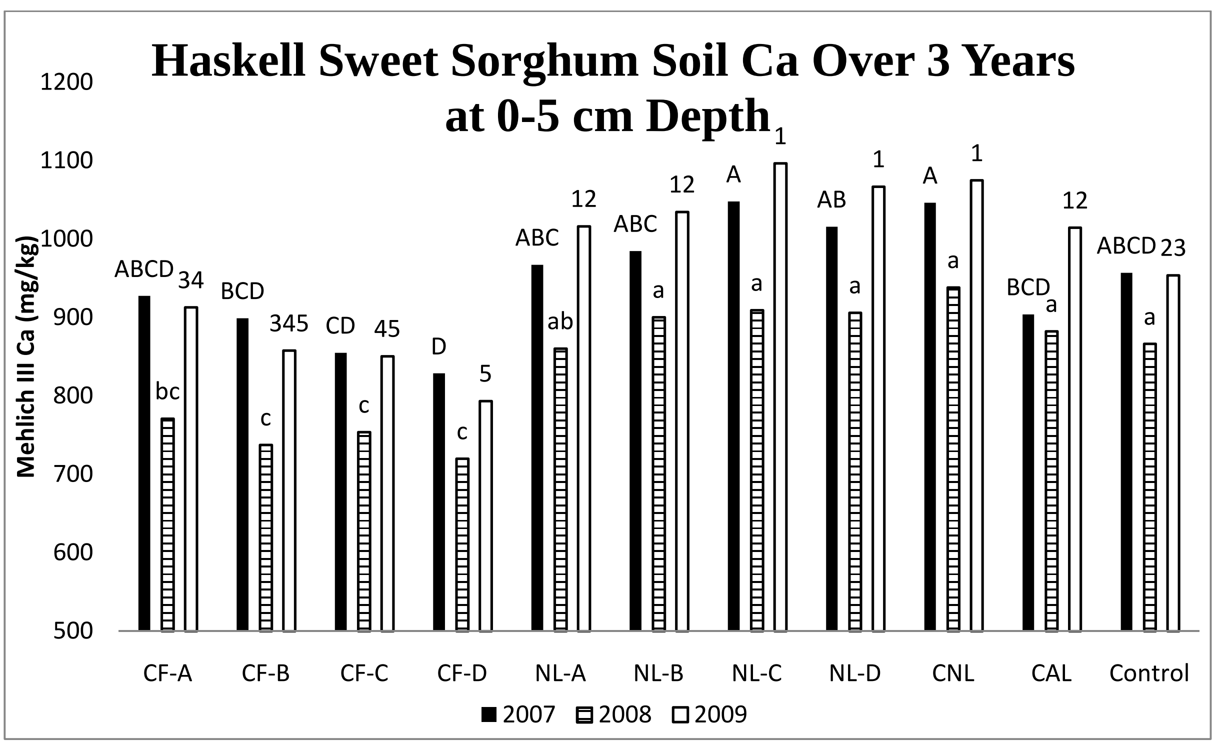

Figure 3.18: Results of soil test Ca at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

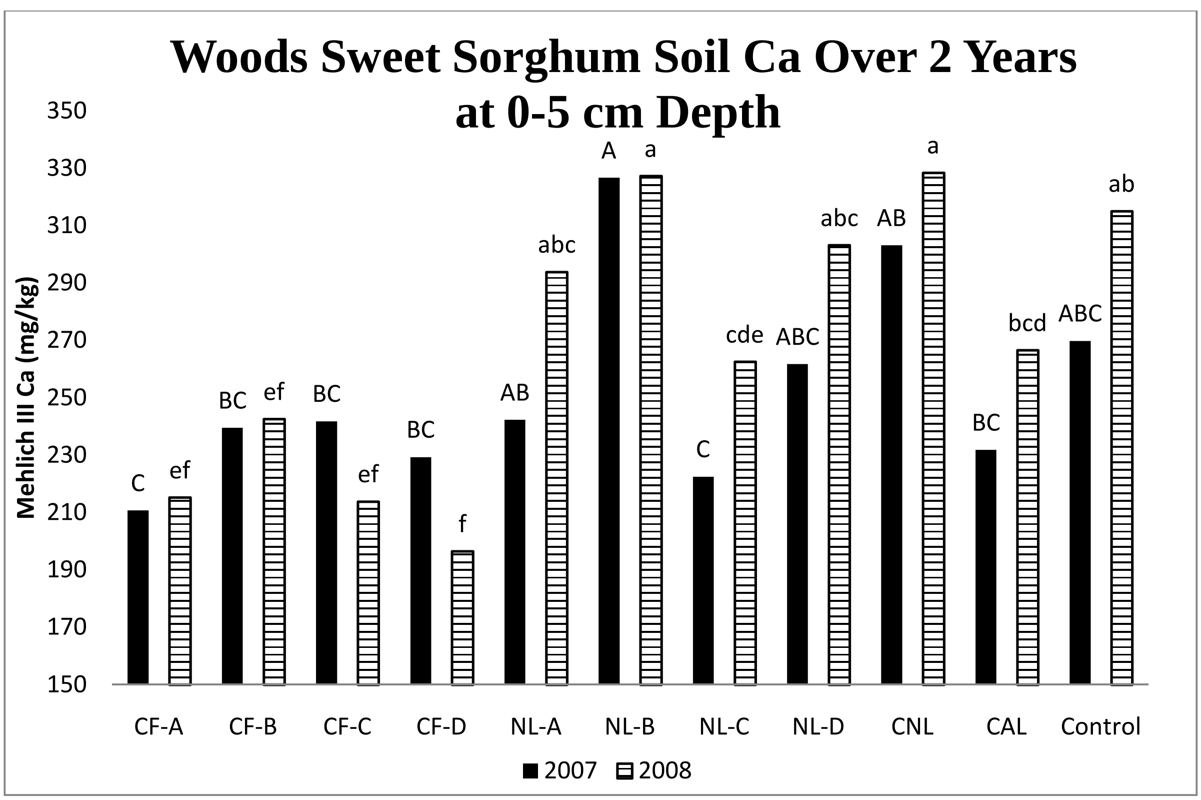

Figure 3.19: Results of soil test Mg at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at $P \leq 0.05$ between various treatments within years.

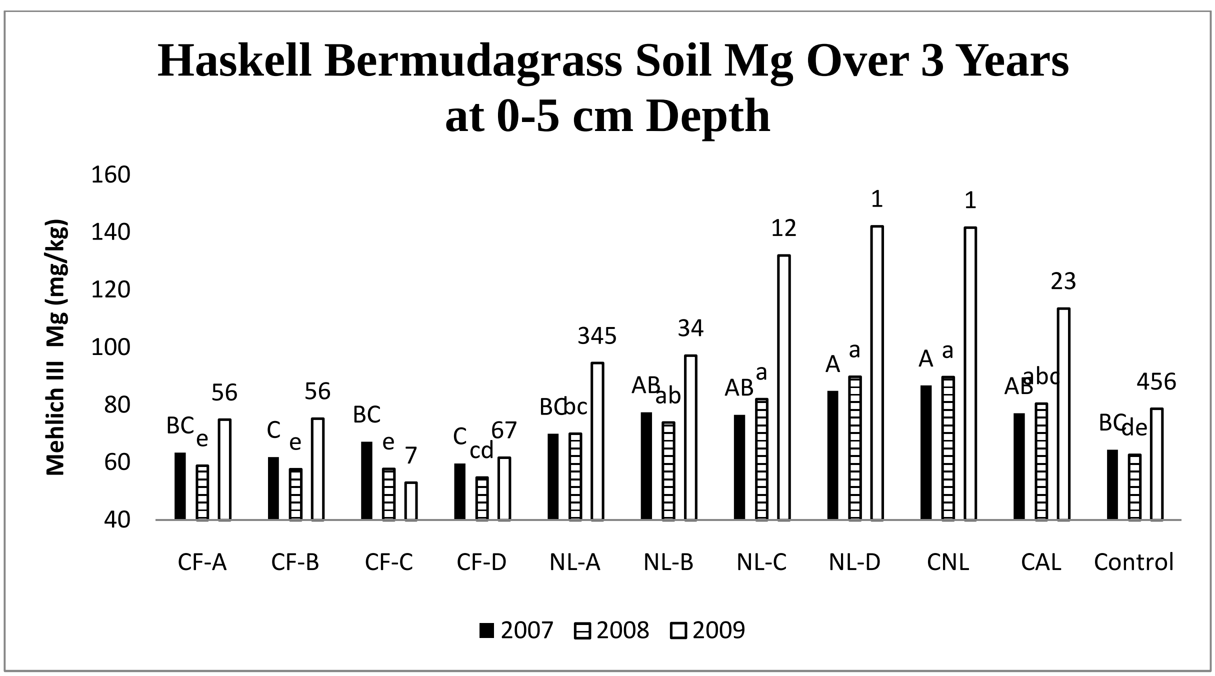

Figure 3.20: Results of soil test Mg at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

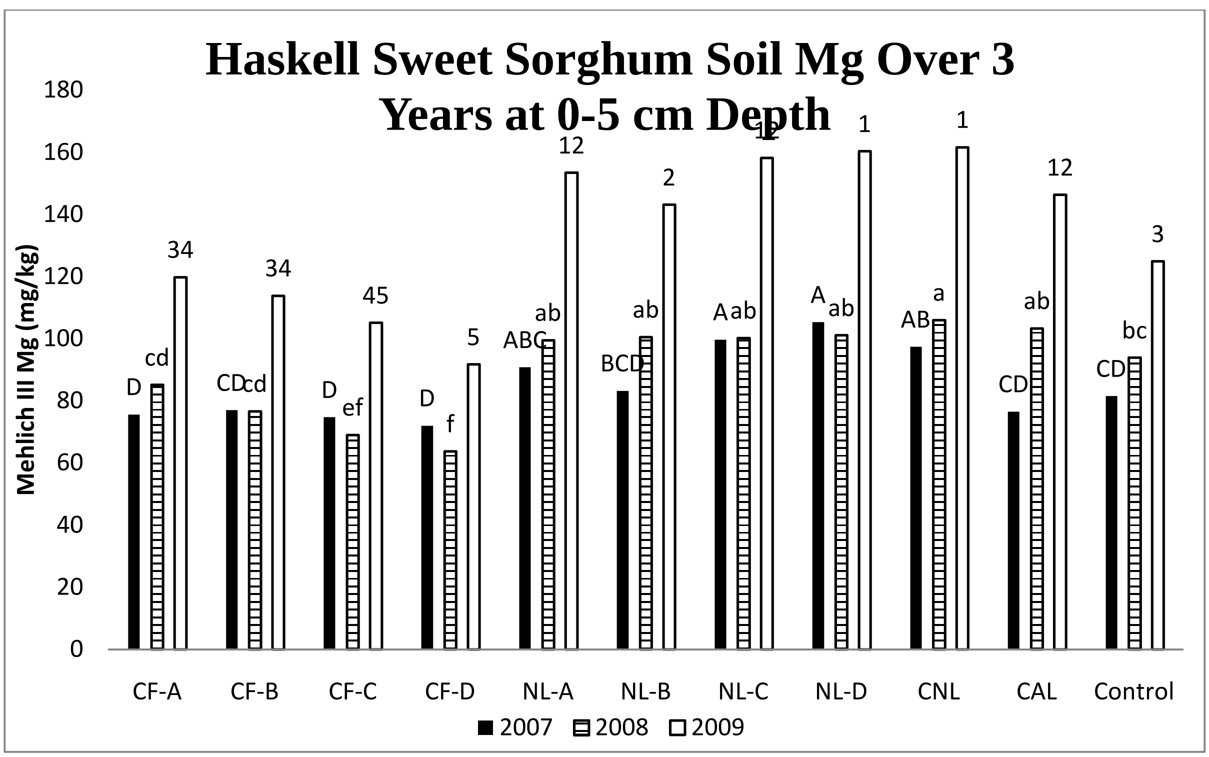

Figure 3.21: Results of soil test Mg at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

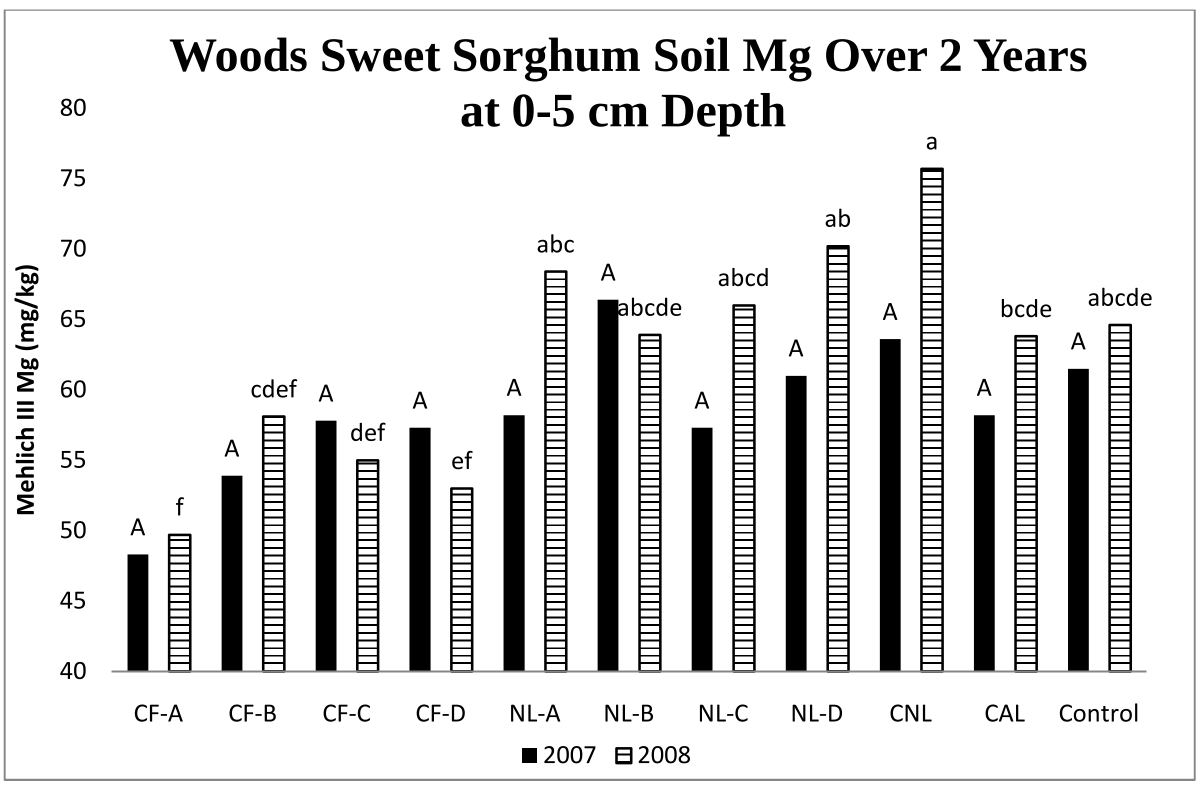

Figure 3.22: Results of soil test S at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P ≤ 0.05 between various treatments within years.

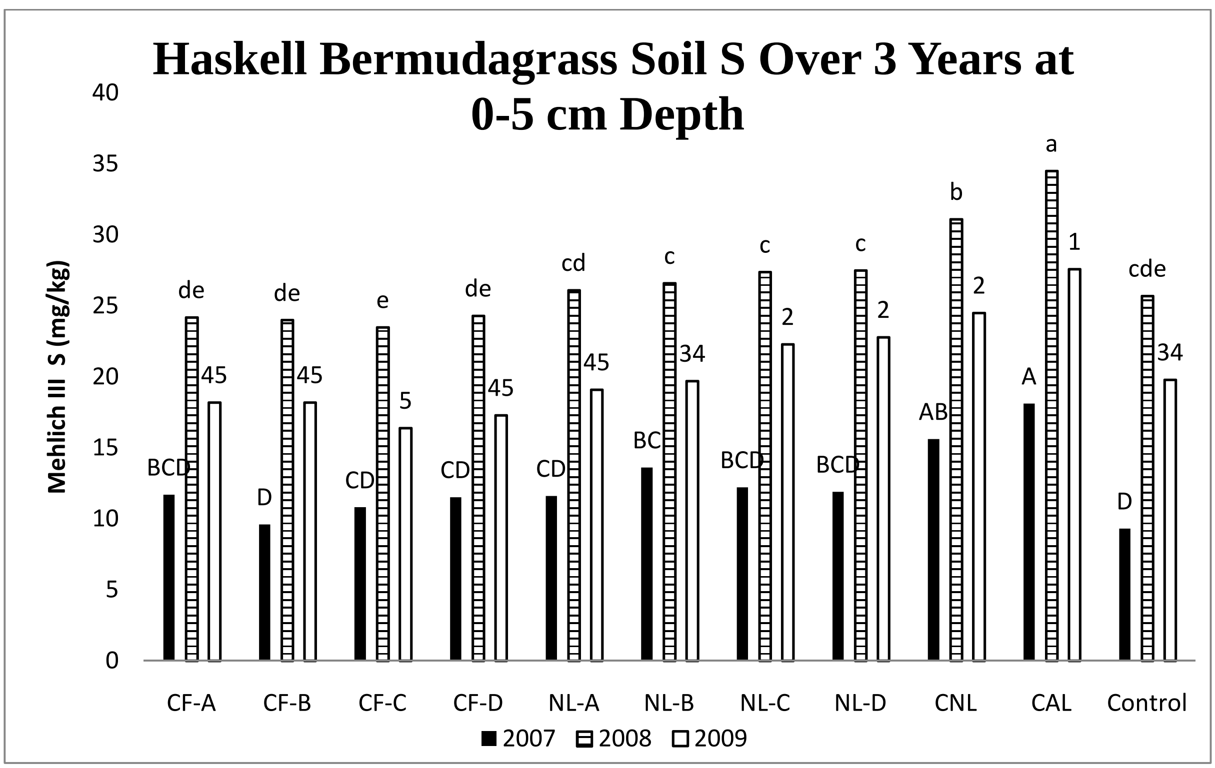

Figure 3.23: Results of soil test S at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

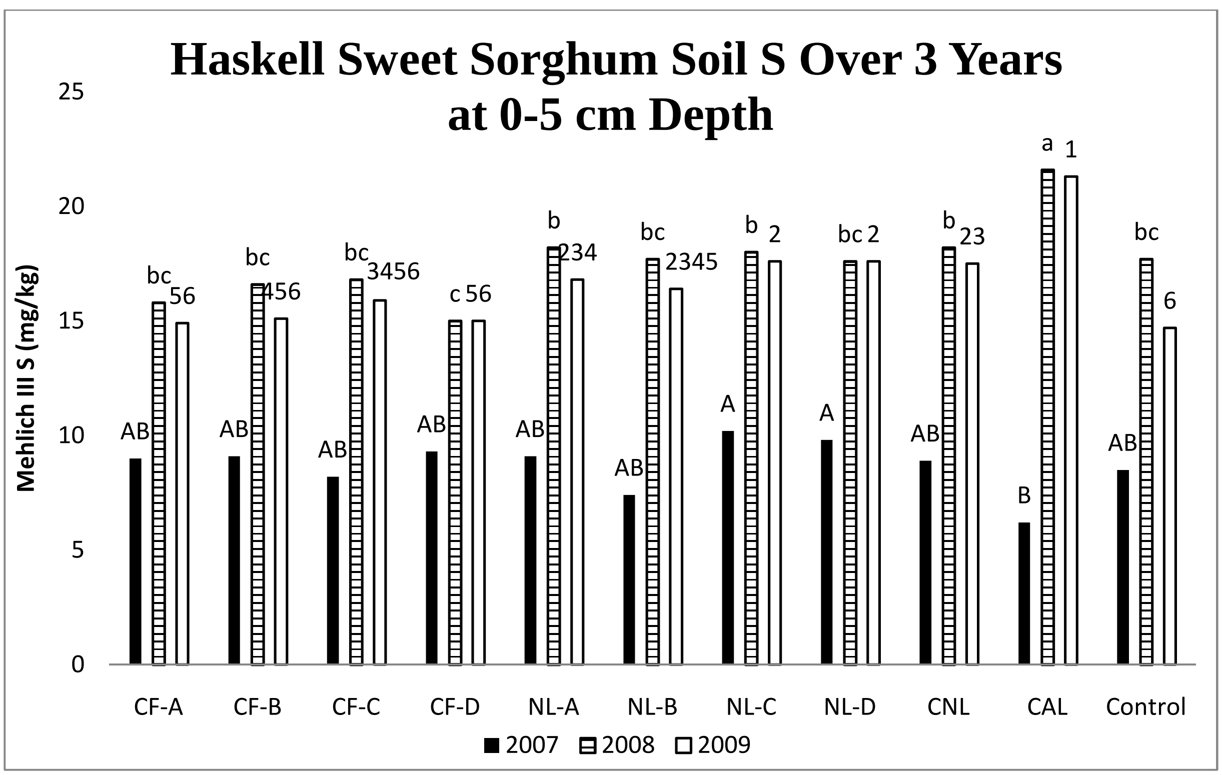

Figure 3.24: Results of soil test S at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

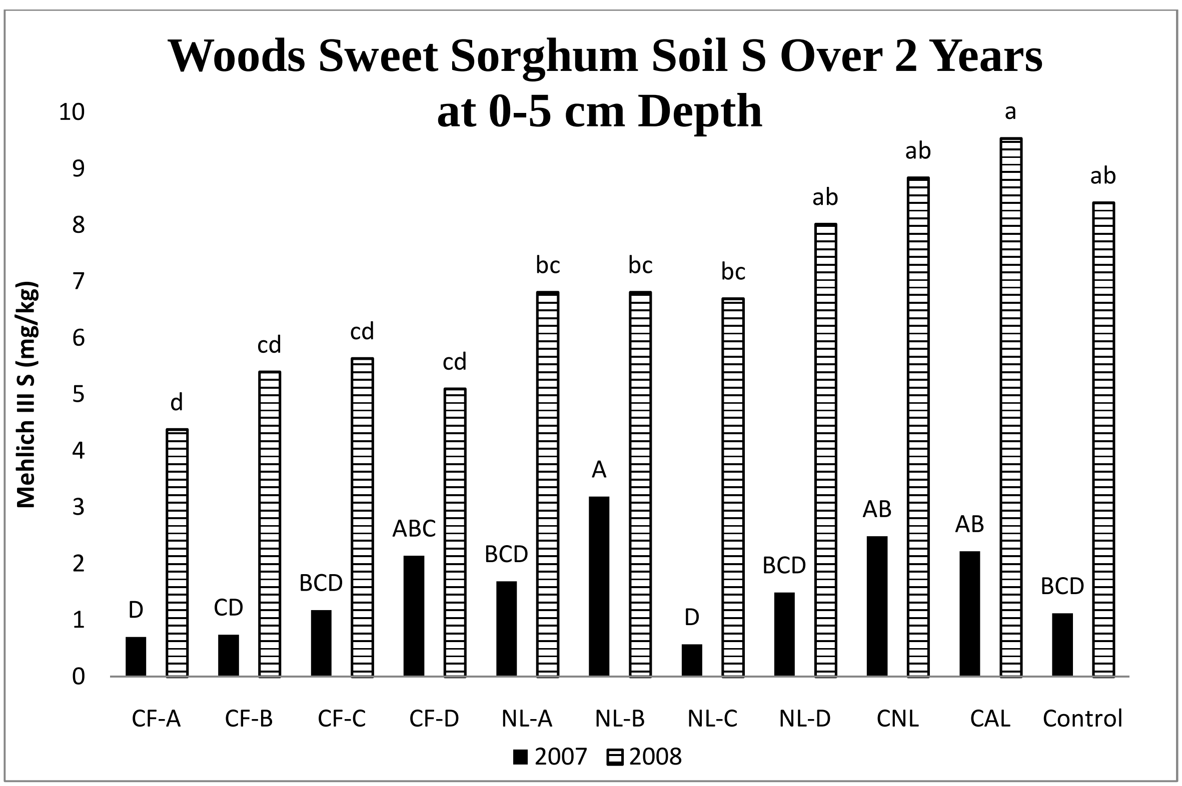

Figure 3.25: Results of soil test Cu at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

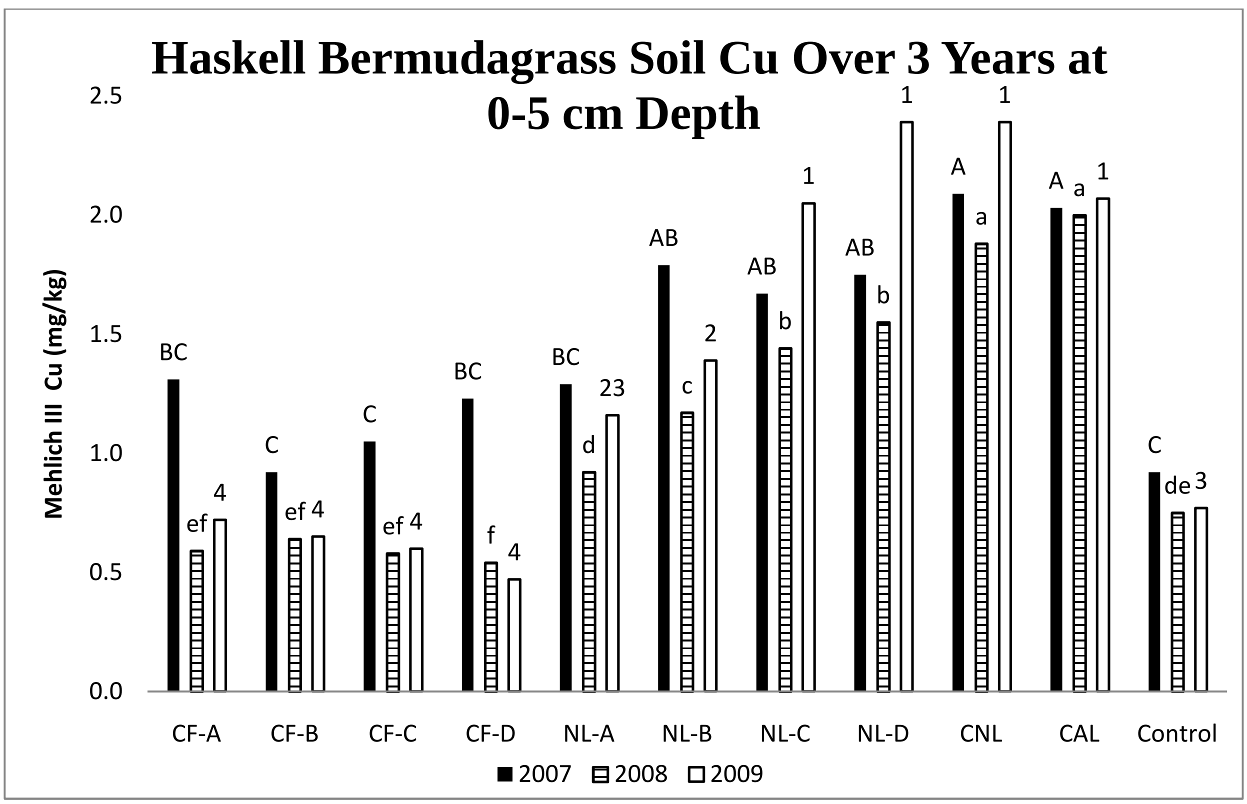

Figure 3.26: Results of soil test Cu at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

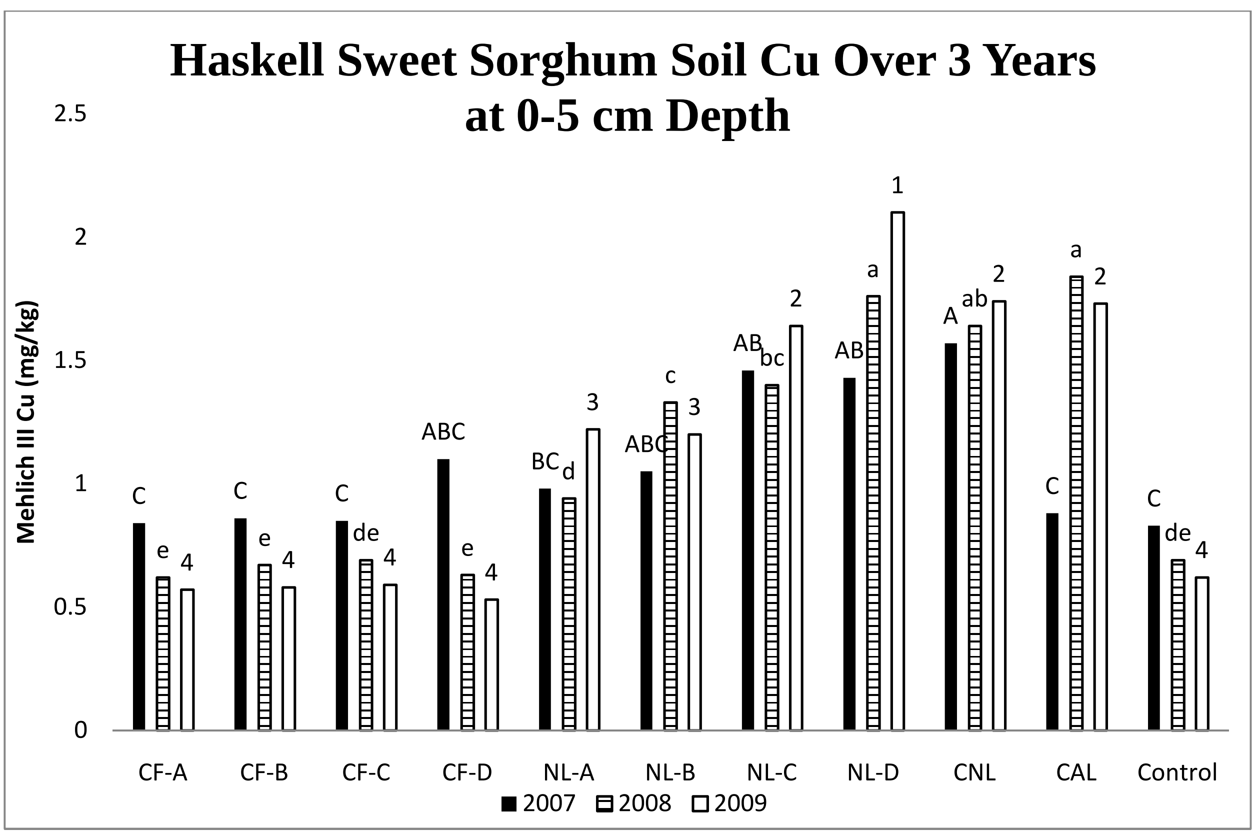

Figure 3.27: Results of soil test Cu at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

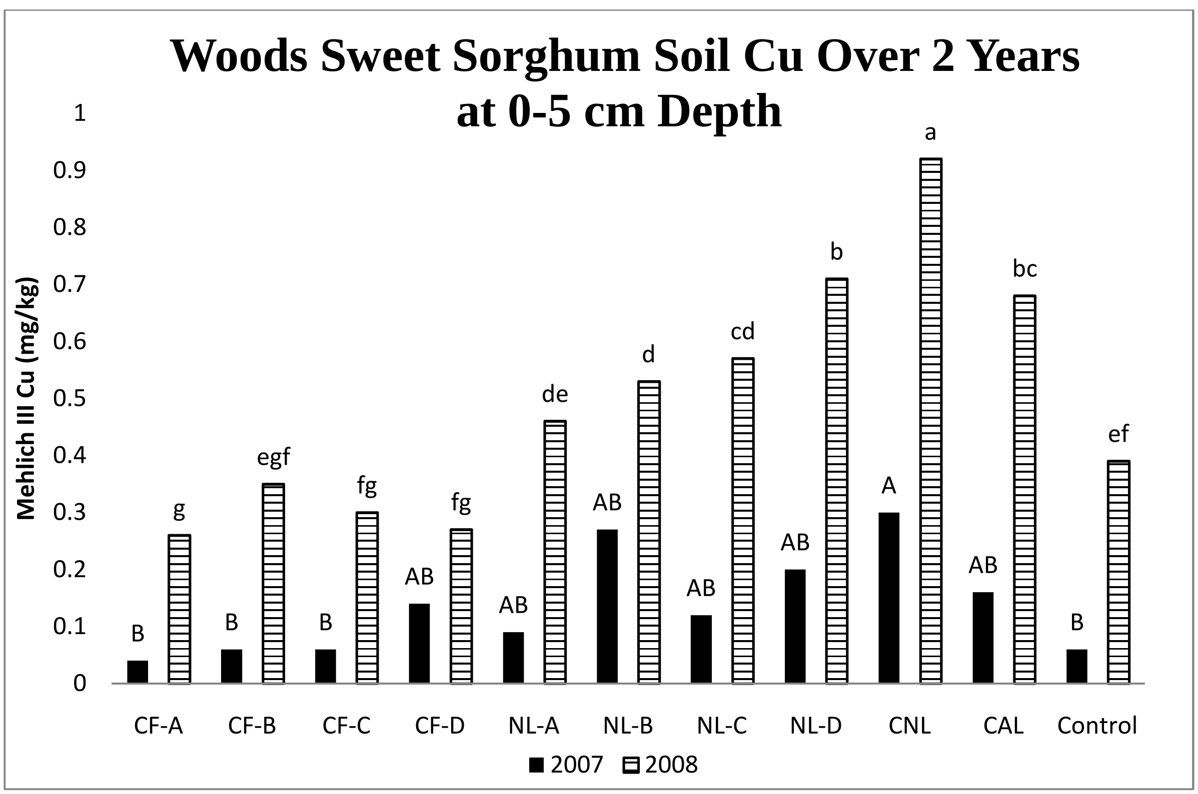

Figure 3.28: Results of soil test Zn at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

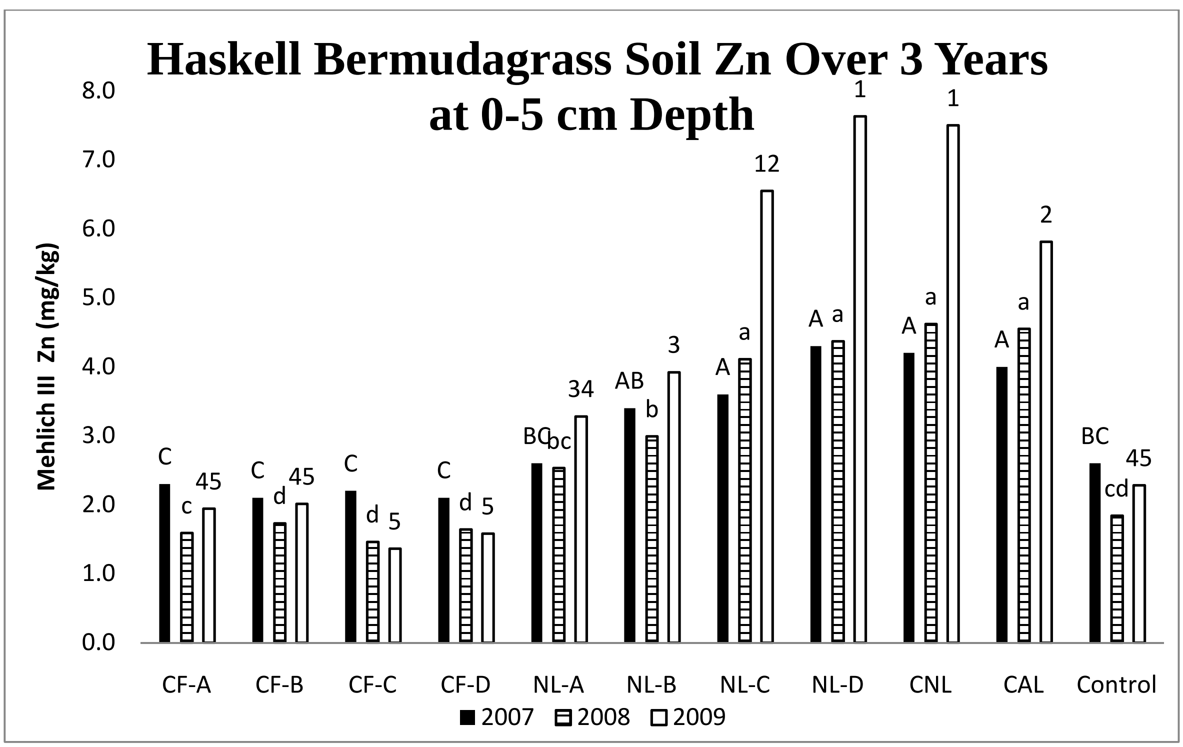

Figure 3.29: Results of soil test Zn at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at $P \leq 0.05$ between various treatments within years.

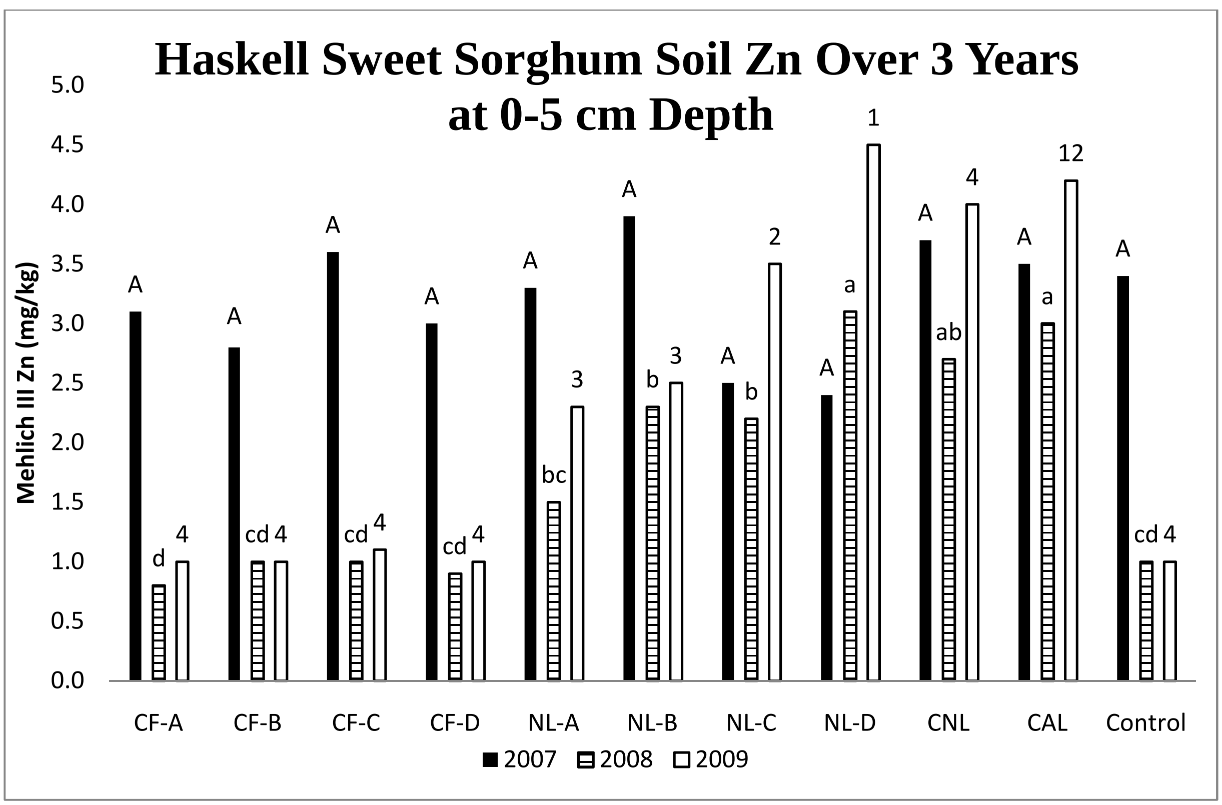

Figure 3.30: Results of soil test Zn at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

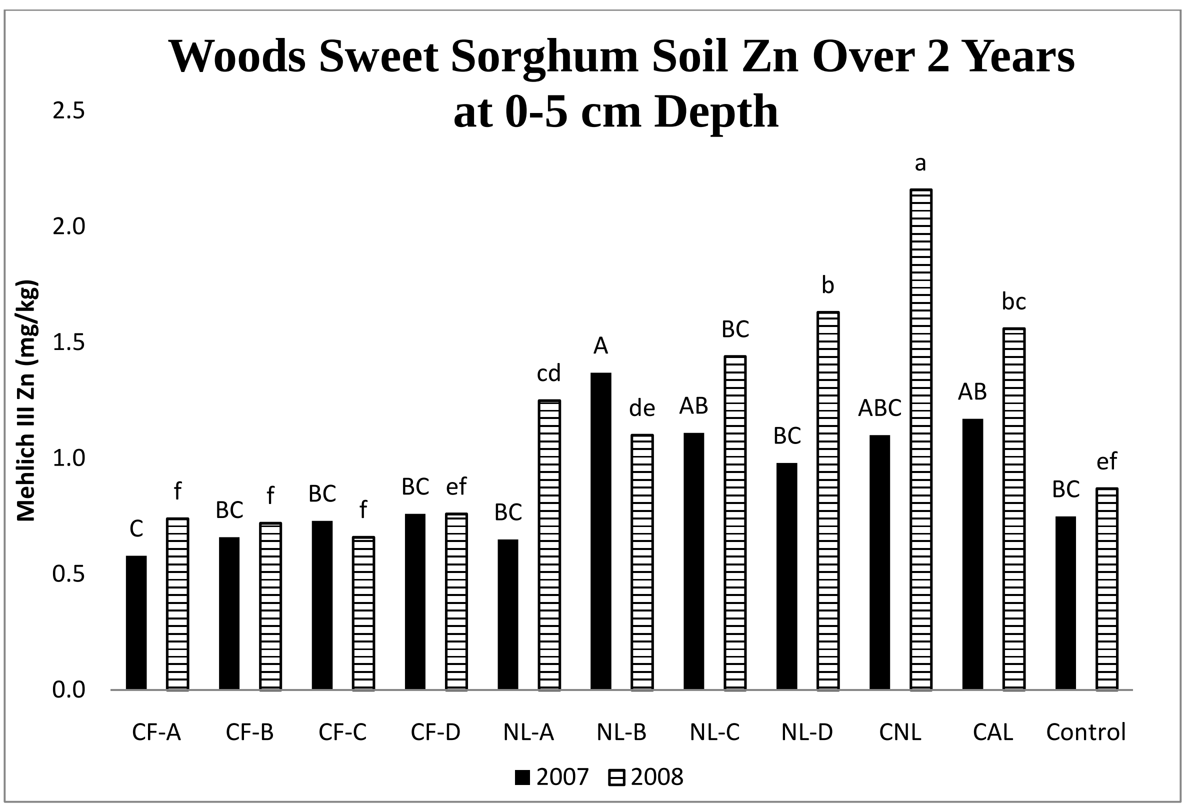

Figure 3.31: Results of soil test Fe at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on $N-P_2O_5-K_2O$ basis ($kg\ ha^{-1}$) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at $P \leq 0.05$ between various treatments within years.

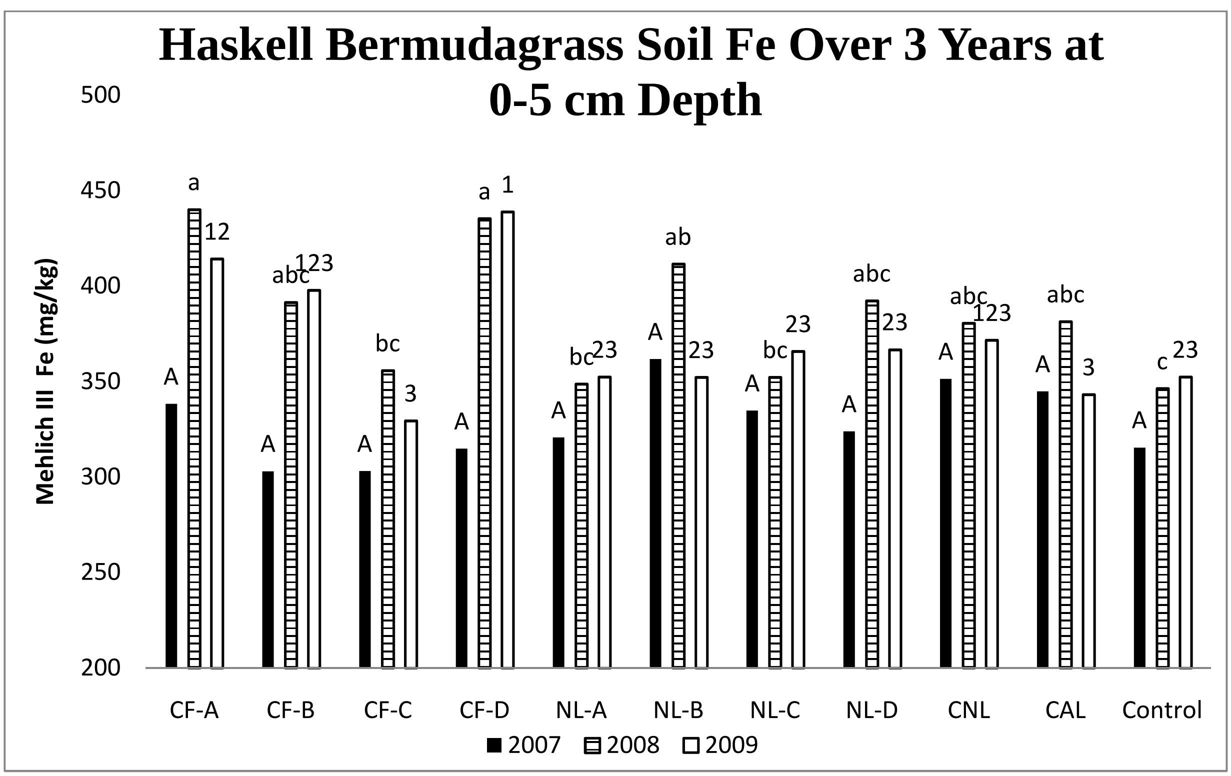

Figure 3.32: Results of soil test Fe at the 0-5 cm soil depth over 3 years of poultry litter and inorganic commercial fertilizer application to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on $N\text{-}P_2O_5\text{-}K_2O$ basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

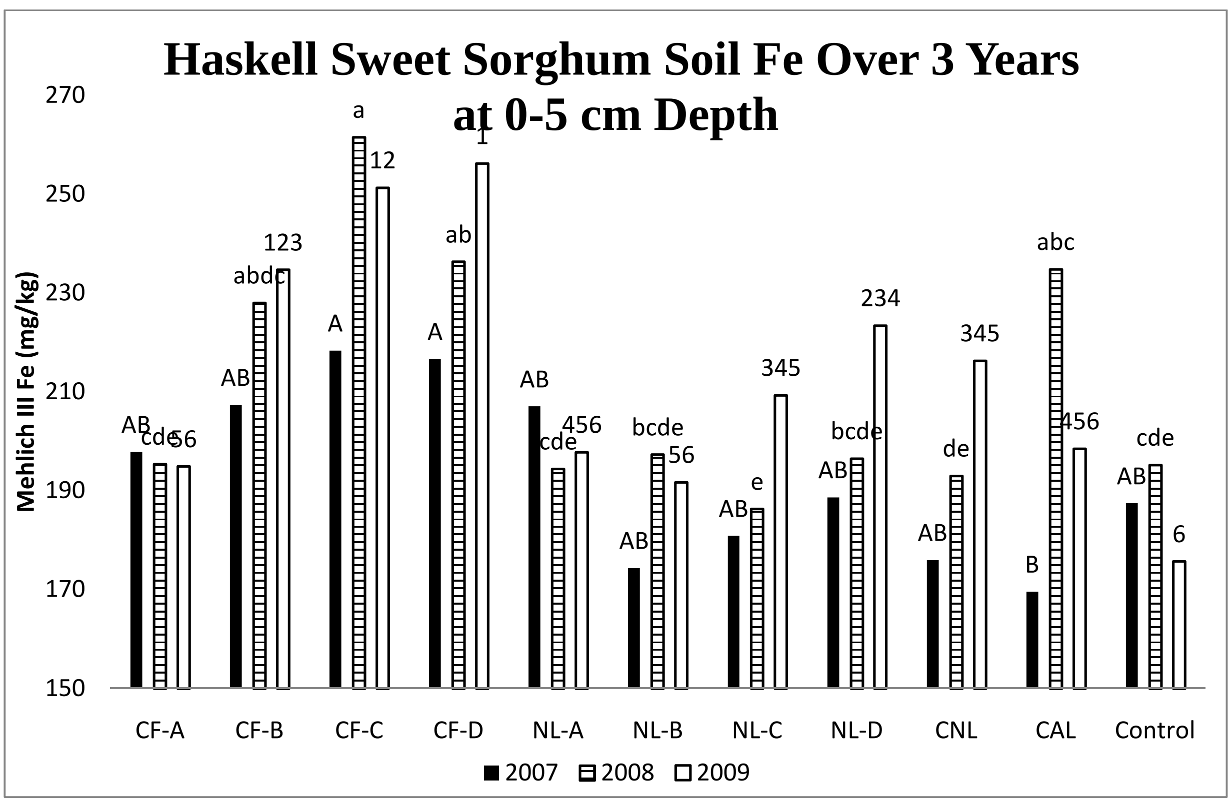

Figure 3.33: Results of soil test Fe at the 0-5 cm soil depth over 2 years of poultry litter and inorganic commercial fertilizer application to a field in the production of sweet sorghum located on a Eda loamy fine sand soil in Woods County, OK west of Aline, OK on a privately owned farm. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters above bars represent LSD at $P \leq 0.05$ between various treatments within years.

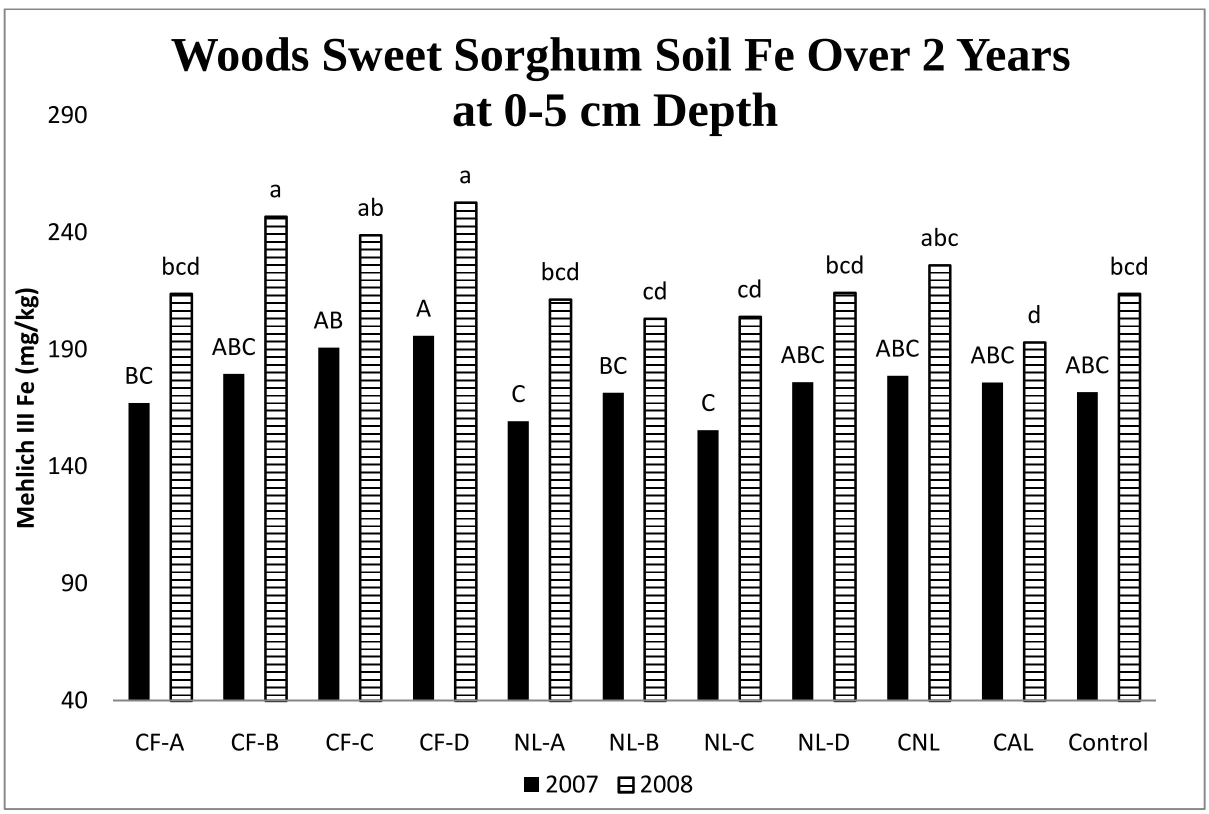

Figure 3.34: Results of aggregate stability of 0-15 cm soil depth after 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station reported as geometric mean diameter (GMD). Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

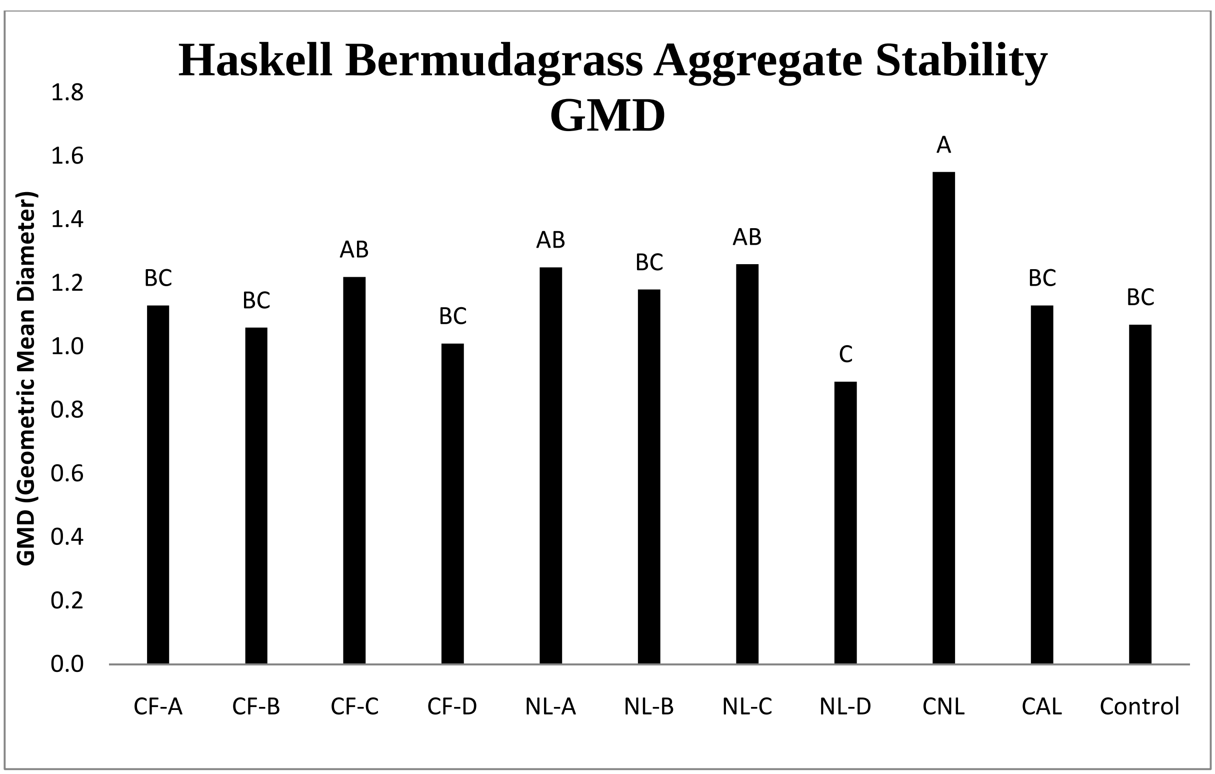

Figure 3.35: Results of aggregate stability of 0-15 cm soil depth after 3 years of poultry litter and inorganic commercial fertilizer application to a field to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station reported as geometric mean diameter (GMD). Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on $N-P_2O_5-K_2O$ basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

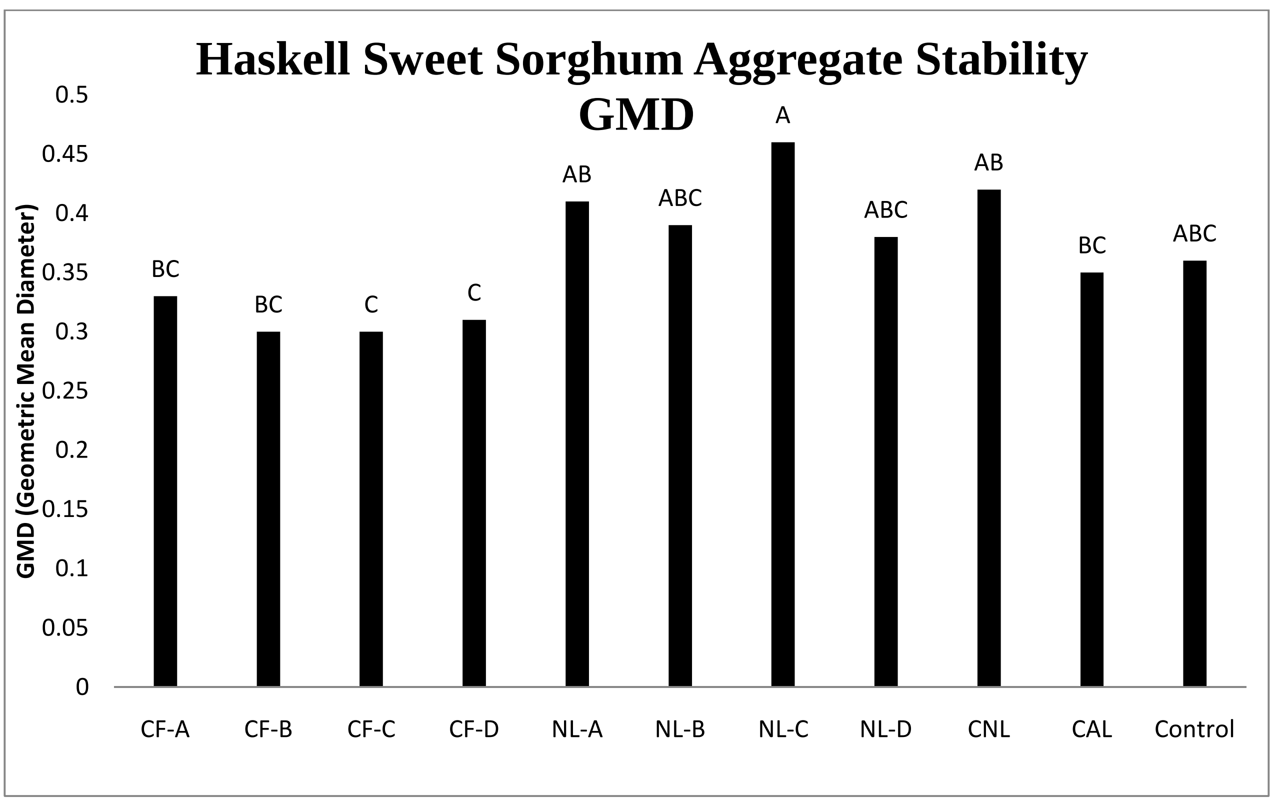

Figure 3.36: Results of bulk density after 3 years of poultry litter and inorganic commercial fertilizer application to bermudagrass pasture located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Upper case letters above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

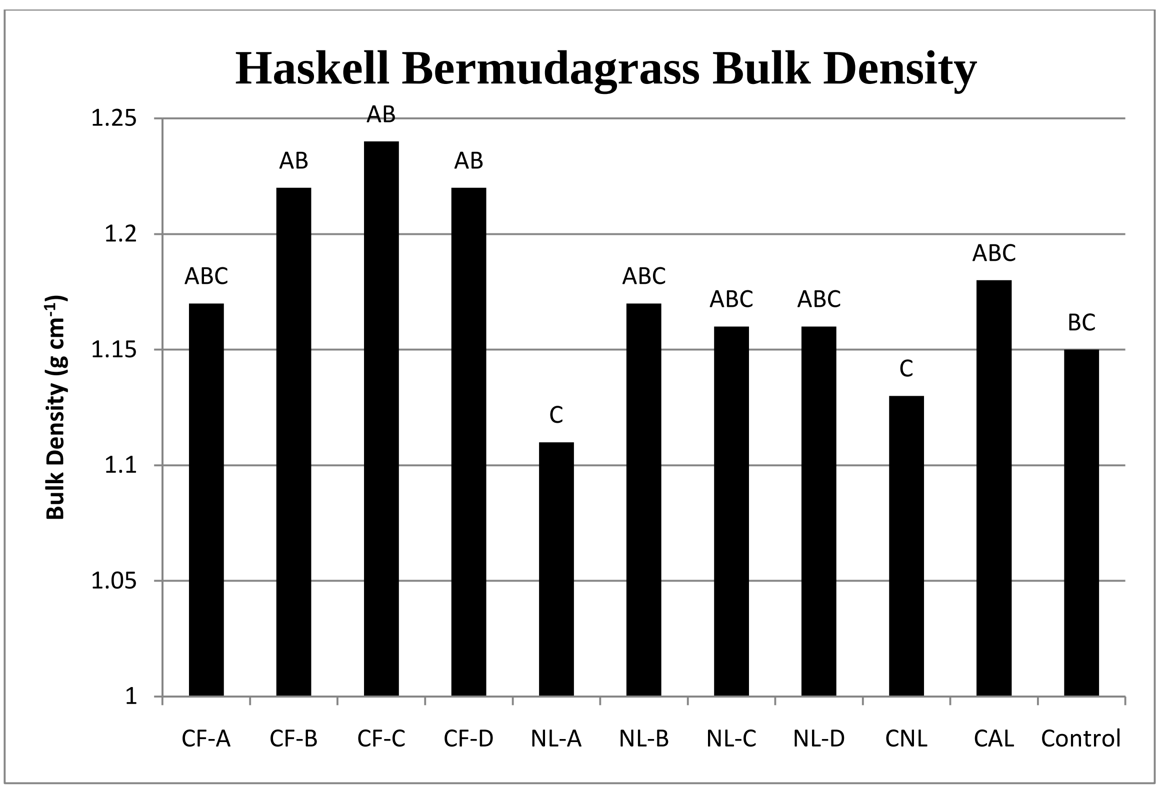

Figure 3.37: Results of bulk density after 3 years of poultry litter and inorganic commercial fertilizer application to a field to a sweet sorghum crop located on a Taloka silt loam in Haskell, OK at the Eastern Oklahoma Research Station. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on $N-P_2O_5-K_2O$ basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Upper case letters above bars represent LSD at $P \leq 0.05$ between various treatments within years.

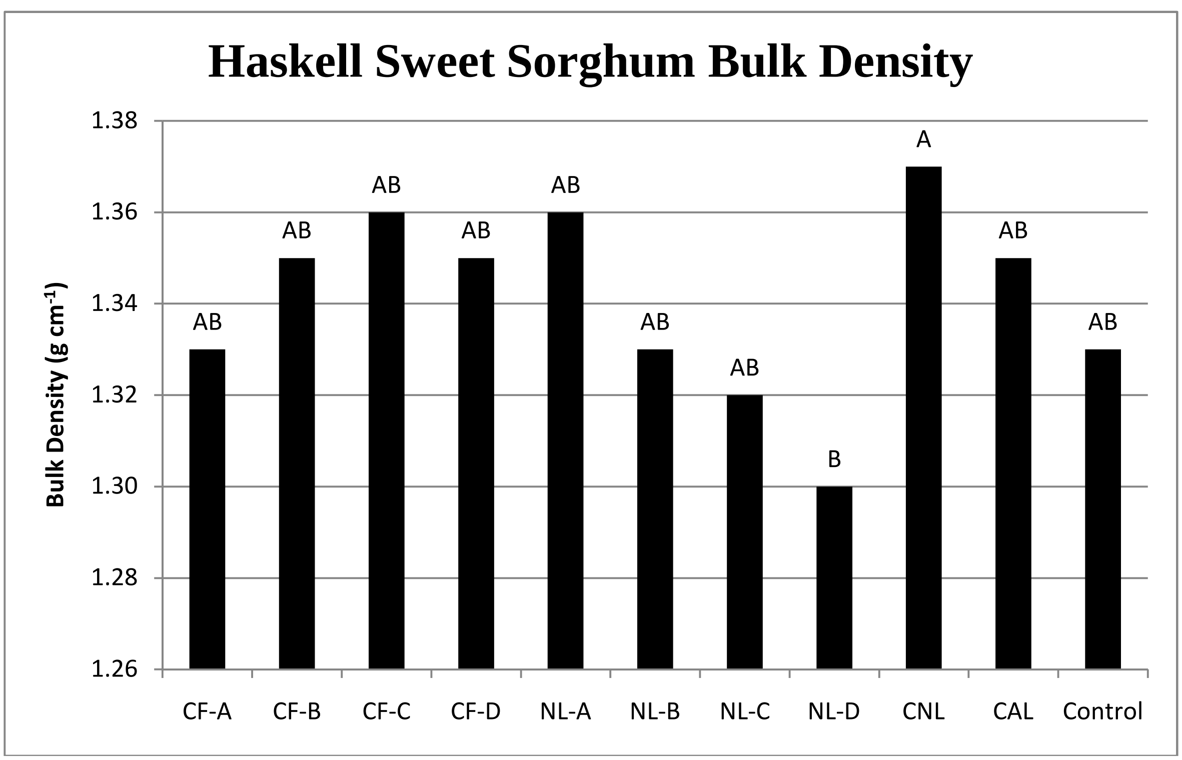

Table 3.1: Target application rate of fertilizer applied to Bermudagrass and Sweet Sorghum plots as N-P_2O_5-K_2O based on average nutrient content of poultry litter.

	Bermudagrass				Sweet Sorghum			
Application Rate†	Litter‡	Total N	Total P_2O_5	Total K_2O	Litter	Total N	Total P_2O_5	Total K_2O
	Mg ha^{-1}	....	kg ha^{-1}	....	Mg ha^{-1}	....	kg ha^{-1}	....
A	2.24	67.2	67.2	50.4	1.5	44.8	44.8	33.6
B	4.48	134.2	134.2	100.8	3.0	89.6	89.6	67.2
C	6.72	201.4	201.4	151.2	4.5	134.4	134.4	100.8
D	8.96	268.6	268.6	201.6	6.0	179.2	179.2	134.4
CAL	7.6	201.4	-	-	5.1	134.4	-	-
CNL	8.0	201.4	-	-	5.3	134.4	-	-

† Rate applied as poultry litter (A, B, C, D) and degraded poultry litters (CNL and CAL). Commercial fertilizer not included as added on exactly the same rates as fresh poultry litter
‡ Total weight of litter applied on a wet basis

Table 3.2: Average Nutrients Added to Haskell Bermudagrass from 2007-2009 with Amendments of Commercial Fertilizer or Poultry Litter.

Average Nutrients Applied 2007-2009

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	67.9	-	-	-	-	29.9	-	53.5	-	-	-	-	-	-	-	-	-
CF-B	136.1	-	-	-	-	59.9	-	107.2	-	-	-	-	-	-	-	-	-
CF-C	203.7	-	-	-	-	89.6	-	160.3	-	-	-	-	-	-	-	-	-
CF-D	272.3	-	-	-	-	119.8	-	214.4	-	-	-	-	-	-	-	-	-
NL-A	67.9	599.7	11.8	3.0	4.4	29.9	53.9	53.5	12.3	18.3	14.7	0.9	0.8	0.5	1.3	0.03	872.7
NL-B	136.1	1201.9	23.6	6.0	8.8	59.9	108.0	107.2	24.7	36.6	29.5	1.8	1.5	1.0	2.5	0.05	1749.2
NL-C	203.7	1798.2	35.3	9.0	13.2	89.6	161.6	160.3	36.9	54.8	44.1	2.7	2.3	1.5	3.8	0.08	2617.0
NL-D	272.3	2404.1	47.2	12.0	17.6	119.8	216.1	214.4	49.3	73.3	58.9	3.6	3.1	2.0	5.1	0.10	3498.8
CNL	216.3	1821.3	39.2	1.6	21.9	109.1	212.2	204.6	44.3	61.6	68.7	12.3	3.1	2.5	5.1	0.09	2823.9
CAL	227.9	1700.2	74.9	2.4	10.1	103.5	192.8	202.3	41.0	59.0	168.3	6.1	2.8	2.2	4.4	0.08	2797.9

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

Table 3.3: Average Nutrients Added to Sweet Sorghum Trials from 2007-2009 with Amendments of Commercial Fertilizer or Poultry Litter.

	Average Nutrients Applied 2007-2009																
	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	45.4	-	-	-	-	20.0	-	35.8	-	-	-	-	-	-	-	-	45.4
CF-B	90.5	-	-	-	-	39.8	-	71.3	-	-	-	-	-	-	-	-	90.5
CF-C	136.0	-	-	-	-	59.8	-	107.1	-	-	-	-	-	-	-	-	136.0
CF-D	181.4	-	-	-	-	79.8	-	142.8	-	-	-	-	-	-	-	-	181.4
NL-A	45.4	400.9	7.9	2.0	2.9	20.0	36.0	35.8	8.2	12.2	9.8	0.6	0.5	0.3	0.8	0.02	45.4
NL-B	90.5	799.3	15.7	4.0	5.9	39.8	71.8	71.3	16.4	24.4	19.6	1.2	1.0	0.7	1.7	0.03	90.5
NL-C	136.0	1200.6	23.6	6.0	8.8	59.8	107.9	107.1	24.6	36.6	29.4	1.8	1.5	1.0	2.5	0.05	136.0
NL-D	181.4	1601.8	31.5	8.0	11.7	79.8	143.9	142.8	32.9	48.8	39.3	2.4	2.1	1.3	3.4	0.07	181.4
CNL	143.9	1212.0	26.1	1.1	14.6	72.6	141.3	136.2	29.5	41.0	45.7	8.2	2.1	1.7	3.4	0.06	143.9
CAL	152.1	1134.4	50.0	1.6	6.7	69.1	128.7	135.0	27.3	39.3	112.3	4.1	1.9	1.5	2.9	0.05	152.1

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

Table 3.4: Results of Site Background Soil Analysis of Sites Prior to Commercial Fertilizer or Poultry Litter Application.

	Haskell Sweet Sorghum			Haskell Bermudagrass			Woods Sweet Sorghum		
	0-5cm	5-15cm	15-30cm	0-5cm	5-15cm	15-30cm	0-5cm	5-15cm	15-30cm
EC† (us)	138.2	71.3	70.5	123.0	40.3	31.6	39.4	46.3	25.1
pH (1:2)	5.5	5.6	5.5	5.2	5.8	5.9	5.5	5.6	6.2
Na(mg kg^{-1})	53.0	49.7	49.4	43.1	80.3	63.1	68.5	68.4	56.7
Mg(mg kg^{-1})	84.6	92.0	99.3	95.6	50.9	82.3	191.0	69.1	80.6
P(mg kg^{-1})	8.0	12.2	10.6	33.1	8.3	4.4	36.7	24.2	10.3
K(mg kg^{-1})	58.0	78.4	66.2	92.9	93.4	45.0	79.9	69.5	58.1
Ca(mg kg^{-1})	1023.3	1036.7	998.8	983.9	1079.1	974.6	364.1	403.3	465.1
Mn(mg kg^{-1})	41.6	48.2	42.4	57.9	49.2	33.0	24.2	17.0	6.6
S(mg kg^{-1})	16.0	15.0	15.1	21.1	19.4	12.2	4.9	4.6	4.3
Fe(mg kg^{-1})	156.1	157.5	150.4	282.5	131.5	99.8	210.4	190.3	159.5
Ni(mg kg^{-1})	1.6	1.6	1.8	4.2	3.4	2.9	1.9	1.4	1.3
Cu(mg kg^{-1})	0.6	0.6	0.6	0.6	1.7	0.6	0.3	0.4	0.7
Zn(mg kg^{-1})	0.9	1.1	0.9	2.0	1.4	0.5	0.9	0.6	0.5
WSP‡(mg kg^{-1})	2.4	1.8	1.1	5.8	2.0	1.4	5.7	3.7	1.5
NO3(mg kg^{-1})	30.7	10.4	11.9	14.9	3.7	3.7	4.6	6.2	3.1
NH3(mg kg^{-1})	4.2	3.7	3.7	20.4	6.6	4.1	3.8	2.5	1.9
TN (%)	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.0

TC (%)	0.8	0.9	0.8	2.0	0.9	0.7	0.6	0.4	0.2

† Electrical Conductivity (us cm-1)
‡ Water Soluble Phosphorous

Table 3.5: Results of Haskell Bermudagrass pH from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.18	0.27	0.36	0.38	0.31	0.31	0.58	0.32	0.22	0.29	0.30
0-5 cm	0.27	5.4AB§c¶	5.5Ab	5.5ABb	5.2Bb	5.6Ab	5.5ABb	5.6Aa	5.6Ab	5.5Ab	5.5Ab	5.5ABb
5-15 cm	0.24	6.0ABCb	6.1Aa	6.0ABCa	5.8Ca	5.9ABCa	6.0ABCa	5.8BCa	6.0ABCa	5.9ABCa	5.9ABCa	6.0ABa
15-30 cm	0.34	6.2Aa	6.2Aa	6.2Aa	6.0Aa	6.2Aa	6.1Aa	6.1Aa	6.2Aa	6.1Aa	6.0Aa	6.2Aa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.25	0.39	0.33	0.15	0.22	0.05	0.35	0.43	0.16	0.19	0.40
0-5 cm	0.42	4.9BCb	5.1ABb	4.8BCb	4.7Cb	5.1ABCb	5.0BCc	5.4Aa	5.2ABb	5.1ABCb	4.9BCb	5.1ABb
5-15 cm	0.32	5.6ABa	5.7Aa	5.8Aa	5.5ABa	5.7Aa	5.5ABb	5.7Aa	5.8Aa	5.6ABa	5.4Ba	5.7Aa
15-30 cm	0.39	5.7ABCa	5.9ABa	5.6ABCa	5.6BCa	5.8ABa	5.6BCa	5.8ABCa	5.9ABa	5.6ABCa	5.4Ca	6.0Aa
2009												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control

LSD Between Depth Interaction		0.15	0.44	0.25	0.27	0.13	0.16	0.31	0.52	0.10	0.11	0.27
0-5 cm	0.18	5.1EFc	5.3DEb	5.0FGc	4.9Gb	5.4CDc	5.4BCb	5.6ABb	5.7Ab	5.6ABb	5.3CDb	5.4CDc
5-15 cm	0.33	5.8BCb	6.1ABCa	5.8BCb	5.7Ca	6.0ABCb	5.9ABCa	6.0ABCa	6.2Aa	6.0ABCa	5.8BCa	6.1ABb
15-30 cm	0.45	6.1ABa	6.3Aa	6.2ABa	5.9ABa	6.1ABa	6.0ABa	6.1ABa	6.2ABa	6.0ABa	5.8Ba	6.3Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.6: Results of Haskell Sweet Sorghum pH from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.3	0.3	0.1	0.5	0.2	0.2	0.4	0.3	0.4	0.6
0-5 cm	0.5	6.3AB§a¶	6.0ABa	6.1ABa	6.01Ba	6.2ABa	6.3ABa	6.2ABa	6.1ABa	6.3ABa	6.5Aa	6.2ABa
5-15 cm	0.4	6.4Aa	6.0Aa	6.1Aa	6.1Aa	6.3Aa	6.3Aa	6.1Aa	6.2Aa	6.4Aa	6.3Aa	6.4Aa
15-30 cm	0.4	6.2Aa	6.2Aa	6.2Aa	6.1Aa	6.3Aa	6.1Aa	6.3Aa	6.2Aa	6.3Aa	6.3Aa	6.0Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.1	0.3	0.2	0.2
0-5 cm	0.2	5.4Ba	5.2Ca	5.2Cc	5.1Cb	5.6ABa	5.8Aa	5.8Aa	5.8Aa	5.9Aa	5.8Aa	5.7Aa
5-15 cm	0.2	5.5ABa	5.3Ba	5.5ABa	5.4Ba	5.5ABa	5.7Aab	5.7Aa	5.7Aa	5.6Aab	5.6Aa	5.5ABab
15-30 cm	0.2	5.4ABCa	5.4ABCa	5.3BCb	5.3Ca	5.4ABCa	5.5ABb	5.5Ab	5.4ABCb	5.4ABCb	5.3Cb	5.5ABCb

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control

LSD Between Depth Interaction		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2
0-5 cm	0.2	5.8Ca	5.6Db	5.4Eb	5.3Ea	6.0Aa	6.2Aa	6.3Aa	6.2Aa	6.3Aa	6.0Ba	5.9BCa
5-15 cm	0.1	5.8CBa	6.6Dab	5.6Da	5.6Db	5.9BCb	6.0ABb	6.0Ab	6.0Ab	6.0Ab	5.8Cb	5.9ABCa
15-30 cm	0.2	5.7ABa	5.7ABCa	5.6BCa	5.7ABCc	5.6BCc	5.6BCc	5.8Ac	5.7ABCc	5.7ABCc	5.6Cc	5.7ABCb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.7: Results of Woods County Sweet Sorghum pH from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.4	0.4	0.6	0.3	0.4	0.4	0.4	0.3	0.9	0.2	0.2
0-5 cm	0.4	5.5BC§b¶	5.6ABCb	5.3Cb	5.3Cb	5.5ABCb	5.9Ac	5.4BCb	5.8ABc	5.6ABCb	5.5BCc	5.7ABCc
5-15 cm	0.4	5.9ABCDEa	6.0ABCDab	5.9ABCDEa	5.6Eb	5.7DEb	6.3Ab	5.9DEa	6.3ABb	6.1ABCab	5.9BCDEb	6.1ABCDb
15-30 cm	0.6	6.2Ba	6.3ABa	6.4ABa	6.3Ba	6.4ABa	6.8ABa	6.2Ba	6.6ABa	7.0Aa	6.3Ba	6.5ABa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.7	0.5	0.2	0.3	0.1	0.4	0.5	0.4	0.2	0.2
0-5 cm	0.3	5.2CDc	5.1CDb	4.9Db	4.9Db	5.5ABb	5.7Ab	5.6ABb	5.6ABa	5.6ABb	5.4BCb	5.5ABb
5-15 cm	0.3	5.5ABCb	5.5ABab	5.2CDb	5.1Db	5.5ABb	5.8Ab	5.6ABb	5.7ABa	5.5ABb	5.4BCb	5.7ABb
15-30 cm	0.5	6.3ABa	6.1ABa	6.1ABa	5.9Ba	6.3ABa	6.4Aa	6.1ABa	6.0ABa	6.2ABa	5.9ABa	6.3ABa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.8: Results of Haskell Bermudagrass Soil Test Phosphorous (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		5.3	9.7	9.7	12.8	2.4	14.0	2.2	11.5	8.6	12.3	1.5
0-5 cm	12.0	16.8EF§a¶	33.0CDa	37.2BCDa	52.0Aa	15.7EFa	27.1DEa	30.2Da	34.5BCDa	44.4ABCa	46.3ABa	11.9Fa
5-15 cm	1.8	3.1ABb	4.1ABb	3.3ABb	3.6ABb	3.2ABb	3.4ABb	3.5ABb	4.2ABb	4.0ABb	4.8Ab	2.8Bb
15-30 cm	1.5	2.5Ab	2.8Ab	2.0Ab	1.9Ab	1.8Ab	2.1Ab	2.6Ab	2.1Ab	3.1Ab	3.0Ab	2.4Ab

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		4.2	4.7	8.4	12.1	3.9	4.1	8.0	12.3	7.2	8.2	0.77
0-5 cm	11.2	36.7EFa	57.3Da	76.1Ba	113.6Aa	30.6FGa	43.6Ea	55.5Da	64.2CDa	72.0BCa	81.2Ba	20.7Ga
5-15 cm	1.6	4.6Cb	6.6ABb	6.2ABCb	7.7Ab	4.8Cb	5.7BCb	5.9BCb	6.5ABb	6.8ABb	7.6Ab	4.6Cb
15-30 cm	2.1	3.2Bb	3.8ABb	3.8ABb	5.0Ab	2.1Bb	3.5ABb	3.3ABb	2.5Bb	3.5ABb	3.3Bb	2.2Bc

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		19.9	10.6	25.1	53.0	7.8	25.0	30.0	23.6	27.3	7.1	3.5
0-5 cm	31.3	51.9DEa	72.7CDa	123.5Ba	167.3Aa	40.9EFa	59.1DEa	96.2BCa	119.5Ba	124.2Ba	115.0BCa	18.5Fa
5-15 cm	3.1	6.3Db	8.6BCDb	11.4ABb	10.6ABCb	5.9Db	7.4Db	7.9CDb	11.1ABCb	12.5Ab	8.2CDb	5.7Db
15-30 cm	2.3	4.7Bb	8.0Ab	6.1ABb	5.9ABb	4.2Bb	6.1ABb	5.2Bb	6.5ABb	5.6ABb	5.2Bb	5.4Bb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.9: Results of Haskell Sweet Sorghum Soil Test Phosphorous (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		2.1	3.7	9.0	23.5	2.4	2.3	14.1	16.7	9.5	9.7	4.5
0-5 cm	16.2	11.2CD§a¶	18.8BCDa	34.5ABa	43.9Aa	10.8CDa	10.3CDa	24.4BCa	28.2ABa	30.2ABa	21.6BCDa	6.6Da
5-15 cm	3.0	8.3BCDb	11.3ABb	8.5BCDb	13.4Ab	8.3BCDb	6.2Db	7.8CDb	9.3CBb	9.2BCb	8.9BCDb	7.8CDa
15-30 cm	3.1	7.8Ab	8.4Ab	8.4Ab	8.6Ab	8.9Aab	7.1Ab	6.8Ab	7.9Ab	7.1Ab	8.0Ab	7.8Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		3.3	11.9	11.1	13.0	12.2	8.6	6.5	5.1	16.5	11.8	2.7
0-5 cm	13.0	15.2EFa	31.1CDa	47.4Ba	65.0Aa	15.7EFa	25.3DEa	29.7Da	44.5Ba	44.0BCa	51.5Ba	7.8Fab
5-15 cm	3.8	9.2CDEb	12.6ABCb	12.8ABCb	15.2Ab	7.1Ea	8.2EDb	9.9BCDEb	11.0BCDb	10.5BCDEb	13.2ABb	8.6EDa
15-30 cm	2.6	6.2ABb	5.8ABb	6.4ABb	7.5Ab	6.2ABa	4.7Bb	5.1ABb	5.4ABc	4.4Bb	6.2ABb	5.2ABb

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		4.0	12.8	18.5	23.8	11.3	4.6	11.0	33.0	19.1	29.3	1.4
0-5 cm	26.9	24.8EFa	46.2CDEa	76.9ABa	94.0Aa	32.9DEFa	35.7DEFa	57.0BCDa	88.01Aa	70.3ABCa	84.7Aa	11.8Fa
5-15 cm	6.0	10.4 CDEb	15.4 BCDb	20.6 ABb	25.5 Ab	9.7 DEb	11.2 CDEb	15.7 BCb	20.1 ABb	18.7 Bb	18.1 Bb	8.5 Eb
15-30 cm	1.9	8.0 DCb	8.5 ABCb	8.8 ABCb	10.3 Ab	9.6 BAb	7.2 DCb	9.9 Bab	9.3 ABb	9.3 Abb	8.8 ABCb	6.4 Dc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.10: Results of Woods County Sweet Sorghum Soil Test Phosphorous (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.4	5.8	8.9	14.6	3.9	14.3	6.8	9.0	11.7	10.8	2.8
0-5 cm	13.0	17.3CD§a¶	19.7BCDa	30.0ABCa	33.8Aa	17.6CDa	29.9ABCa	31.5ABa	22.4BCDa	34.4Aa	25.8ABCDa	14.9Da
5-15 cm	6.3	12.1CDb	13.3CDb	13.7BCDb	28.1ABb	5.3Db	22.6ABb	21.9ABCb	10.7CDb	28.4Ab	10.9CDb	6.7Db
15-30 cm	3.5	4.2Ab	3.7Ab	3.5Ab	10.0Ab	7.9Ab	9.5Ab	3.5Ac	6.5Ab	7.9Ab	7.0Ab	7.2Ab

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.5	2.8	14.2	15.8	5.8	8.1	4.4	8.1	11.4	10.4	5.9
0-5 cm	12.9	46.0DEa	66.9Ba	69.2Ba	83.7Aa	46.9CDa	45.5DEa	59.0BCa	67.3Ba	85.5Aa	68.6Ba	33.7Ea
5-15 cm	7.9	27.0DEFb	33.8CDb	35.4BCb	47.4Ab	21.1FGb	22.1EFGb	31.8CDb	29.5CDEb	41.9ABb	28.0CDEFb	17.0Gb
15-30 cm	3.7	9.9CDc	12.4ABCc	11.1BCDc	15.4Ac	8.3Dc	8.9CDc	11.1BCDc	9.9CDc	14.6ABc	9.4CDc	8.4Dc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.11: Results of Haskell Bermudagrass Soil Water Soluble Phosphorous (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.4	1.4	0.9	7.8	2.6	4.1	4.3	5.0	5.0	1.7	2.2
0-5 cm	2.2	2.2CD§a¶	5.5ABa	6.0Aa	3.7CDa	2.0Da	3.0CDa	2.9CDa	2.5DCa	2.5DCa	4.3ABCa	1.8Da
5-15 cm	1.6	0.8Bb	1.2ABb	1.0ABb	2.6Aa	1.2ABa	1.4ABa	1.5ABa	2.1ABa	1.1ABa	0.8Bb	1.3ABa
15-30 cm	2.3	0.7Bb	1.1ABb	0.7Bb	3.1Aa	1.3ABa	1.7ABa	1.6ABa	2.5ABa	2.5ABa	0.6Bb	1.2ABa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		3.8	4.3	1.4	5.6	1.6	3.9	2.3	6.2	2.6	4.7	1.9
0-5 cm	3.7	3.9Da	6.6ABCDa	10.1Aa	9.8Aa	6.6ABCDa	5.3BCDa	8.6ABa	8.6ABa	8.2ABCa	5.9BCDa	4.8DCa
5-15 cm	3.0	1.7Ba	3.0ABab	2.0ABb	4.8Aab	1.7Bb	3.5ABab	3.1ABb	3.5ABab	1.9ABb	1.9ABa	2.1ABb
15-30 cm	1.8	2.5Aa	1.4Ab	1.5Ab	2.1Ab	1.6Ab	1.3Ab	2.3Ab	1.4Ab	1.6Ab	2.3Aa	1.6Ab

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.4	0.9	2.3	5.0	0.5	3.1	2.9	5.1	4.1	2.8	0.5
0-5 cm	3.7	6.8CDa	9.3Ca	14.6ABa	17.9Aa	6.9CDa	8.2CDa	13.3Ba	17.9Aa	15.2ABa	8.1CDa	4.7Da
5-15 cm	0.5	2.1Fb	2.5CDEFb	2.8ABCDb	2.8ABCDEb	2.4CDEFb	2.4CDEFb	2.8ABCb	2.9ABb	3.2Ab	2.3EFb	2.3DEFb
15-30 cm	0.6	1.7Ab	1.9Ab	1.8Ab	2.1Ab	1.9Ac	1.7Ab	2.0Ab	1.9Ab	1.8Ab	1.9Ac	1.6Ac

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.12: Results of Haskell Sweet Sorghum Soil Water Soluble Phosphorous (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.5	1.7	0.9	2.9	0.9	0.4	1.7	2.4	3.2	0.7	0.7
0-5 cm	1.8	1.6D§a¶	2.8BCDa	4.1ABa	5.5Aa	1.7CDa	1.3Da	2.9BCDa	4.1ABa	3.5BCa	2.0CDa	1.3Da
5-15 cm	1.1	1.6Aa	2.1Aa	1.5Ab	2.0Ab	2.1Aa	1.45Aa	1.8Aa	1.8Aab	2.2Aa	1.7Aa	1.8Aa
15-30 cm	1.5	1.4ABa	1.5ABa	1.3Bb	1.7ABb	1.7ABa	1.3Ba	1.4ABa	1.4ABb	2.8Aa	1.4ABa	1.6ABa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.5	2.8	3.8	3.4	1.5	1.3	2.4	2.4	4.5	1.4	0.6
0-5 cm	2.4	2.1DEa	3.7CDEa	6.4ABa	8.1Aa	2.7DEa	5.5BCa	4.3BCDa	6.3ABa	8.0Aa	5.4BCa	1.8Ea
5-15 cm	1.1	1.9Ba	3.1Aa	2.7ABab	2.2ABb	1.8Ba	1.9Bb	2.1ABab	2.1ABb	2.3ABb	23ABb	1.9Ba
15-30 cm	2.0	2.0ABa	1.4Ba	1.5Bb	1.6Bb	1.5Ba	1.7Bb	1.9ABb	1.8ABb	3.8Aab	1.5Bb	1.4Ba
2009												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.4	1.7	1.9	2.2	1.4	1.1	2.3	2.4	2.5	1.3	0.7

0-5 cm	2.3	4.1FGa	6.6DEa	9.7ABCa	11.9Aa	5.1FGHa	6.4DEFa	8.7BCDa	10.3ABa	11.7Aa	7.7CDa	3.0Ga
5-15 cm	1.2	2.4CDb	2.9BCDb	3.3ABCDb	3.5ABCb	2.4CDb	2.7BCDb	4.2Ab	3.7ABb	3.3ABCDb	2.8BCDb	2.1Db
15-30 cm	0.3	1.8BCc	1.9ABCb	2.0ABb	2.0ABCb	1.9ABCb	1.9ABCb	2.1Ab	2.0ABb	1.9ABCb	1.8BCb	1.7Cb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table 3.13: Results of Woods County Sweet Sorghum Soil Water Soluble Phosphorous (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		1.1	1.09	1.52	2.15	1.41	3.66	1.46	2.74	2.26	1.27	1.10
0-5 cm	2.8	5.2BC§a¶	5.6BCa	7.0ABCa	7.6ABa	5.9BCa	7.2ABCa	7.8ABa	7.5ABa	9.0Aa	5.8BCa	4.5Ca
5-15 cm	1.1	7.8CDb	3.3BCb	3.2BCDb	4.5Ab	2.2Db	3.6ABCab	4.1ABb	3.3BCb	3.4ABCb	2.5CDb	2.5CDb
15-30 cm	0.9	1.6ABc	1.9ABc	2.0ABb	1.7ABc	1.4ABb	2.2Ab	2.0ABc	1.9ABb	1.9ABb	1.6ABb	1.3Bc
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.71	0.95	2.47	2.35	1.51	2.58	0.91	1.41	1.21	2.47	0.62
0-5 cm	2.4	8.2Ea	10.9Da	12.8BCDa	14.6ABa	8.4Ea	8.3Ea	11.7CDa	13.8ABCa	15.8Aa	10.8Da	5.7Fa
5-15 cm	1.5	4.0DEFb	5.4DCb	5.5CDb	7.9Ab	3.9EFb	4.1DEFb	5.3CDEb	5.9BCb	7.1ABb	4.0DEFb	3.0Fb
15-30 cm	0.6	1.7ABc	1.9ABc	1.7ABc	2.3Ac	1.6Bc	1.7ABb	1.9ABc	1.5Bc	2.1ABc	1.7ABb	1.6Bc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N\text{-}P_2O_5\text{-}K_2O$ basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

CHAPTER IV

EFFECTS OF INORGANIC FERTILIZER AND POULTRY LITTER ON POTENTIAL BIOFUEL CROPS

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Abstract

Bermudagrass [*Cynodon dactylon L.*] and sweet sorghum [*Sorghum bicolor (L.) Monech*] have emerged as leading candidates in the production of biomass to meet the proposed future cellulosic bioenergy needs of the U.S. This study was conducted for comparison of poultry litter and inorganic commercial fertilizer applications to nutrient deficient soils in the production of plant biomass and total nutrient removal. The effects of fertilizer type on plant yield and nutrient uptake of bermudagrass (BD) and sweet sorghum (SS) plots were investigated in Haskell, OK on Taloka silt loam and Woods County, OK on Eda loamy fine sand (sorghum only with only 1 year; drought loss). Bermudagrass biomass yields responded to fertilizer rate in a linear fashion for both fertilizer types ranging from

3.6-14.4 Mg biomass ha^{-1}. The 2009 growing season was extremely dry with no difference in fertilizer types observed, while 2008 and 2009 resulted in significantly higher yield for inorganic applications in these moderate and extremely dry years. Haskell SS biomass yields in 2007 and 2009 were not substantially different due to non-ideal conditions, while 2008 produced significantly higher yields and was the only year with a linear response to N and significant differences between fertilizer type as the inorganic outperformed the litter. Yield over the 3 years ranged from 9.1-29.7 Mg ha^{-1}. Woods county SS produced a linear result to N application with no difference between fertilizer types with yield ranging from 4.9-7.9 Mg ha^{-1}. No significant difference between fertilizer types was observed for nutrient uptake among both crops and sites. Nutrient removal appeared to be controlled by the rate of fertilizer applied and total biomass removed. Use of poultry litter appears to be a good alternative to inorganic commercial fertilizer especially when P and K deficiencies are present and ideal mineralization conditions occur.

Introduction

As the United States continues to take a harder look at becoming energy independent in the near future, the use of bio-fuel crops comes to our attention. Preliminary research has shown that ethanol production from cellulosic fermentation will become more energy efficient, cost effective, and environmentally beneficial than corn grain based ethanol production (Solomon et al., 2007). As these technologies are being advanced and developed it becomes apparent that production of these fuel stocks must be researched and advanced to meet their potential future need. Agricultural products that have potential include anything that can produce biomass efficiently and economically (Solomon et al., 2007; Chen et al., 2007). The use of grasses as a source for bio-fuel production makes even greater sense as over 150 million tons of hay and silage are already produced yearly for livestock feed and could easily be transitioned to the focus of a dual purpose crop (Chen et al., 2007).

One of the major issues and reasons for use of bio-fuels is the reduction of energy use from fossil fuels. As we continue to move towards more sustainable goals, the use of high energy, commercial inorganic fertilizer input must be taken into account. Limited alternatives to inorganic fertilizers are found throughout the U.S. depending on the geographic region. In Oklahoma both swine effluent and poultry litter are available as alternatives with poultry litter being the more available and better fertilizer. Yet, the use of poultry litter outside of high poultry production areas is somewhat limited and this has lead to environmental concerns in these areas caused by the over application of P.

Areas outside of these nutrient sensitive watersheds are seen to have the greatest potential for future bio-fuel production. The majority of these soils are seen as nutrient poor and in need of fertilizer amendments, making the use of poultry an even more viable option with its ability to supply a large amount of various essential plant nutrients. Use of poultry litter as a fertilizer for biomass production for bio-fuels results in the resolution of two problems: 1) increasing viability for litter use outside of poultry production areas and 2) the reduction in the use of high energy commercial fertilizer.

Bermudagrasses (*Cynodon dactylon L.)* is one of the most widely adapted and produced C4 perennial forage crop grown in the southeastern United States and other temperate regions (Anderson, 2007 and Muir, 2009). At present, over 4 million ha of bermudagrass are grown in the United States (Sanderson et al., 2008). Bermudagrass has the ability to produce high yields and maintains itself as a very durable forage (Ball et al 1991). Anderson et al. (2007) found bermudagrass to be a superior feedstock for the conversion of ethanol via saccharification and fermentation. Use of bermudagrass as bio-fuel feedstock could also offer producers another opportunity to utilize their forage crops, especially in years of low nutrient quality production as feedstock nutrient quality has no effects on bio fuel production (Anderson et al., 2007). For these reasons it has strong potential as a producer of biomass for cellulosic ethanol production of the future.

Sweet sorghum (*Sorghum bicolor (L.) Moench)* is another crop that has come to the forefront as an annual C4 grass with very high biomass and sugar production, water logging resistance, salinity tolerance, and drought tolerance (Reddy et al., 2005 and

Mastrorilli et al., 1999). These attributes have earned sweet sorghum the nickname the 'camel' among the bio-fuels community (Li., 1997). Sweet sorghum dry matter yields are accepted to be only moderately affected by N application as shown by Buxton et al. (1999). These low N rate requirements favor sweet sorghum over grain crops for ethanol production (Wortmann et al., 2010). Sweet sorghum has the ability to produce solely juice or biomass or both for ethanol production resulting in an even more adaptable crop for bio-fuel production.

Numerous studies have been completed showing the effects on poultry litter on soil properties and crop production. Poultry litter is a mixture of both poultry manure and bedding materials, usually rice hulls or woods chips (Edwards, 1992). Poultry litter is considered to be the most valuable of all animal waste for application as a soil amendment with its diverse and more importantly high concentration of nutrients (Wilkinson, 1979).

Wood et al. (1990) found that using poultry litter as a fertilizer for bermudagrass to be "an excellent sustainable agricultural practice". When soils fertilized with organic fertilizers (manure) are compared to those using inorganic fertilizers in long term studies they have been shown to have higher organic matter, P, K, Ca, and Mg; they also possess lower bulk density and higher porosity and aggregate stability, with no difference in yield between fertilizer type (Edmeades, 2003). Moore and Edwards (2005) suggested pasture application of poultry litter as a fertilizer as more sustainable practice than using ammonium-nitrate.

The primary objective of this study are to (i) determine the value of poultry litter compared to inorganic commercial fertilizer when applied at equal rates to pasture (bermudagrass) and croplands (sweet sorghum) for the purpose of producing biomass as potential bio-fuel crops.

Material and Methods

Study location and treatments

A 3 year study was established at two locations in the spring of 2007 with two plots at Oklahoma State University's Eastern Oklahoma Research Station located south of Haskell, OK (35 44' 46" N, -95 38' 23"W) and 2 years (weather limited) of production from a plot located west of Aline, OK in Woods County (36 29' 25" N, -98 40' 24" W). Plots were established on a Taloka fine mixed, active, thermic, mollic, Albaqualfs at Haskell and Eda mixed, thermic Lamellic Ustipsamments at Woods County. Taloka soils are described as very deep, somewhat poorly drained, very slowly permeable soils that formed in loamy and clayey material weathered from colluvium and alluvium over interbedded shales and sandstone. Eda soils consist of very deep, somewhat excessively drained, rapidly permeable soils that formed in sandy eolian deposits on dunes. The Haskell site has on average 215 growing days, average temperature of 15.5^{o}C, and 1130 mm of precipitation a year. Woods County site has on average 191 growing days, average temperature of 14.3^{o}C, and 683 mm of precipitation a year. These sites were chosen as background soil nutrient levels showed deficiencies of N, P, and K for crop production allowing for better interpretation of effects litter and commercial fertilizer affects on target nutrient deficient soils.

The experiments were designed as a completely randomized block design with 4 repetitions and 11 treatments. Plots were 3 m wide by 9 m in length with 3 m alleys between repetitions. The single site in Woods County and one of the sites in Haskell were planted to sweet sorghum (*Sorghum bicolor* (L.) Moench) using conventional tillage system with the variety Topper for all three years of the experiment, seeded at a seeding rate of 52,000 plants ha^{-1}, spaced on 76 cm rows. The other site at Haskell was an established bermudagrass (*Cynodon dactylon L.)* hay pasture. The 11 treatments consisted of fresh poultry litter, commercial fertilizers, degraded poultry litter, and a control for each repetition. Poultry litter and commercial fertilizer were amended at 4 different rates (A, B, C, D; Table 3.1-3.3) with equal N, P, and K addition. However, degraded litter was only applied at rate C (Table 3.1) due to limited quantities. Poultry litter was surface in the bermudagrass plots while the sweet sorghum was incorporated with field cultivator to a depth of 7.5 cm. Fertilizer source used for the commercial fertilizers included urea, di-ammonium phosphate and potash in granular form.

Fresh litter was started in a low-input degradation system 2 months prior to application of fertilizer. The degraded litter consisted of two degradation treatments both treated exactly the same way except for addition of alum on a 10% by weight basis, which is discussed in more detail in Chapter 2. When the degraded piles were initiated, fresh litter for later applications was collected, weighed out and refrigerated for 2 months prior to field application in the second week of May every year.

Weeds were controlled in the sweet sorghum with pre and post emergence application of atrazine (Atrazine 4L Makhteshium Agan, Inc. Raleigh, NC) depending on need at 1.1 kg ha^{-1} and a post emergence application of glyphosate (Round-up Power-Max, Monsanto , St. Louis, MO) at 200 g ha^{-1} with a backpack hooded sprayer when needed through the crop season. Accepted best management practices were used in bermudagrass plots to maintain the best weed free environment possible with these accepted practices (Redfearn et al, 2009).

Physical and Chemical Analysis

Forage yield and nutrient composition were monitored every year for 3 yr along with nutrient uptake efficiency. Bermuda grass was harvested twice a year (early July and September) while sweet sorghum was harvested once a year (late September). Bermuda grass was harvested with a Carter forage harvester with one 0.91 m wide swath down the middle of each plot (Carter Mfg Co., Inc. Brookston, IN). Before harvesting, all alley ways were removed and yield was calculated on area of each plot harvested between alleys. A random biomass sample was removed from each bag to determine moisture and nutrient content. Sweet sorghum was harvested by hand by randomly harvesting two 3 m long sections from the middle 2 rows. A random sub-sample from both sections was removed for moisture and nutrient analysis after weighing the samples. Both sub-samples were then dried at 35 degrees C° for 3 days or until dry and ground to pass through a 0.75mm screen then submitted for nutrient analysis to Oklahoma State University Soil, Water, and Forage Laboratory for total digestion of P, K, Mg, Ca, Na, Mn, Cl, Cu, Fe, Zn, Mo (EPA 3050 acid digestion method with solution analyzed by inductively coupled argon plasma analyzer (ICP-AES) Spectro Ciros, Mahwah, NJ) and Total Nitrogen (TN) and Total Carbon (TC) (combustion method, Leco TruSpec St. Joseph, MI). Nitrogen use efficiency was calculated for both bermudagrass and sweet sorghum using the difference method (Moll et al., 1982)

Experiments were analyzed as a Randomized Complete Block design with 4 replications and 11 treatments. Biomass yield and nutrient concentrations were analyzed with years independent. Data were analyzed using PROC GLM in PC SAS Version 9.2 (SAS Institute, Cary.NC). Differences in treatments were assessed with an LSMEANS statement and significance was determined at a $P \leq 0.05$ level.

Results and Discussion

Above average rainfall was recorded for the first two years at the Haskell site while the third year resulted in below average rainfall during the growing season (Figure 4.1). Rainfall during the growing season at Woods County in 2007 was above normal while 2008 resulted in a lost crop due to insufficient rainfall (Figure 4.2). After the loss of the sweet sorghum crop, a winter wheat crop was planted in November of 2008 that was also lost due to insufficient moisture. For these reasons the use of this location was discontinued before the final year.

Background soil nutrient levels showed deficiencies of N, P, and K in Haskell sweet sorghum site and N and K deficiencies in the Haskell bermudagrass and Woods sweet sorghum sites for crop production when compared to Oklahoma State University recommended optimum nutrient requirements as desired (Table 4.2), allowing for better interpretation of effects of litter and commercial fertilizer on the target nutrient deficient soils of Oklahoma. Actual average nutrients added each year per plot are given in Table 4.3 and 4.4.

Biomass Yield

Haskell bermudagrass yields varied between years of the study most likely due to the differences in environmental conditions and their effects on N mineralization. The highest biomass yield among all three years was observed in 2007 with the lowest yield observed in 2009 (Figure 4.3; Table 4.5). The low yields in 2009 were likely a result of the below average rainfall and severe water stress placed on the forage crop. Bermudagrass biomass yield showed a linear response to N rate application every year (Table 4.5).

A significant increase in yield over the control was seen in every treatment application rate except for the lowest rate of fresh poultry litter. In all years of the study an increase in biomass of around 2 Mg ha^{-1} between treatment rates was observed for every 50 kg N ha^{-1} applied, generally agreeing with Zhang et al.'s (2009) general assumption for bermudagrass response to N fertilizer in Oklahoma

Yield results of inorganic fertilizer application were on average higher than all forms of poultry litter applied at the same fertilizer rate (Table 4.5). These differences were significant every year except 2007(Figure 4.3). McGrath et al. (2010) produced very similar results; 2 years of inorganic fertilizer yielded consistently more biomass over poultry litter applied at the same rate to fescue in Virginia. Woods et al. (1990) found similar yield results as poultry litter applied at 5.6 Mg ha^{-1} resulted in roughly 10 Mg ha^{-1} of forage yield a year. They also found that yields from inorganic fertilizer applied at similar rates of available N were numerically higher but not statistically different. The above study differed from the current study in that the inorganic N application was applied at a lower rate to account for the greater loss of N volatilization from poultry litter. Greater N loss and/or lower N availability of the litter can account for the difference in yield. Comparing years based on rainfall totals, one can assume a greater mineralization of N in the wetter years from the poultry litter. Higher rainfall in 2007 could also be used to suggest potential of N leaching from the inorganic fertilizer with its higher N solubility compared to the litter. This increased leaching could explain the similar yields in 2007 as the commercial fertilizer was susceptible to leaching, while the litter slowly released N reducing chance of mass N loss and greater long term plant availability.

Degraded alum litter resulted in higher yields than degraded normal litter every year and was only significantly different than commercial fertilizer at equal rate (rate C) in 2009 (Figure 4.3). Alum treated litter would be expected to produce higher biomass yields as a result of more stable, plant available N and the higher concentrations of P and K added. Greater P and K additions are a result of degradation process and increased P and K in relation to N concentration on which degraded litter applications were based. These results are similar to with Moore and Edwards (2005) results that alum treated litter was a better fertilizer practice for fescue than fresh litter, but they also showed it to be more productive than NH_4NO_3 application at the same N rate. Observations from this study that inorganic fertilizer did not yield less could be due to the fact that we also applied P and K fertilizer at the same rate and better supplied those needs reducing the chance of sufficiency issues. By better meeting P and K requirements in our own study, plant yield was then only limited by the amount of N available resulting in a more honest response comparison of the fertilizer types.

Haskell sweet sorghum yields varied during the study due to the differences in environmental conditions each year (Figure 4.4). Unlike bermudagrass yields, sweet sorghum produced its largest yielding biomass year in 2008 (Table 4.6). Yields in 2007 and 2009 were very similar. The low yields of 2007 could be a result of substantially too much rain resulting in a hindrance of biomass production as the study site exhibited it's "somewhat poorly drained" characteristics, while 2009 can be explained by the below normal rainfall during the growing season and the accompanying drought stress. Range in biomass yields at a similar N rate over the three years agrees with Hallam et al. (2001) yields observed over five years in central Iowa. Using two separate cultivars of sweet sorghum and an inorganic N rate of 140 kg ha^{-1} Hallam et al. (2001) produced 15.3-22.9 Mg ha^{-1} biomass.

Biomass yields in 2007 show relatively little response to fertilizer application. 2008 yields showed a very linear response to N application rate, yet poultry litter applications produced significantly less than inorganic fertilizer especially at the higher rates (Figure 4.4). Biomass yields between poultry litter and inorganic N were significantly different only in the second year of application. This difference in 2008 could be a result of rainfall timing and below normal rainfall in August that reduced the mineralization of organic N from the litter. In 2009, when drought conditions were present, N availability and mineralization were reduced by the dry conditions. Sleugh et al (2006) comparisons of poultry litter to inorganic fertilizer in the production of sorghum-sudangrass resulted in higher biomass production with inorganic fertilizer in 2 of the 3 years of the study.

In our study, 2009 produced a response to N application but the response was in no way as consistent as 2008 (Figure 4.4). Prior research has suggested that sweet sorghum shows no response to N rates over 112 kg ha^{-1} (Wiedenfeld, 1984). The N response for 2008 and 2009 disagree with prior studies as a significant N response was observed up to the 134.1 kg ha^{-1} rate.

Degraded litters produced relatively similar yields every year but unlike the bermudagrass study, yields were significantly lower than other treatments applied at similar N rates (rate C) except for 2007 (Figure 4.4). Lower biomass yields for degraded litters has no obvious explanation and cannot be explained as the more stable N and increased nutrient content of the degraded litter should have at least produced equal yield as plots with the same N rate.

Woods County sweet sorghum only produced one year of usable biomass yields due to crop loss following the first year. The 2007 biomass yields of sweet sorghum produced an excellent response to N application in a linear fashion (Figure 4.5). Yield results of inorganic fertilizer application were on average higher than all forms of poultry litter applied at the same fertilizer rate. Yet these higher biomass yields were not significantly different from each other (Figure 4.5). A statistically significant increase in yield over the control was not seen until the commercial fertilizer rates reached rate C (134.4kg N ha^{-1}), while the poultry litter required the highest rate (179.2 kg N ha-1) (Table 4.7). The degraded litters applied at rate C were not significantly different the highest rate of commercial applied and resulted in higher yields than all the fresh litters (Figure 4.5). Biomass yield for the Woods County site was noticeably lower than the yield produced in Haskell as a result of the more arid conditions.

Nutrient Uptake

Nutrient uptake and removal between all treatments both crops resulted in no significant trend in the amount of nutrient removed per crop. The amount of nutrient removed was dependent on the total amount of biomass produced as a function of fertilizer rate applied. Another study using a similar crop (sorghum-sudangrass) showed increased uptake and removal of P, yet that study applied inorganic P at substantially lower rates than the current study where P was applied at the same rate for better comparison of application effects (Sleugh et. al, 2006).

Another consideration is the fact that biomass cropping systems remove significantly more nutrients than grazing or grain crop production systems. The plant removal of secondary macro and micro nutrients are balanced out with their application in poultry litter making litter use an even more sustainable long-term practice than inorganic application where these nutrients could be slowly depleted over years of removal. Applying litter to these bio-fuel crops also is more ideal from an environmental perspective as entire biomass removal reduces the chance of nutrient build-up compared to grazing and grain-only focused cropping systems.

Nitrogen use efficiency (NUE) of inorganic commercial fertilizer was numerically higher in all treatments and years, yet this difference was not significant (Table 4.8). The higher NUE of commercial fertilizer can be attributed to the greater plant availability of urea compared to the poultry litter in which environmental conditions have a much greater role in determining plant availability. The difference in NUE between inorganic and litter N sources indicates that the “effective” N mineralization of litter varied from 50-70% (Table 4.8). The highest “effective” N mineralization was displayed in the bermudagrass during 2007 (the most wet year).

Conclusions

A significant difference in biomass yield between inorganic commercial fertilizer and poultry litter does not exist when applied at exactly the same rate of N, P, and K under ideal weather conditions for sufficient N mineralization from the litter. For this reason, N availability should be taken into account when applying litter, and adjust rate of application to meet yearly requirements. Variability in N availability from poultry litter is difficult to predict since weather conditions control thier ability to release N through mineralization. Models for predicting N availability have been suggested using decay coefficients, yet no truly accurate method for N availability has been determined (Edwards and Daniel, 1992).

Alum and natural degraded litter produced yields very similar to the plots receiving the highest rate of N while they only received the second highest application rate. The degradation process likely resulted in these litters possessing more stable, slower releasing N and increased P and K that made them more valuable than the fresh litters. Greater P and K additions are a result of degradation process and increased P and K in relation to N concentration on which degraded litter applications were based. Nutrient removal was not affected by the type of fertilizer applied as yield had a more dominate role in the control of nutrient removal than actual nutrients applied, especially when it comes to secondary macro and micro nutrients. Poultry litter's ability to replace the large amount of micro and trace nutrients removed by biomass harvest further increase its potential as a sustainable long term practice in the production of bio-fuel crops. The use of poultry litter as fertilizer is good alternative to inorganic commercial fertilizer application and should be taken into account by all farmers as alternative to commercial fertilizers, especially when it can be acquired at a cheaper price than conventional methods of fertilization.

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Figure 4.1: 2007-2009 Haskell Mesonet Station Monthly Rainfall Data Compared to the 30 Year Average.

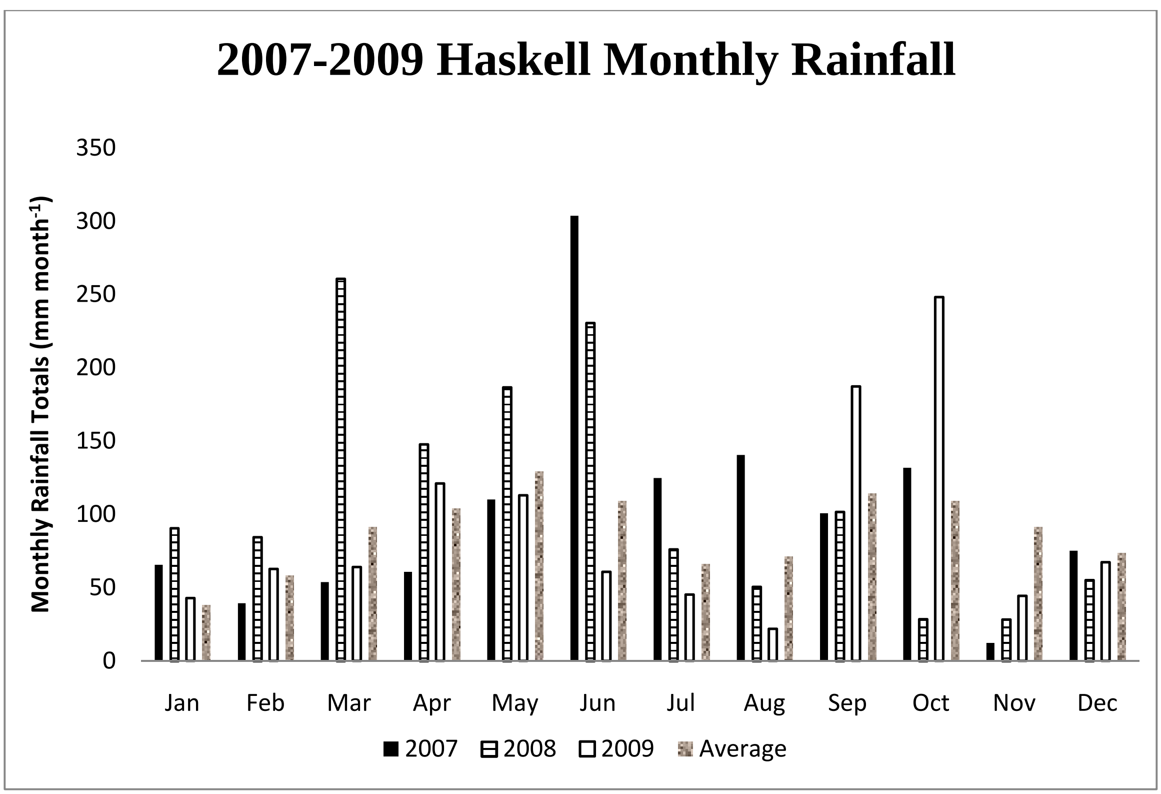

Figure 4.2: 2007-2008 Woods County Monthly Rainfall Data taken from the Cherokee, OK Mesonet Station Compared to the 30 Year Average.

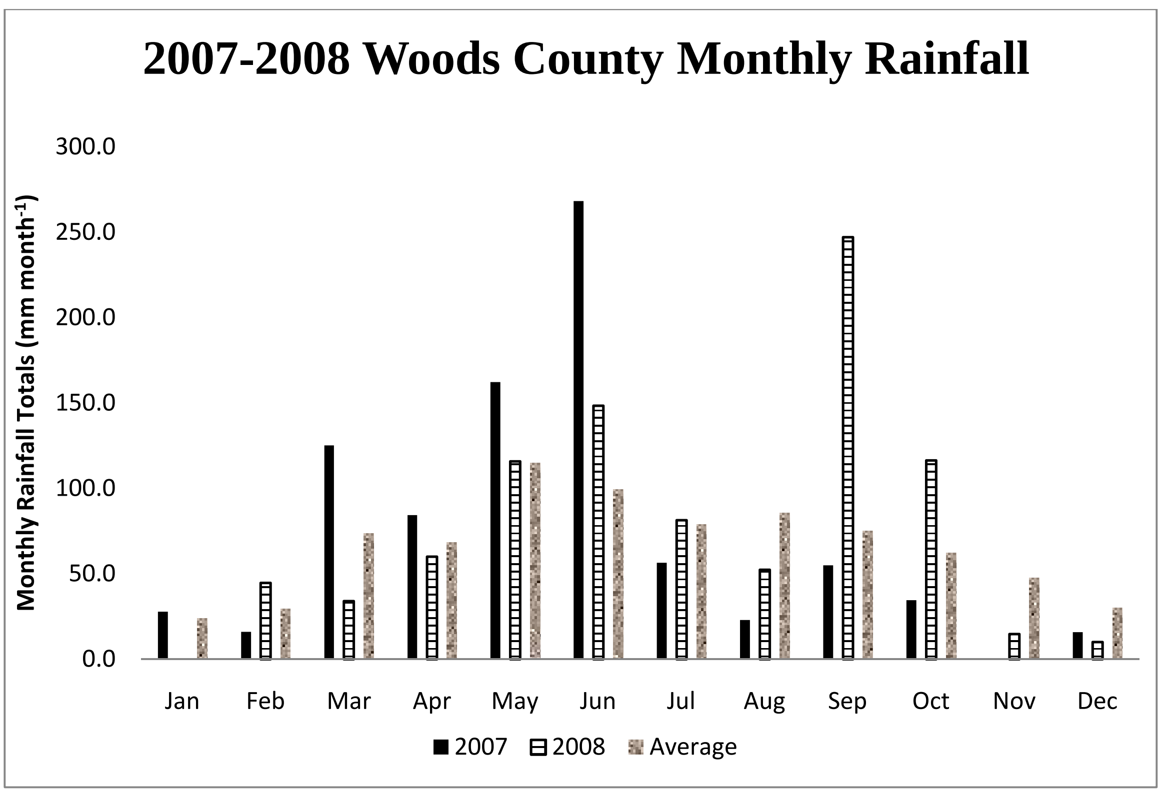

Figure 4.3: Average biomass yield (dry wt.) for Haskell Bermudagrass for 2007-2009 with various fertilizer treatments. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on N-P_2O_5-K_2O basis (kg ha^{-1}) as A=67.1-67.1-50.4, B=134.2-134.2-100.8, C=201.4-201.4-151.2 D=268.6-268.6-201.6 CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

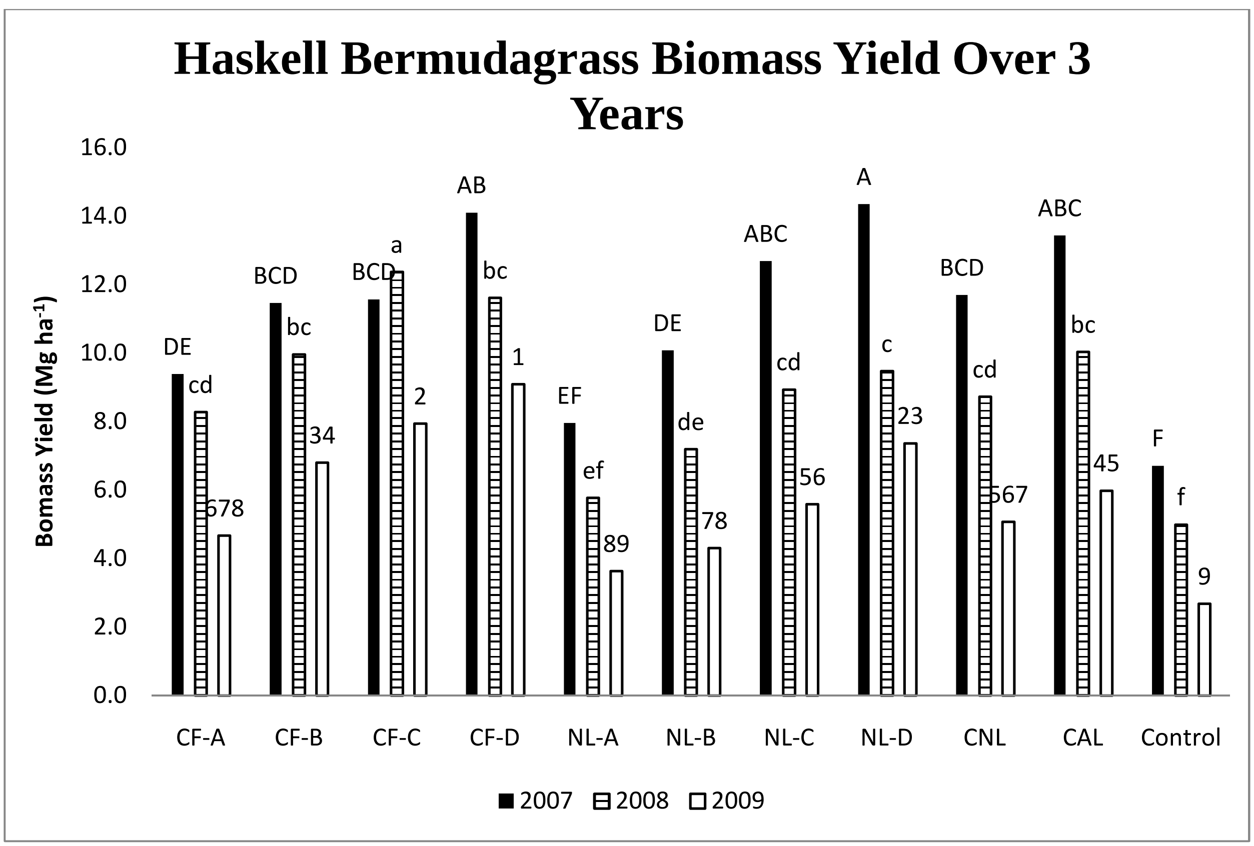

Figure 4.4: Average biomass yield (dry wt.) for Haskell Sweet Sorghum for 2007-2009 with various fertilizer treatments. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied on $N\text{-}P_2O_5\text{-}K_2O$ basis (kg ha^{-1}) as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at $P \leq 0.05$ between various treatments within years.

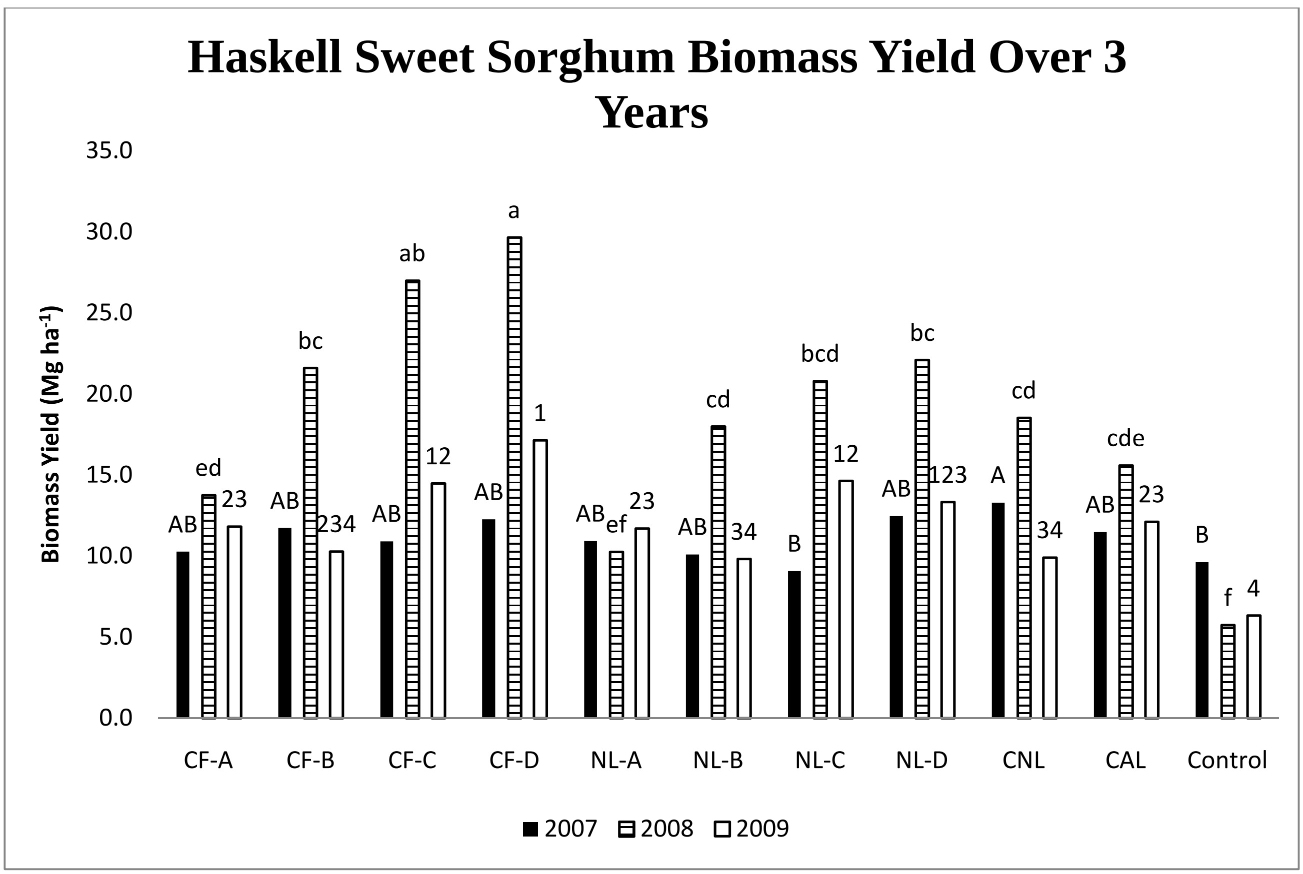

Figure 4.5: Average biomass yield (dry wt.) for Woods county sweet sorghum for 2007with various fertilizer treatments. Fertilizers treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment. Fertilizer rates applied (kg ha^{-1}) on N-P_2O_5-K_2O basis as A=44.8-44.8-33.6, B=89.6-89.6-67.2, C=134.4-134.4-100.8 D=179.2-179.2-134.4. CNL and CAL applied on N basis alone to match rate C. Lower and upper case letters and numbers above bars represent LSD at P $\leq$ 0.05 between various treatments within years.

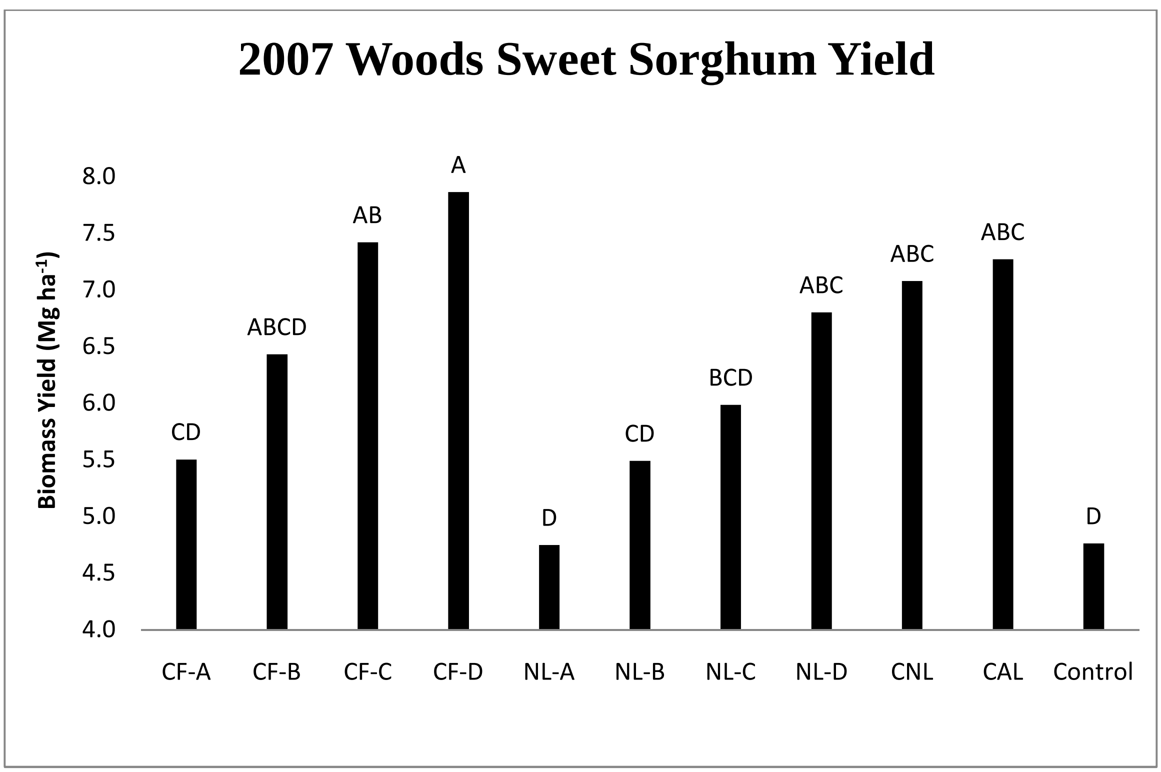

Table 4.1: Target application rate of fertilizer applied to Bermudagrass and Sweet Sorghum plots as N-P_2O_5-K_2O based on average nutrient content of poultry litter.

	Bermudagrass				Sweet Sorghum			
Application Rate†	Litter‡	Total N	Total P_2O_5	Total K_2O	Litter	Total N	Total P_2O_5	Total K_2O
	Mg ha^{-1}	.... kg ha^{-1}			Mg ha^{-1}	.... kg ha^{-1}		
A	2.24	67.2	67.2	50.4	1.5	44.8	44.8	33.6
B	4.48	134.2	134.2	100.8	3.0	89.6	89.6	67.2
C	6.72	201.4	201.4	151.2	4.5	134.4	134.4	100.8
D	8.96	268.6	268.6	201.6	6.0	179.2	179.2	134.4
CAL	7.6	201.4	-	-	5.1	134.4	-	-
CNL	8.0	201.4	-	-	5.3	134.4	-	-

† Rate applied as poultry litter (A, B, C, D) and degraded poultry litters (CNL and CAL). Commercial fertilizer not included as added on exactly the same rates as fresh poultry litter
‡ Total weight of litter applied on a wet basis

Table 4.2: Results of Site Background Soil Analysis of Sites Prior to Commercial Fertilizer or Poultry Litter Application.

	Haskell Bermudagrass			OSU Optimum Nutrient Requirements§	Haskell Sweet Sorghum			OSU Optimum Nutrient Requirements	Woods Sweet Sorghum		
	0-5cm	5-15cm	15-30cm	Bermudagrass	0-5cm	5-15cm	15-30cm	Sweet Sorghum	0-5cm	5-15cm	15-30cm
pH	5.2	5.8	5.9	-	5.5	5.6	5.5	-	5.5	5.6	6.2
EC† (us cm^{-1})	123.0	40.3	31.6	-	138.2	71.3	70.5	-	39.4	46.3	25.1
Na(mg kg^{-1})	43.1	80.3	63.1	-	53.0	49.7	49.4	-	68.5	68.4	56.7
Mg(mg kg^{-1})	95.6	50.9	82.3	100	84.6	92.0	99.3	100	191.0	69.1	80.6
P(mg kg^{-1})	33.1	8.3	4.4	32.5	8.0	12.2	10.6	32.5	36.7	24.2	10.3
K(mg kg^{-1})	92.9	93.4	45.0	125	58.0	78.4	66.2	125	79.9	69.5	58.1
Ca(mg kg^{-1})	983.9	1079.1	974.6	750	1023.3	1036.7	998.8	750	364.1	403.3	465.1
Mn(mg kg^{-1})	57.9	49.2	33.0	1.0	41.6	48.2	42.4	1.0	24.2	17.0	6.6
S(mg kg^{-1})	21.1	19.4	12.2	-	16.0	15.0	15.1	-	4.9	4.6	4.3
Fe(mg kg^{-1})	282.5	131.5	99.8	$\geq$4.5	156.1	157.5	150.4	$\geq$4.5	210.4	190.3	159.5
Ni(mg kg^{-1})	4.2	3.4	2.9	-	1.6	1.6	1.8	-	1.9	1.4	1.3
Cu(mg kg^{-1})	0.6	1.7	0.6	-	0.6	0.6	0.6	-	0.3	0.4	0.7
Zn(mg kg^{-1})	2.0	1.4	0.5	2.0	0.9	1.1	0.9	2.0	0.9	0.6	0.5

WSP‡(mg kg^{-1})	5.8	2.0	1.4	-	2.4	1.8	1.1	-	5.7	3.7	1.5
NO_3-N(mg kg^{-1})	14.9	3.7	3.7	-	30.7	10.4	11.9	-	4.6	6.2	3.1
NH_4-N(mg kg^{-1})	20.4	6.6	4.1	-	4.2	3.7	3.7	-	3.8	2.5	1.9
TN (%)	0.2	0.1	0.1	-	0.1	0.1	0.1	-	0.1	0.1	0.0
TC (%)	2.0	0.9	0.7	-	0.8	0.9	0.8	-	0.6	0.4	0.2

† Electrical Conductivity (us cm-1)
‡ Water Soluble Phosphorous
§ Recommendations based taken form OSU Soil Test Interpretations (Zhang et al., 2009a)

Table 4.3: Average Nutrients Added to Haskell Bermudagrass from 2007-2009 with Amendments of Commercial Fertilizer or Poultry Litter.

	Average Nutrients Applied 2007-2009																
	TN	TC	NH_4-N	NO_3-N	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	67.9	-	-	-	-	29.9	-	53.5	-	-	-	-	-	-	-	-	-
CF-B	136.1	-	-	-	-	59.9	-	107.2	-	-	-	-	-	-	-	-	-
CF-C	203.7	-	-	-	-	89.6	-	160.3	-	-	-	-	-	-	-	-	-
CF-D	272.3	-	-	-	-	119.8	-	214.4	-	-	-	-	-	-	-	-	-
NL-A	67.9	599.7	11.8	3.0	4.4	29.9	53.9	53.5	12.3	18.3	14.7	0.9	0.8	0.5	1.3	0.03	872.7
NL-B	136.1	1201.9	23.6	6.0	8.8	59.9	108.0	107.2	24.7	36.6	29.5	1.8	1.5	1.0	2.5	0.05	1749.2
NL-C	203.7	1798.2	35.3	9.0	13.2	89.6	161.6	160.3	36.9	54.8	44.1	2.7	2.3	1.5	3.8	0.08	2617.0
NL-D	272.3	2404.1	47.2	12.0	17.6	119.8	216.1	214.4	49.3	73.3	58.9	3.6	3.1	2.0	5.1	0.10	3498.8
CNL	216.3	1821.3	39.2	1.6	21.9	109.1	212.2	204.6	44.3	61.6	68.7	12.3	3.1	2.5	5.1	0.09	2823.9
CAL	227.9	1700.2	74.9	2.4	10.1	103.5	192.8	202.3	41.0	59.0	168.3	6.1	2.8	2.2	4.4	0.08	2797.9

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

Table 4.4: Average Nutrients Added to Sweet Sorghum Trials from 2007-2009 with Amendments of Commercial Fertilizer or Poultry Litter.

	Average Nutrients Applied 2007-2009																
	TN	TC	NH_4-N	NO_3-N	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	45.4	-	-	-	-	20.0	-	35.8	-	-	-	-	-	-	-	-	45.4
CF-B	90.5	-	-	-	-	39.8	-	71.3	-	-	-	-	-	-	-	-	90.5
CF-C	136.0	-	-	-	-	59.8	-	107.1	-	-	-	-	-	-	-	-	136.0
CF-D	181.4	-	-	-	-	79.8	-	142.8	-	-	-	-	-	-	-	-	181.4
NL-A	45.4	400.9	7.9	2.0	2.9	20.0	36.0	35.8	8.2	12.2	9.8	0.6	0.5	0.3	0.8	0.02	45.4
NL-B	90.5	799.3	15.7	4.0	5.9	39.8	71.8	71.3	16.4	24.4	19.6	1.2	1.0	0.7	1.7	0.03	90.5
NL-C	136.0	1200.6	23.6	6.0	8.8	59.8	107.9	107.1	24.6	36.6	29.4	1.8	1.5	1.0	2.5	0.05	136.0
NL-D	181.4	1601.8	31.5	8.0	11.7	79.8	143.9	142.8	32.9	48.8	39.3	2.4	2.1	1.3	3.4	0.07	181.4
CNL	143.9	1212.0	26.1	1.1	14.6	72.6	141.3	136.2	29.5	41.0	45.7	8.2	2.1	1.7	3.4	0.06	143.9
CAL	152.1	1134.4	50.0	1.6	6.7	69.1	128.7	135.0	27.3	39.3	112.3	4.1	1.9	1.5	2.9	0.05	152.1

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

Table 4.5: Results of Haskell Bermudagrass Biomass Yield (Mg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	2.6	9.4DE§	11.5BCD	11.6BCD	14.1AB	8.0EF	10.1DE	12.7ABC	14.4A	11.7CD	13.4ABC	6.7F
2008	1.9	8.3CD	10.0BC	12.4A	11.6AB	5.8EF	7.2DE	8.9CD	9.5C	8.7CD	10.0BC	5.0F
2009	1.1	4.7EFG	6.8CD	7.9B	9.1AA	3.6HI	4.3GH	5.6EF	7.4C	5.1EFG	6.0DE	2.7I

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table 4.6: Results of Haskell Sweet Sorghum Biomass Yield (Mg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	3.4	10.3AB§	11.7AB	10.9AB	12.3AB	10.9AB	10.1AB	9.1B	12.5AB	13.3A	11.5AB	9.6B
2008	7.2	13.8ED	21.6BC	27.0AB	29.7A	10.3EF	18.0CD	20.8BCD	22.1BC	18.5CD	15.6CDE	5.7F
2009	4.5	11.8BC	10.3BCD	14.5AB	17.1A	11.7BC	9.8CD	14.6AB	13.3ABC	9.9CD	12.1BC	6.3D

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL- Degraded Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table 4.7: Results of Woods County Sweet Sorghum Biomass Yield (Mg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.8	5.5CD§	6.4ABCD	7.4AB	7.9A	4.9D	5.5CD	6.0BCD	6.8ABC	7.1ABC	7.3BC	4.8D

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL- Degraded Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table 4.8: Results of Nitrogen Use Efficiency§§ from 2007-2009 over Various Sites Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL
					Haskell Bermudagrass						
2007	0.24	0.46A§	0.46B	0.37AB	0.48A	0.21B	0.31AB	0.35AB	0.32AB	0.19B	0.33AB
2008	0.19	0.65A	0.60AB	0.54AB	0.43BC	0.15D	0.32CD	0.28CD	0.28CD	0.31CD	0.37CD
2009	0.18	0.50A	0.50A	0.46A	0.43AB	0.27BC	0.26BC	0.26BC	0.34ABC	0.22C	0.28BC
					Haskell Sweet Sorghum						
2007	0.72	0.17A	0.14A	0.24A	-0.02A	-0.43A	-0.38A	-0.16A	0.12A	0.19A	0.28A
2008	1.06	1.08A	1.26A	1.43A	0.95A	0.56A	0.84A	0.58A	0.46A	0.69A	0.46A
2009	0.9	2.14A	0.84BC	0.88BC	0.81BC	1.55AB	0.51C	0.94BC	0.54C	0.37C	0.64A
					Woods County Sweet Sorghum						
2007	0.35	0.14A	0.09A	0.30A	0.27A	0.06A	0.02A	0.06A	0.07A	0.03A	0.14A

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL- Degraded Normal Litter, CAL- Degraded Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

§§ Nitrogen Use Efficiency is defined as percent plant uptake and removal of N applied.

Table 4.9: Results of Chemical and Physical Analysis of Poultry Litter from 2007-2009 Degraded at Haskell, OK.

Litter Treatment	% DM[†]	% mass reduction[‡]	pH	TC[§]	TN[¶]	NH_4	NO_3	WSP[#]	HI[††]	P[§§]	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Bulk Density
				%	%	------ mg kg^{-1} -----				----------------------- mg kg^{-1} -----------------------										g cm^{-1}
2007																				
Pre-degraded	68.7	-	8.6	41.0	4.4	8976	1128	4078	1.49	16047	29897	27017	6583	9933	6723	388	381	261	576	0.29
Normal degraded	72.0	23.2	8.5	33.8	4.1	8307	371	4861	0.94	16690	36707	28620	5920	7643	11860	550	413	422	538	0.40
Alum degraded	73.0	26.9	8.0	35.3	4.3	14804	303	2049	0.89	15110	29673	26827	5180	6857	23537	592	481	510	737	0.42
2008																				
Pre-degraded	65.5	-	8.8	55.5	5.3	8879	2117	3536	1.50	13267	23710	23393	5210	8363	7307	217	381	228	542	0.32
Normal degraded	65.4	15.9	8.9	44.5	4.7	7882	439	5025	1.13	13370	24990	28043	6060	9833	8770	241	402	236	558	0.33
Alum degraded	64.6	18.1	8.1	40.6	5.2	14833	1031	2727	1.15	12953	24763	25383	5633	8993	21700	360	409	245	569	0.35
2009																				
Pre-degraded	64.5	-	8.4	33.2	4.4	10457	133	2184	1.53	10963	19013	21673	4783	6343	5813	592	277	179	593	0.30
Normal degraded	60.0	19.8	8.9	31.2	4.2	6938	139	3043	1.29	13203	22333	24927	5660	7327	6693	788	351	236	719	0.31
Alum degraded	69.4	24.1	8.0	26.8	4.3	15351	183	1375	1.35	14627	25067	31340	6140	8653	24247	1247	353	224	718	0.39

Averages

Pre-degraded	66.2	-	8.6	43.2	4.7	9437	1126	3266	1.51	13426	24207	24028	5526	8213	6614	399	347	223	571	0.30
Normal degraded	65.8	19.6	8.8	36.5	4.3	7709	316	4310	1.12	14421	28010	27197	5880	8268	9108	540	412	327	671	0.35
Alum degraded	69.0	23.0	8.0	34.3	4.6	14996	506	2050	1.13	14230	26501	27850	5651	8168	23161	719	392	297	608	0.38
LSD‡‡	ns	2.7	0.37	7.0	0.31	1796	ns	913	0.25	ns	ns	ns	ns	ns	4000	ns	59	ns	ns	ns

† Percent dry matter

‡ Percent of the initial litter mass (not including added aluminum sulfate) that was degraded; calculated based on changes in concentration of a non-gaseous and recoverable element (phosphorus) after degradation

§ Total carbon

¶ Total nitrogen

Water soluble phosphorus

†† HI: humification index. non-humic carbon / (fulvic acid + humic acid). A lower index indicates a greater degree of humicfication.

‡‡ Least significant difference at P = 0.05. ns; not significant

§§ Total nutrient content (EPA 3051A acid digestion

CHAPTER V

Summary

Poultry litter production in U.S. will continue to increase as human population increases. With this continued increase in production comes the continued use of CAFOs in broiler production. The use of these production systems will continue to create a nutrient imbalance on poultry production farms and the land around them through continued long-term application of litter based solely of N needs of crops. One solution to this problem is the transportation of these nutrients outside of these production areas into surrounding nutrient deficient soils. The majority of the agricultural soils in Oklahoma are found to be nutrient deficient and are exceptional areas to land apply the poultry litter. If the U.S. continues to look to a future in bio-fuels satisfying our countries energy needs, Oklahoma can better prepare itself for a future role in supplying these bio-fuel crops with the use of poultry litter additions to soil fertility.

Through the use of a low input degradation system poultry litter nutrient content was significantly increased while reducing total mass of litter. This process resulted in an economic increase of $5.00 Mg of litter, allowing for an additional 24 miles of transport of litter away from the production house. The inclusion of alum in this process resulted in more retained N and less soluble P in the final product, but the cost of treatment outweighed the gain.

Soil nutrient content of P, K, Mg, Ca, Cu, Zn, and S of the soil increased in relation to total amount applied in the individual fertilizer. No significant difference in soil test P (STP) or water soluble P (WSP) were observed between fresh or degraded normal litter and inorganic fertilizers applied at identical rates suggesting no difference in environmental risk between source. Degraded alum treated litter resulted in similar STP levels as higher P application rates while the WSP concentrations were significantly less and similar to the lower rates of application. Alum treatment could be used to reduce the environmental risk of applying litter in nutrient limited watersheds. Soil pH significantly increased with litter additions while inorganic application resulted in decreases. Increase in soil pH is important as most fertilizer systems practiced result in long-term decrease in soil pH with the need for costly lime additions to correct. Soil physical properties were positively affected by litter application and as a result both bulk density and aggregate stability improved leading to probable increases in water infiltration and decreases in erosion.

Bio-fuels production compared with inorganic and organic fertilizer sources showed no significant difference in biomass yield when applied at the same rate and grown under ideal weather conditions. Years in which ideal weather conditions were not present significant differences in biomass yield were observed in bermudagrass and sweet sorghum. For this reason N availability of litter must be taken in account and adjusted to obtain consistent yields with litter application. The addition of nutrients in poultry litter had no effect on plant nutrient uptake which was a function of yield. The degraded litter produced yields very similar or higher to the highest rate of fertilizer applied of both fresh litter and inorganic sources; even though a quarter less was applied on a weight basis.

Poultry litter additions to potential soils for bio-fuel production has been shown to be valid alternatives to inorganic commercial fertilizer commonly used throughout the U.S. The use of litter to improve soil quality of these soils will no doubt improve the viability of these soils to produce a future bio-fuel crop to fuel future energy needs.

APPENDIX A

Chemical and physical analysis of soils amended with poultry litter and commercial fertilizers over 3 year in Haskell, OK at the Eastern Oklahoma Research Station and 2 years at a private farm in Woods County, OK near Aline, OK. Soil analyzed by Agro-Environmental Chemistry Laboratory, Oklahoma State University, Stillwater, OK and Soil, Water and Forage Analytical Laboratory, Oklahoma State University, OK.

Table A.1: Results of Haskell Bermudagrass pH from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.18	0.27	0.36	0.38	0.31	0.31	0.58	0.32	0.22	0.29	0.30
0-5 cm	0.27	5.4AB§c¶	5.5Ab	5.5ABb	5.2Bb	5.6Ab	5.5ABb	5.6Aa	5.6Ab	5.5Ab	5.5Ab	5.5ABb
5-15 cm	0.24	6.0ABCb	6.1Aa	6.0ABCa	5.8Ca	5.9ABCa	6.0ABCa	5.8BCa	6.0ABCa	5.9ABCa	5.9ABCa	6.0ABa
15-30 cm	0.34	6.2Aa	6.2Aa	6.2Aa	6.0Aa	6.2Aa	6.1Aa	6.1Aa	6.2Aa	6.1Aa	6.0Aa	6.2Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.25	0.39	0.33	0.15	0.22	0.05	0.35	0.43	0.16	0.19	0.40
0-5 cm	0.42	4.9BCb	5.1ABb	4.8BCb	4.7Cb	5.1ABCb	5.0BCc	5.4Aa	5.2ABb	5.1ABCb	4.9BCb	5.1ABb
5-15 cm	0.32	5.6ABa	5.7Aa	5.8Aa	5.5ABa	5.7Aa	5.5ABb	5.7Aa	5.8Aa	5.6ABa	5.4Ba	5.7Aa
15-30 cm	0.39	5.7ABCa	5.9ABa	5.6ABCa	5.6BCa	5.8ABa	5.6BCa	5.8ABCa	5.9ABa	5.6ABCa	5.4Ca	6.0Aa

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control

LSD Between Depth Interaction		0.15	0.44	0.25	0.27	0.13	0.16	0.31	0.52	0.10	0.11	0.27
0-5 cm	0.18	5.1EFc	5.3DEb	5.0FGc	4.9Gb	5.4CDc	5.4BCb	5.6ABb	5.7Ab	5.6ABb	5.3CDb	5.4CDc
5-15 cm	0.33	5.8BCb	6.1ABCa	5.8BCb	5.7Ca	6.0ABCb	5.9ABCa	6.0ABCa	6.2Aa	6.0ABCa	5.8BCa	6.1ABb
15-30 cm	0.45	6.1ABa	6.3Aa	6.2ABa	5.9ABa	6.1ABa	6.0ABa	6.1ABa	6.2ABa	6.0ABa	5.8Ba	6.3Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.2: Results of Haskell Bermudagrass Soil Electrical Conductivity (EC) (us cm^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		165.83	383.9	229.41	264.72	250.42	44.90	246.34	196.97	150.06	206.89	170.67
0-5 cm	558.63	250.0B§a¶	391.0ABa	203.4Ba	170.3Ba	448.7ABa	182.9Ba	260.2Ba	225.0Aa	284.7Ba	238.4Ba	224.0Ba
5-15 cm	199.19	174.6Ba	434.5Aa	172.8Ba	276.1ABa	159.5Bb	177.9Ba	320.4ABa	231.8Ba	151.2Ba	195.2Ba	198.1Ba
15-30 cm	332.88	133.4Ba	236.2Ba	261.4ABa	122.3Ba	170.2Bb	150.2Ba	274.2ABa	222.7Aa	253.8Ba	184.3Ba	154.5Ba

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		29.14	19.24	13.62	21.68	13.66	30.07	25.22	28.06	14.39	23.49	23.52
0-5 cm	22.08	144.1BCDa	139.6DCa	125.1Da	140.1CDa	123.5Da	145.1BDCa	162.9ABa	166.0ABa	160.3ABCa	168.9Aa	147.9ABCa
5-15 cm	13.5	95.9CDEb	97.6BCDEb	87.7Eb	96.1CDEb	91.4DEb	92.4DEb	103.0BCDb	109.6Bb	107.8BCb	155.9Aa	89.1Eb
15-30 cm	17.58	80.6CDb	80.0CDb	80.8CDb	85.1BCDb	74.9CDc	76.9CDb	86.5BCDb	92.2BCb	103.0Bb	127.7Ab	73.2Db

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		9.90	12.13	11.55	18.02	20.22	15.23	12.49	12.39	21.93	21.13	21.05a
0-5 cm	17.63	92.1Da	91.2Da	84.5Da	89.4Da	89.9Da	95.0CDa	117.4ABa	120.9ABa	130.5Aa	110.0BCa	91.2Db
5-15 cm	14.83	49.6CDb	53.7BCDb	43.5Db	48.5CDb	52.0CDb	57.6ABCDb	60.9ABCb	67.1ABb	70.6Ab	68.2ABb	56.0ABCDb
15-30 cm	18.10	36.2Dc	51.4CDb	44.0CDb	38.7CDb	47.8CDb	45.0CDb	55.4BCb	56.5BCb	70.6Bb	95.5Aa	44.4CD

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.3: Results of Haskell Bermudagrass Soil Calcium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		130	171	73	99	168	119	92	136	62	43	177
0-5 cm	169.56	886A§a¶	918Aa	872Aa	810Aa	896Aa	854Aa	886Aa	979Aa	902Aa	921Aa	892Aa
5-15 cm	174.19	910ABa	1013Aa	921ABa	897ABa	906ABa	829Ba	902ABa	868ABab	849ABab	881ABab	956ABa
15-30 cm	211.94	908Aa	944Aa	927Aa	891Aa	883Aa	778Aa	835Aa	837Ab	822Ab	851Ab	977Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		123	220	165	99	184	82	152	178	114	122	144
0-5 cm	133	863Ea	900DEa	906CDEa	829Eb	1021ABCDa	931BCDEa	1060ABa	1039ABCa	1065Aa	936ABCDEa	1014ABCDa
5-15 cm	137	966ABCa	1013ABCa	1071Aa	963BCa	1016ABCa	886Ca	977ABCab	995ABCa	980ABCa	928BCa	1056ABa
15-30 cm	215	872Aa	953Aa	939Aa	829Ab	858Aa	758Ab	876Ab	878Aa	821Ab	827Aa	930Aa

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
		2009										
LSD Between Depth Interaction		107	170	202	78	71	83	138	212	115	127	92
0-5 cm	207	962CDb	1110ABCa	964CDa	809Dc	1019BCab	1025BCa	1218ABa	1250Aa	1237Aa	1054ABCa	1171ABab
5-15 cm	244	1075Aa	1223Aa	1079Aa	1048Aa	1074Aa	998Aa	1093Aab	1193Aab	1031Ab	1033Aa	1240Aa
15-30 cm	266	948Ab	1107Aa	1018Aa	945Ab	961Ab	870Ab	964Ab	981Ab	896Ac	938Aa	1123Ab

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.4: Results of Haskell Bermudagrass Soil Magnesium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		39.9	21.5	12.7	13.3	22.0	20.1	14.6	27.8	18.8	19.3	18.2
0-5 cm	14.4	63.4BC§a¶	61.8Ca	67.2BCa	59.6Ca	69.9BCa	77.4ABa	76.5ABa	84.8Aa	86.7Aa	77.1ABa	64.4BCa
5-15 cm	14.2	42.2Aa	30.0ABb	30.4ABb	29.3ABb	31.0ABb	25.8Bb	33.4ABb	28.3ABb	34.8ABb	33.5ABb	26.4Bb
15-30 cm	18.4	50.5Aa	63.4Aa	62.8Aa	64.1Aa	64.4Aa	57.6Aa	66.1Aa	62.0Aa	65.1Ac	66.0Aa	53.8Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		11.2	17.2	36.3	11.8	14.1	17.0	16.3	20.3	10.8	11.9	22.5
0-5 cm	11.0	58.9Eb	57.7Eb	57.8Ea	54.8Eb	70.1DCa	73.9BCa	82.1ABa	89.9Aa	89.7Aa	80.5ABCa	62.7DEa
5-15 cm	10.3	31.3Bc	35.1ABc	44.7Aa	34.8ABc	39.2ABb	35.1ABb	38.9ABb	38.3ABb	40.0ABc	43.1Ab	38.0ABb
15-30 cm	14.9	76.5Aa	75.5Aa	70.9Aa	77.7Aa	79.3Aa	75.5Aa	79.5Aa	75.2Aa	75.6Ab	80.4Aa	72.0Aa

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		13.8	15.2	31.3	9.8	11.7	20.0	28.7	24.6	25.6	20.9	121.5
0-5 cm	21.7	74.9EFa	75.3EFa	53.0Gab	61.68FGb	94.6CDEa	97.2CDa	132.0ABa	142.2Aa	141.7Aa	113.6BCa	78.7DEFa
5-15 cm	12.3	36.7BCb	36.4BCb	42.9ABCb	32.5Cc	39.8ABCc	34.4Cc	41.4ABCb	43.7ABCc	48.2ABc	49.0Ac	37.1ABCa
15-30 cm	12.4	74.9Aa	70.6Aa	76.5Aa	73.6Aa	80.5Ab	71.3Ab	77.0Ac	70.3Ab	81.3Ab	75.7Ab	72.0Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.5: Results of Haskell Bermudagrass Soil Potassium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

						2007						
	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.0	5.6	5.3	4.6	9.2	6.6	3.7	9.3	5.2	6.9	8.4
0-5 cm	10.1	64.7A§a¶	62.7Aa	67.1Aa	63.6Aa	66.1Aa	70.4Aa	64.9Aa	71.9Aa	70.9Aa	72.1Aa	65.5Aa
5-15 cm	5.4	47.0Ab	47.9Ab	47.0Ab	45.7Ab	45.0Ab	46.8Ab	47.5Ab	45.9Ab	47.9Ab	49.5Ab	44.6Ab
15-30 cm	7.3	45.8Ab	46.7Ab	46.2Ab	45.7Ab	46.8Ab	43.3Ab	45.2Ab	46.0Ab	44.7Ab	48.1Ab	49.0Ab
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.8	6.2	37.3	18.1	7.7	5.7	11.2	9.4	9.4	8.3	10.6
0-5 cm	23.1	76.6Ba	78.2ABa	99.8Aa	82.9ABa	73.8Ba	87.0ABa	84.2ABa	82.8ABa	92.2ABa	82.2ABa	78.8ABa
5-15 cm	11.4	49.0Bb	53.3ABb	64.3Aab	49.9Bb	51.2Bb	54.1ABb	51.2Bb	52.1Bb	56.9ABb	54.6ABb	51.6Bb
15-30 cm	5.7	55.0Ab	52.4Ab	55.3Ab	51.7Ab	52.1Ab	54.0Ab	51.4Ab	51.8Ab	54.3Ab	55.0Ab	53.1Ab

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		8.2	9.3	27.1	6.6	6.6	14.1	21.2	21.1	24.7	22.3	27.1
0-5 cm	20	81.9Da	83.8Da	75.2Da	82.1Da	86.9CDa	87.2CDa	120.6Ba	123.6ABa	142.5Aa	104.8BCa	77.9Da
5-15 cm	14	54.1Bb	55.8ABb	64.5ABa	50.7Bb	51.1Bb	51.4Bb	56.0ABb	59.6ABb	61.7ABb	60.1ABb	68.5Aa
15-30 cm	6	51.8BCb	54.4BCb	57.3ABa	52.2BCb	51.7BCb	51.5Cb	55.8ABCb	55.5ABCb	55.9ABCb	60.2Ab	56.8ABCa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.6: Results of Haskell Bermudagrass Soil Sodium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	2007 CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		85.8	78.2	34.4	57.7	63.3	101.7	50.4	249.2	30.2	85.0	51.1
0-5 cm	103.4	490.6Aa	416.2ABb	447.6ABa	500.6Aa	457.3ABa	504.4Aa	458.7ABa	487.4Aa	483.9ABa	472.9ABa	383.25Bb
5-15 cm	124.5	494.9Aa	482.0ABab	461.3ABb	472.4ABa	477.3ABa	458.7ABa	482.7ABa	366.7Ba	470.2ABa	522.9Aa	404.0Bb
15-30 cm	115.4	439.8Aa	516.8Aa	496.8Ab	478.4Aa	491.5Aa	459.3Aa	477.8Aa	472.4Aa	456.4Aa	521.9Aa	459.3Aa

		2008 CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.2	13.9	9.2	3.4	12.7	8.4	12.9	10.8	21.7	7.2	8.0
0-5 cm	21.9	85.9Bb	87.7Ba	107.7ABa	90.7Bb	107.1ABa	103.9ABa	118.0Aa	102.0ABa	114.6Aa	103.5ABb	99.4ABa
5-15 cm	27.2	88.3Cb	91.1Ca	108.2ABCa	89.7Cb	109.2ABCa	105.3ABCa	120.9Aa	100.1ABCa	118.7ABa	111.5ABCa	91.8BCa
15-30 cm	25.2	102.4ABa	101.4Ba	115.6ABa	95.5Ba	117.2ABa	109.5ABa	127.3Aa	99.8Ba	118.2ABa	111.1ABa	99.3Ba

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.4	12.6	11.3	3.4	15.5	5.3	27.4	9.1	10.9	16.2	33.6
0-5 cm	12.0	49.1Db	52.6CDb	56.7BCDb	49.9Dc	59.4BCDa	60.3BCDc	74.7Aa	67.7ABb	64.1ABCb	57.1BCDb	51.8D
5-15 cm	16.0	56.0CDEa	61.7BCDEab	55.3DEb	53.7Eb	59.0CDEa	70.3ABCDb	74.8ABa	82.5Aa	72.1ABCab	60.6BCDEab	71.1ABCD
15-30 cm	11.4	62.1Ea	66.9CDEa	74.1BCDa	59.3Ea	70.0BCDEa	75.9BCa	90.1Aa	74.5BCDab	80.7ABa	74.6BCDa	63.8DE

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.7: Results of Haskell Bermudagrass Soil Phosphorous (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		5.3	9.7	9.7	12.8	2.4	14.0	2.2	11.5	8.6	12.3	1.5
0-5 cm	12.0	16.8EF§a¶	33.0CDa	37.2BCDa	52.0Aa	15.7EFa	27.1DEa	30.2Da	34.5BCDa	44.4ABCa	46.3ABa	11.9Fa
5-15 cm	1.8	3.1ABb	4.1ABb	3.3ABb	3.6ABb	3.2ABb	3.4ABb	3.5ABb	4.2ABb	4.0ABb	4.8Ab	2.8Bb
15-30 cm	1.5	2.5Ab	2.8Ab	2.0Ab	1.9Ab	1.8Ab	2.1Ab	2.6Ab	2.1Ab	3.1Ab	3.0Ab	2.4Ab
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		4.2	4.7	8.4	12.1	3.9	4.1	8.0	12.3	7.2	8.2	0.77
0-5 cm	11.2	36.7EFa	57.3Da	76.1Ba	113.6Aa	30.6FGa	43.6Ea	55.5Da	64.2CDa	72.0BCa	81.2Ba	20.7Ga
5-15 cm	1.6	4.6Cb	6.6ABb	6.2ABCb	7.7Ab	4.8Cb	5.7BCb	5.9BCb	6.5ABb	6.8ABb	7.6Ab	4.6Cb
15-30 cm	2.1	3.2Bb	3.8ABb	3.8ABb	5.0Ab	2.1Bb	3.5ABb	3.3ABb	2.5Bb	3.5ABb	3.3Bb	2.2Bc

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		19.9	10.6	25.1	53.0	7.8	25.0	30.0	23.6	27.3	7.1	3.5
0-5 cm	31.3	51.9DEa	72.7CDa	123.5Ba	167.3Aa	40.9EFa	59.1DEa	96.2BCa	119.5Ba	124.2Ba	115.0BCa	18.5Fa
5-15 cm	3.1	6.3Db	8.6BCDb	11.4ABb	10.6ABCb	5.9Db	7.4Db	7.9CDb	11.1ABCb	12.5Ab	8.2CDb	5.7Db
15-30 cm	2.3	4.7Bb	8.0Ab	6.1ABb	5.9ABb	4.2Bb	6.1ABb	5.2Bb	6.5ABb	5.6ABb	5.2Bb	5.4Bb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.8: Results of Haskell Bermudagrass Soil Manganese (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		37.5	26.4	34.5	17.0	15.1	16.2	22.7	18.0	17.8	7.1	21.2
0-5 cm	13.1	48.5BC§a¶	47.6BCb	62.0Aa	57.4ABab	47.8BCb	42.3Cb	43.0Cb	45.4BCb	44.6BCb	49.8ABCb	45.8BCc
5-15 cm	24.7	71.6BCDa	86.8ABCDa	96.3Aa	66.5Da	80.1ABCDa	82.3ABCDa	84.8ABCDa	67.6CDa	92.2ABCa	83.5ABCDa	93.6ABa
15-30 cm	25.2	73.4Aa	62.7ABab	68.0ABa	45.7Bb	55.3ABb	47.3Bb	50.8ABb	49.1ABb	56.0ABb	54.6ABb	67.8Ab
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		12.2	12.1	23.9	9.4	8.1	8.3	8.9	14.4	6.7	8.0	14.5
0-5 cm	7.2	56.1Aab	57.1Aab	61.7Aa	58.9Aa	57.8Ab	58.3Aa	55.4Aa	54.6Aab	59.1Aa	61.7Aa	58.9Aab
5-15 cm	10.3	64.8ABCa	68.5ABa	57.8Ca	56.8Ca	66.2ABa	63.7ABCa	59.1BCa	60.8ABCa	64.5ABCa	66.8ABCa	70.8Aa
15-30 cm	14.3	47.1Ab	49.8Ab	49.1Aa	40.0Ab	41.2Ac	39.3Ab	39.7Ab	45.4Ab	38.1Ab	37.5Ab	46.0Ab

							2009					
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.6	17.3	8.5	4.6	5.9	7.2	5.9	12.7	4.4	5.1	8.6
0-5 cm	6.7	46.1ABa	50.6Aa	51.8Aa	48.3ABa	45.4ABb	43.7Bb	47.6ABa	47.8ABab	50.0ABa	47.8ABa	51.1Ab
5-15 cm	15.9	52.0ABa	60.6ABa	52.9ABa	49.3Ba	56.4ABa	52.4ABa	49.7Ba	54.9ABa	53.2ABa	50.8Ba	66.9Aa
15-30 cm	15.4	37.2Ab	46.4Aa	39.5Ab	36.4Ab	38.7Ac	35.0Ac	34.8Ab	37.9Ab	34.4Ab	36.1Ab	48.2Ab

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N\text{-}P_2O_5\text{-}K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.9: Results of Haskell Bermudagrass Soil Iron (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		52.2	30.9	23.9	37.1	21.4	32.1	19.6	28.0	37.1	36.4	49.3
0-5 cm	59.1	338.3A§a¶	303.0Aa	303.1Aa	314.8Aa	320.7Aa	361.7Aa	334.8Aa	323.8Aa	351.4Aa	344.8Aa	315.4Aa
5-15 cm	43.0	153.3Ab	140.3Ab	156.4Ab	136.1Ab	150.8Ab	172.2Ab	163.4Ab	136.2Ab	167.4Ab	159.9Ab	148.1Ab
15-30 cm	28.9	132.2Ab	101.6Bc	121.6ABc	106.1ABb	107.8ABc	107.7ABc	106.6ABc	100.7Bc	119.7ABc	118.5ABc	106.2ABb
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		43.5	45.9	27.4	31.7	31.0	29.6	25.3	39.5	28.7	56.7	37.6
0-5 cm	63.8	440.1Aa	391.5ABCa	355.7BCa	435.4Aa	348.7BCa	411.5ABa	352.2BCa	392.2ABCa	380.5ABCa	381.3ABCa	346.3Ca
5-15 cm	28.7	168.7Ab	152.8ABb	130.8Bb	154.8ABb	149.1ABb	167.8Ab	143.4ABb	149.1ABb	155.5ABb	163.5Ab	145.3ABb
15-30 cm	19.2	117.5Ac	113.4Ac	113.5Ab	120.6Ac	105.1Ac	120.3Ac	110.1Ac	108.1Ac	109.2Ac	120.2Ab	104.8Ac

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		31.5	32.7	209.4	94.0	28.8	39.4	38.0	45.7	18.3	67.3	38.2
0-5 cm	69.9	414.2ABa	397.8ABCa	329.4Ca	438.9Aa	352.3BCa	352.2BCa	365.8BCa	366.7BCa	371.7ABCa	343.2Ca	352.4BCa
5-15 cm	55.2	166.2Bb	153.1Bb	228.1Aa	162.4Bb	158.0Bb	165.2Bb	157.7Bb	175.6ABb	163.1Bb	158.2Bb	152.3Bb
15-30 cm	22.1	127.4ABc	121.1ABb	123.9ABa	142.2Ab	122.6ABc	127.8ABb	117.9Bc	119.0Bc	118.5Bc	137.1ABb	118.5Bb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.10: Results of Haskell Bermudagrass Soil Sulfur (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		1.7	2.0	0.9	1.4	2.3	1.6	1.4	4.6	1.9	3.1	1.5
0-5 cm	4.0	11.7BCD§a¶	9.6Da	10.8CDa	11.5CDa	11.6CDa	13.6BCa	12.2BCDa	11.9BCDa	15.6ABa	18.1Aa	9.3Da
5-15 cm	3.7	8.2BCb	7.0Cab	7.2Cb	6.6Cb	7.4Cb	8.0BCb	8.8BCb	5.9Cb	11.5Bb	16.1Aa	5.8Cb
15-30 cm	3.9	7.0Cb	7.9Cb	7.2Cb	6.6Cb	7.6Cb	7.8Cb	8.3Cb	8.4Cab	12.5Bb	17.5Aa	6.0Cb
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.9	4.3	2.4	1.3	2.6	2.0	3.3	2.7	3.4	5.2	1.9
0-5 cm	2.3	24.2DEa	24.0DEa	23.5Ea	24.3DEa	26.1CDa	26.6Ca	27.4Ca	27.5Ca	31.1Ba	34.5Aa	25.7CDEa
5-15 cm	2.2	19.5Cb	19.5Cb	19.9Cb	19.1Cb	20.8Cb	20.7Cb	20.5Cb	21.2Cb	24.3Bb	31.6Aa	20.7Cb
15-30 cm	3.8	13.3Cb	19.0Cb	19.4Cb	17.4Cc	18.5Cb	19.1Cb	20.3BCb	19.5Cb	23.5Bb	32.9Aa	18.2Cc

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.7	1.6	4.0	1.6	1.5	2.9	1.9	2.6	2.5	7.1	0.9
0-5 cm	2.7	18.2DEa	18.2DEa	16.4Ea	17.3DEa	19.1DEa	19.7CDa	22.3BCa	22.8Ba	24.5Ba	27.6Aa	19.8CDa
5-15 cm	2.4	13.7Cb	14.6BCb	15.0BCa	13.4Cb	13.8Cb	14.2Cb	15.6BCb	16.7Bb	16.7Bb	19.5Ab	14.7BCb
15-30 cm	3.3	12.6Dc	13.1CDb	12.5Da	12.8CDb	13.2CDb	14.3CDb	16.1BCb	15.4CDb	19.2Bb	26.4Aab	13.2CDc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.11: Results of Haskell Bermudagrass Soil Copper (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.3	0.5	0.3	0.1	0.3	0.3	0.5	0.4	0.4	0.3	0.4
0-5 cm	0.6	1.31BC§a¶	0.92Ca	1.05Ca	1.23BCa	1.29BCa	1.79ABa	1.67ABa	1.75ABa	2.09Aa	2.03Aa	0.92Ca
5-15 cm	0.6	1.00Aab	1.06Aa	1.03Aa	0.86Ab	1.00Ab	1.00Ab	1.15Ab	0.94Ab	1.03Ab	1.25Ab	0.94Aa
15-30 cm	0.5	0.79Ab	1.04Aa	0.93Aa	0.72Ac	0.79Ab	0.56Ac	0.81Ab	0.69Ab	0.68Ab	0.97Ab	0.81Aa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.2	1.9	0.1	0.2	0.1	0.2	0.4	0.3	0.1	0.2
0-5 cm	0.2	0.59EFa	0.64EFa	0.58EFa	0.54Fab	0.92Da	1.17Ca	1.44Ba	1.55Ba	1.88Aa	2.0Aa	0.75DEa
5-15 cm	0.2	0.64ABa	0.76ABa	0.53Ba	0.58ABa	0.64ABb	0.66ABb	0.65ABb	0.80Ab	0.72ABb	0.60ABb	0.76ABa
15-30 cm	0.1	0.51ABa	0.58Aa	0.41Ba	0.43Bb	0.47ABb	0.43Bc	0.50ABb	0.46ABb	0.49ABb	0.41Bc	0.48ABb

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.3	0.2	0.1	0.2	0.4	0.4	0.4	0.4	0.6	0.2
0-5 cm	0.4	0.72Da	0.65Da	0.60Da	0.47Db	1.16BCa	1.39Ba	2.05Aa	2.39Aa	2.39Aa	2.07Aa	0.77CDa
5-15 cm	0.4	0.71ABa	0.79ABa	0.67ABa	0.57Ba	0.78ABb	0.64ABb	0.78ABb	0.84ABb	0.69ABb	0.66ABb	0.93Aa
15-30 cm	0.3	0.44Ab	0.60Aa	0.47Aa	0.44Ab	0.64Ab	0.47Ab	0.52Ab	0.55Ab	0.48Ab	0.60Ab	0.57Ab

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.12: Results of Haskell Bermudagrass Soil Zinc (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		0.5	0.3	0.3	0.6	0.7	1.1	0.8	1.0	1.3	1.3	1.1
0-5 cm	0.9	2.3C§a¶	2.1Ca	2.2Ca	2.1Ca	2.6BCa	3.4ABa	3.6Aa	4.3Aa	4.2Aa	4.0Aa	2.6CBa
5-15 cm	0.4	0.73Ab	0.88Ab	0.82Ab	0.78Ab	0.76Ab	0.77Ab	0.95Ab	0.73Ab	1.13Ab	0.87Ab	0.90Ab
15-30 cm	0.3	0.87Ab	0.87Ab	0.78Ab	0.65Ab	0.68Ab	0.62Ab	0.70Ab	0.67Ab	0.78Ab	0.74Ab	0.77Ab
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.5	0.4	0.4	0.3	0.6	0.5	1.0	1.0	0.7	1.1	0.7
0-5 cm	0.8	1.59Da	1.73Da	1.46Da	1.64Da	2.53BCa	2.99Ba	4.11Aa	4.37Aa	4.62Aa	4.55Aa	1.84DCa
5-15 cm	0.3	0.67BCb	0.73ABCb	0.51BCb	0.48Cb	0.63ABCb	0.73ABCb	0.70ABCb	0.79ABb	0.64ABCb	0.77ABCb	0.87Ab
15-30 cm	0.4	0.57Ab	0.62Ab	0.63Ab	0.40Ab	0.68Ab	0.41Ab	0.44Ab	0.63Ab	0.49Ab	0.43Ab	0.64Ab

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.1	0.7	1.0	0.3	0.4	1.7	1.9	1.7	1.9	2.3	0.4
0-5 cm	1.5	1.94DEa	2.01DEa	1.36Ea	1.58Ea	3.28CDa	3.92Ca	6.55ABa	7.63Aa	7.50Aa	5.81Ba	2.28DEa
5-15 cm	0.5	0.70ABb	0.85ABb	1.17Aa	0.59Bb	0.66Bb	0.63Bb	0.77ABb	0.85ABb	0.78ABb	0.72ABb	1.01ABb
15-30 cm	0.3	0.52Bc	0.94Ab	0.49Ba	0.54Bb	0.52Bb	0.57ABb	0.55ABb	0.59ABb	0.53Bb	0.84Ab	0.70ABb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.13: Results of Haskell Bermudagrass Soil Nickel (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

						2007						
	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.2	2.4	2.0	2.9	2.2	2.3	2.4	0.9	1.7	0.9	3.4
0-5 cm	2.5	1.7AB§a¶	1.9ABa	2.8ABa	2.1ABa	0.9Ba	3.7Aa	1.5ABa	1.6ABb	1.4ABa	1.3ABb	3.5Aa
5-15 cm	2.6	1.9Aa	1.7Aa	2.1Aa	1.5Aa	1.7Aa	2.9Aab	1.7Aa	1.4Ab	1.2Aa	3.0Aa	2.7Aa
15-30 cm	2.6	1.5BCa	3.2ABa	3.0ABCa	3.5ABa	1.7BCa	0.6Cb	1.9BCa	3.1ABCa	0.7Ca	3.0Aa	2.6ABCa
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.6	0.6	0.7	0.4	0.5	0.4	0.2	0.5	0.3	0.4	0.4
0-5 cm	0.6	1.7Aa	1.4ABa	1.2ABa	1.8Aa	1.2ABa	1.7Aa	1.4ABa	1.4ABa	1.3ABa	1.6ABa	1.0Ba
5-15 cm	0.3	0.94Ab	0.64Bb	0.48Bb	0.54Bb	0.61Bb	0.62Bb	0.51Bb	0.70ABb	0.65Bb	0.62Bb	0.62Bb
15-30 cm	0.4	0.66ABb	0.47Bb	0.89Aab	0.50Bb	0.39Bb	0.34Bb	0.35Bb	0.38Ab	0.52Bb	0.38Bb	0.29Bb

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.7	0.4	0.5	1.2	0.4	0.6	0.6	0.2	0.4	1.0	0.4
0-5 cm	0.6	2.04Aa	1.60Aa	1.58Aab	2.02Aa	1.58Aa	1.53Aa	1.52Aa	1.62Aa	1.55Aa	1.86Aa	1.80Aa
5-15 cm	0.2	1.04ABCb	0.95ABCb	1.14Ab	0.82Cb	0.88BCb	0.81Cb	0.83BCb	0.86BCb	0.94ABCb	0.89BCa	1.06ABb
15-30 cm	0.4	1.49Aab	1.56Aa	1.66Aa	1.40Aab	1.64Aa	1.34Aab	1.35Aab	1.61Aa	1.45Aa	1.49Aa	1.65Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.14: Results of Haskell Bermudagrass Soil Water Soluble Phosphorous (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.4	1.4	0.9	7.8	2.6	4.1	4.3	5.0	5.0	1.7	2.2
0-5 cm	2.2	2.2CD§a¶	5.5ABa	6.0Aa	3.7CDa	2.0Da	3.0CDa	2.9CDa	2.5DCa	2.5DCa	4.3ABCa	1.8Da
5-15 cm	1.6	0.8Bb	1.2ABb	1.0ABb	2.6Aa	1.2ABa	1.4ABa	1.5ABa	2.1ABa	1.1ABa	0.8Bb	1.3ABa
15-30 cm	2.3	0.7Bb	1.1ABb	0.7Bb	3.1Aa	1.3ABa	1.7ABa	1.6ABa	2.5ABa	2.5ABa	0.6Bb	1.2ABa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		3.8	4.3	1.4	5.6	1.6	3.9	2.3	6.2	2.6	4.7	1.9
0-5 cm	3.7	3.9Da	6.6ABCDa	10.1Aa	9.8Aa	6.6ABCDa	5.3BCDa	8.6ABa	8.6ABa	8.2ABCa	5.9BCDa	4.8DCa
5-15 cm	3.0	1.7Ba	3.0ABab	2.0ABb	4.8Aab	1.7Bb	3.5ABab	3.1ABb	3.5ABab	1.9ABb	1.9ABa	2.1ABb
15-30 cm	1.8	2.5Aa	1.4Ab	1.5Ab	2.1Ab	1.6Ab	1.3Ab	2.3Ab	1.4Ab	1.6Ab	2.3Aa	1.6Ab

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.4	0.9	2.3	5.0	0.5	3.1	2.9	5.1	4.1	2.8	0.5
0-5 cm	3.7	6.8CDa	9.3Ca	14.6ABa	17.9Aa	6.9CDa	8.2CDa	13.3Ba	17.9Aa	15.2ABa	8.1CDa	4.7Da
5-15 cm	0.5	2.1Fb	2.5CDEFb	2.8ABCDb	2.8ABCDEb	2.4CDEFb	2.4CDEFb	2.8ABCb	2.9ABb	3.2Ab	2.3EFb	2.3DEFb
15-30 cm	0.6	1.7Ab	1.9Ab	1.8Ab	2.1Ab	1.9Ac	1.7Ab	2.0Ab	1.9Ab	1.8Ab	1.9Ac	1.6Ac

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.15: Results of Haskell Bermudagrass Soil NO_3^- (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		1.1	2.7	1.0	3.2	2.8	4.0	7.7	1.6	6.0	2.3	2.1
0-5 cm	4.8	3.6B§a¶	6.4ABa	3.7Ba	5.9ABa	7.2ABa	7.2ABa	10.0Aa	6.6ABa	6.4ABa	4.6Ba	5.2ABa
5-15 cm	1.1	2.2Bb	3.3Ab	2.7ABb	3.4Aab	2.8ABb	2.6ABb	3.1ABa	3.3Ab	3.0ABa	2.5ABa	2.9ABb
15-30 cm	0.9	2.2Bb	2.4Bb	2.5ABb	2.6ABb	2.4ABb	2.6ABb	2.6ABa	2.6ABb	2.4ABa	2.4ABa	3.3Aab
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.1	0.2	0.8	0.2	0.2	0.2	0.5	0.4	0.5	3.4	0.2
0-5 cm	0.7	1.3Da	1.9ABCDa	1.9ABCDa	1.8BCDa	1.7CDa	1.8BCDa	2.3ABa	2.5Aa	2.0ABCDa	2.3ABCa	1.6Da
5-15 cm	0.2	1.3Da	1.6Ab	1.4Da	1.5ABCa	1.4CDb	1.4BCDb	1.59ABb	1.7Ab	1.4Db	1.3Da	1.4BCDab
15-30 cm	1.3	1.3Ba	1.3Bc	1.5ABa	1.3Bb	1.3Bb	1.3Bc	1.2Bb	1.3Bb	1.3Bb	2.7Aa	1.3Bb

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2009						
LSD Between Depth Interaction		0.7	1.1	0.3	0.7	0.9	0.5	0.1	0.8	0.8	0.7	1.0
0-5 cm	1.0	1.8Ea	3.4Ba	1.9Ea	2.2CDEa	2.0Ea	2.3CDEa	3.2BCa	4.7Aa	3.1BCDa	2.0Ea	2.1DEa
5-15 cm	0.4	1.2Da	1.9ABb	1.5BCDb	1.8ABCa	1.1Db	1.3Db	1.2Db	1.9Ab	1.2Db	1.2Db	1.4CDa
15-30 cm	0.5	1.1ABa	1.4ABb	1.2ABb	1.5Aa	1.1Bb	1.1Bb	1.2ABb	1.3ABb	1.1ABb	1.4ABab	1.2ABa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.16: Results of Haskell Bermudagrass Soil NH_3 (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		2.1	3.4	3.2	3.8	14.0	3.9	6.9	2.5	4.3	2.9	6.1
0-5 cm	6.7	9.3B§a¶	10.8Ba	7.0Ba	11.5Ba	20.5Aa	10.0Ba	13.4Ba	8.8Ba	12.7Ba	9.6Ba	10.5Ba
5-15 cm	2.8	5.3ABb	4.4ABb	4.5ABa	5.4ABb	4.9ABb	3.8Bb	5.0ABb	4.5ABb	5.1ABb	5.7ABb	7.2Aab
15-30 cm	2.6	3.9Ab	3.1Ab	4.3Aa	3.6Ab	4.0Ab	3.0Ab	3.8Ab	2.8Ab	3.5Ab	5.2Ab	4.1Ab

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.5	0.8	2.0	1.4	1.4	2.0	1.0	2.0	1.0	1.3	1.3
0-5 cm	2.1	10.0ABCa	10.2ABCa	8.3Ca	9.8ABCa	9.9ABCa	9.6ABCa	8.6BCa	8.9ABCa	10.9Aa	10.5ABa	9.5ABCa
5-15 cm	1.8	5.4ABb	6.5Ab	4.7Bb	7.0Ab	5.5ABb	6.1ABb	6.1ABb	5.7ABb	5.6ABb	5.6ABb	5.8Ab
15-30 cm	1.4	4.7Ab	4.9Ac	5.2Ab	5.8Ab	5.2Ab	5.3Ab	4.6Ac	5.3Ab	4.6Ab	4.8Ab	4.4Ac

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.2	2.2	2.1	4..41	2.7	3.2	1.1	3.5	3.0	4.2	4.3
0-5 cm	3.5	14.9Ba	13.9Ba	15.3ABa	16.1ABa	16.5ABa	15.9ABa	14.8Ba	18.5Aa	13.8Ba	14.8Ba	16.5ABa
5-15 cm	1.2	8.0Ab	7.2Ab	7.6Ab	7.6Ab	7.5Ab	7.3Ab	7.4Ab	8.0Ab	7.2Ab	7.1Ab	6.9Ab
15-30 cm	1.3	6.8BCDEb	6.9ABCDb	6.8BCDEb	7.9ABb	5.6Eb	7.3ABCb	6.4CDEb	7.2ABCDb	6.2CDEb	8.2Ab	6.0DEb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.17: Results of Haskell Bermudagrass Soil Total Nitrogen (TN) (%)) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.03	0.02	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.04	0.11
0-5 cm	0.05	0.22B§a¶	0.23ABa	0.25ABa	0.23ABa	0.23ABa	0.23ABa	0.24ABa	0.22Ba	0.24ABa	0.24ABa	0.28Aa
5-15 cm	0.01	0.09Ab	0.09Ab	0.09Ab	0.09Ab	0.09Ab	0.09Ab	0.08Ab	0.09Ab	0.09Ab	0.09Ab	0.09Ab
15-30 cm	0.01	0.08ABb	0.06Cb	0.07BCb	0.07ABCb	0.07ABCb	0.07ABCc	0.08ABb	0.07BCc	0.08Ab	0.07ABCb	0.07ABCb

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.02	0.01	0.02	0.02	0.14	0.03	0.02	0.04	0.03	0.03	0.02
0-5 cm	0.03	0.23BCDa	0.24ABCDa	0.22CDa	0.24ABCDa	0.25ABCa	0.27Aa	0.26ABa	0.24ABCDa	0.26ABa	0.25ABa	0.21Da
5-15 cm	0.04	0.12BCb	0.13ABCb	0.11BCb	0.11BCb	0.16Aa	0.10BCb	0.12BCb	0.09Cb	0.14ABb	0.11BCb	0.11BCb
15-30 cm	0.07	0.10ABb	0.10ABc	0.11ABb	0.10ABb	0.17Aa	0.10ABb	0.11ABb	0.10ABb	0.10ABc	0.09Bb	0.09Bc

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.03	0.03	0.02	0.03	0.06	0.07	0.12	0.06	0.04	0.04	0.02
0-5 cm	0.05	0.22ABa	0.21Ba	0.21Ba	0.20Ba	0.23ABa	0.21Ba	0.20Ba	0.20Ba	0.27Aa	0.22ABa	0.23ABa
5-15 cm	0.04	0.12Ab	0.10Ab	0.11Ab	0.11Ab	0.12Ab	0.13Ab	0.12Aa	0.11Ab	0.11Ab	0.12Ab	0.11Ab
15-30 cm	0.04	0.11ABb	0.09ABb	0.10ABb	0.10ABb	0.13Ab	0.10ABb	0.13Aa	0.09Bb	0.09Bb	0.10ABb	0.09Bc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.18: Results of Haskell Bermudagrass Soil Total Carbon (TC) (%)) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
		2007										
LSD Between Depth Interaction		0.15	0.17	0.3	0.41	0.18	0.34	0.13	0.14	0.52	0.51	1.32
0-5 cm	0.67	2.6B§a¶	2.6Ba	2.8ABa	2.6Ba	2.7ABa	2.7ABa	2.7ABa	2.6Ba	2.9ABa	2.7ABa	3.3Aa
5-15 cm	0.08	0.99Ab	1.04Ab	1.03Ab	1.03Ab	1.04Ab	1.00Ab	0.99Ab	0.98Ab	1.03Ab	1.03Ab	1.03Ab
15-30 cm	0.07	0.82BCc	0.82ABCc	0.84ABCb	0.83ABCb	0.88ABb	0.81BCb	0.85ABCc	0.80Cc	0.90Ab	0.89ABb	0.87ABCb
		2008										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.16	0.21	0.18	0.16	0.28	0.25	0.19	0.07	0.15	0.12
0-5 cm	0.21	2.22BCa	2.26BCa	2.14Ca	2.19BCa	2.39ABa	2.37ABa	2.35ABa	2.36ABa	2.47Aa	2.38ABa	2.07Ca
5-15 cm	0.08	0.90ABCb	0.94ABCb	0.86Cb	0.94ABb	0.96Ab	0.88BCb	0.92ABCb	0.88BCb	0.96ABb	0.94ABb	0.93ABCb
15-30 cm	0.05	0.74BCb	0.73BCc	0.80Ab	0.73BCc	0.77ABc	0.72BCb	0.75ABb	0.69Cb	0.75ABc	0.75ABc	0.74Bc

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.13	0.24	0.15	0.45	0.16	0.74	1.32	0.78	0.48	0.53	0.38
0-5 cm	0.53	2.24ABa	2.16ABa	2.09ABa	2.07ABa	2.33ABa	2.09ABa	1.97Ba	1.99Ba	2.54Aa	2.14ABa	2.32ABa
5-15 cm	0.32	0.91ABb	0.92ABb	0.96ABb	0.84Bb	0.94ABb	1.21Ab	0.86Ba	0.91ABb	0.92ABb	0.86Bb	1.01ABb
15-30 cm	0.31	0.72Bc	0.70Bb	0.78ABc	0.75ABb	0.72Bc	0.81ABb	1.03Aa	0.67Bb	0.71Bb	0.83ABb	0.70Bb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.19: Results of Haskell Sweet Sorghum pH from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.3	0.3	0.1	0.5	0.2	0.2	0.4	0.3	0.4	0.6
0-5 cm	0.5	6.3AB§a¶	6.0ABa	6.1ABa	6.01Ba	6.2ABa	6.3ABa	6.2ABa	6.1ABa	6.3ABa	6.5Aa	6.2ABa
5-15 cm	0.4	6.4Aa	6.0Aa	6.1Aa	6.1Aa	6.3Aa	6.3Aa	6.1Aa	6.2Aa	6.4Aa	6.3Aa	6.4Aa
15-30 cm	0.4	6.2Aa	6.2Aa	6.2Aa	6.1Aa	6.3Aa	6.1Aa	6.3Aa	6.2Aa	6.3Aa	6.3Aa	6.0Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.1	0.3	0.2	0.2
0-5 cm	0.2	5.4Ba	5.2Ca	5.2Cc	5.1Cb	5.6ABa	5.8Aa	5.8Aa	5.8Aa	5.9Aa	5.8Aa	5.7Aa
5-15 cm	0.2	5.5ABa	5.3Ba	5.5ABa	5.4Ba	5.5ABa	5.7Aab	5.7Aa	5.7Aa	5.6Aab	5.6Aa	5.5ABab
15-30 cm	0.2	5.4ABCa	5.4ABCa	5.3BCb	5.3Ca	5.4ABCa	5.5ABb	5.5Ab	5.4ABCb	5.4ABCb	5.3Cb	5.5ABCb

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control

LSD Between Depth Interaction		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2
0-5 cm	0.2	5.8Ca	5.6Db	5.4Eb	5.3Ea	6.0Aa	6.2Aa	6.3Aa	6.2Aa	6.3Aa	6.0Ba	5.9BCa
5-15 cm	0.1	5.8CBa	6.6Dab	5.6Da	5.6Db	5.9BCb	6.0ABb	6.0Ab	6.0Ab	6.0Ab	5.8Cb	5.9ABCa
15-30 cm	0.2	5.7ABa	5.7ABCa	5.6BCa	5.7ABCc	5.6BCc	5.6BCc	5.8Ac	5.7ABCc	5.7ABCc	5.6Cc	5.7ABCb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.20: Results of Haskell Sweet Sorghum Soil Electrical Conductivity (EC) (us cm^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		76.4	123.8	61.0	115.1	245.7	88.2	311.4	154.7	26.9	81.6	473.0
0-5 cm	209.6	97.3B§a¶	120.8Ba	80.2Ba	155.4ABa	155.8ABa	87.3Ba	339.1Aa	94.0Ba	96.9Ba	96.7Ba	95.9Ba
5-15 cm	115.3	110.7Aa	130.7Aa	91.2Aa	109.1Aa	132.5Aa	76.9Aa	150.8Aa	164.0Aa	56.4Ab	152.8Aa	159.0Aa
15-30 cm	228.2	170.3ABa	143.6ABa	62.4Ba	64.4Ba	174.9ABa	91.2Aa	183.4ABa	91.0Ba	61.5Bb	87.7Ba	352.3Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		25.2	7.0	49.2	33.6	26.9	19.9	27.2	43.8	125.8	46.2	21.5
0-5 cm	23.8	103.4DEa	106.6CDEc	101.8Eb	113.1CDEb	126.2ABCDa	129.6ABb	133.0ABa	128.4ABCa	145.1Aa	147.8Aa	106.4CDEa
5-15 cm	55.2	110.3Ca	118.18Cb	117.0Cab	130.43CBb	120.59BCa	130.4BCb	142.9BCa	148.0ABCa	201.6Aa	175.7ABa	120.8BCa
15-30 cm	37.9	127.3DEa	149.3CDEa	163.7BCDa	206.8Aa	114.0Ea	159.9BCDa	149.9CDEa	167.4BCa	152.7BCDa	189.3ABa	113.3Ea

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		13.4	9.5	15.4	27.9	16.5	15.6	120.8	30.9	66.3	23.7	21.4
0-5 cm	39.7	83.1BCa	78.9BCa	86.0BCa	84.6ABCa	83.3BCa	105.7ABCa	107.4ABCa	117.1ABa	127.6Aa	109.3ABCa	73.6Ca
5-15 cm	62.2	69.4Bb	73.9Ba	75.8Ba	80.8Ba	73.5Ba	80.7Bb	151.1Aa	87.2Aab	104.9ABa	104.1ABa	57.8Ba
15-30 cm	17.7	68.5BCb	70.1BCa	78.8BCa	71.1BCa	79.0BCa	75.5BCb	79.7BCa	84.7Bb	80.9BCa	112.3Aa	64.3Ca

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.21: Results of Haskell Sweet Sorghum Soil Calcium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		88	59	90	125	52	83	90.0	117.6	55.8	96.3	64.0
0-5 cm	137	927ABCD§a¶	899BCDb	855CDb	829Db	967ABCa	985ABCa	1048Aa	1016ABa	1046Aa	904BCDa	957ABCDa
5-15 cm	128	1010ABa	1011ABa	946ABa	949ABab	964ABa	1009ABa	1033Aa	1032Aa	1023Aab	893Ba	949ABa
15-30 cm	115	970ABa	1029Aa	963ABa	994Aa	989ABa	1031Aa	991Aa	963ABa	989ABb	876Ba	943ABa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		73	143	102	75	97	80	83	59	91	60	64
0-5 cm	92	771BCb	738	754Cb	720Cb	860ABa	901Aa	910Aa	906Aa	938Aa	883Ab	867Aa
5-15 cm	85	879ABa	846Ba	933Aa	899ABa	880ABa	913ABa	961Aa	899ABa	938Aa	948Aa	921ABa
15-30 cm	81	823Bab	847ABa	888ABa	916Aa	861ABa	906Aa	881ABa	839ABb	868ABa	858ABb	881ABa

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		87	53	82	26	62	37	86	71	93	56	55
0-5 cm	100.6	913CDb	858CDEb	851DEb	794Ec	1017ABa	1035ABa	1097Aa	1067Aa	1075Aa	1015ABa	954BCb
5-15 cm	85	1002ABCa	951BCa	962BCa	934Cb	1025ABa	1022ABa	1036ABa	1014ABCab	1054Aa	1036ABab	1027ABa
15-30 cm	82	992ABab	994ABa	987ABa	1011ABa	970ABa	948Bb	1045Aa	946Bb	991ABa	947Bb	1003ABab

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.22: Results of Haskell Sweet Sorghum Soil Magnesium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

						2007						
	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		15.8	8.5	16.2	4.7	14.8	8.4	14.0	13.4	10.9	7.2	12.4
0-5 cm	14.5	75.6D§a¶	77.0DCb	74.7Da	72.0Db	90.8ABCa	83.2BCDb	99.7Aa	105.3Aa	97.4ABa	76.5DCa	81.5DCab
5-15 cm	12.7	65.6ABa	67.5ABc	61.3Ba	61.8Bc	70.5ABb	72.6ABc	70.8ABb	76.7Ab	77.3Ab	69.5ABa	69.6ABb
15-30 cm	13.9	77.6Ba	85.6ABa	76.1Ba	77.1Ba	81.8ABab	94.9Aa	83.4ABb	77.7Bb	82.2ABb	75.1Ba	83.3ABa

						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		2.8	8.5	11.1	7.6	14.0	13.5	15.6	7.6	5.6	12.5	11.1
0-5 cm	11.1	85.1CDa	76.6DEa	69.0EFab	63.7Fb	99.5ABa	100.5ABa	100.2ABa	101.1ABa	106.0Aa	103.3ABa	93.9BCa
5-15 cm	11.4	61.4BCc	62.1BCb	63.4BCb	57.9Cb	69.3ABCb	72.4ABb	71.3ABb	68.5ABCb	77.2Ac	78.3Ab	70.9ABb
15-30 cm	12.5	68.7Cb	77.8ABCa	74.6ABCa	73.6BCa	74.9ABCb	80.0ABCb	82.4ABb	71.8BCb	83.2ABc	82.5ABb	86.2Aa

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		16.5	11.2	9.9	6.3	12.4	14.1	37.6	20.8	19.3	14.6	15.5
0-5 cm	15.7	119.8CDa	113.8CDa	105.1DEa	91.7Ea	153.4ABa	143.1Ba	158.2ABa	160.3Aa	161.6Aa	146.3ABa	124.9Ca
5-15 cm	8.8	81.3DEb	81.2DEb	77.6EFb	70.3Fc	90.1BCb	87.6DCb	95.0ABCb	97.0ABb	99.9Ab	97.0ABb	88.6BCDb
15-30 cm	16.3	77.1Cb	81.3BCb	88.6ABCc	79.5BCb	83.8ABCb	90.4ABb	99.2Ab	83.5ABCb	95.6ABb	89.1ABCb	89.6ABCb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.23: Results of Haskell Sweet Sorghum Soil Potassium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		7.6	22.0	14.7	24.0	16.9	7.6	7.1	27.3	13.6	14.8	13.9
0-5 cm	18.8	86.5DE§a¶	110.5ABa	106.4ABa	112.0Aa	85.4DEa	85.1DEa	99.2ABCDa	114.4Aa	104.5ABCa	92.8CDEa	79.4Ea
5-15 cm	8.2	58.7ABCb	63.1ABCb	58.2BCb	60.4ABCb	57.3Cb	59.7ABCb	58.8ABCb	66.6Ab	65.3ABCb	66.3ABb	59.4ABCb
15-30 cm	10.1	58.5Ab	58.5Ab	58.1Ab	59.8Ab	63.9Ab	64.8Ab	58.6Ab	60.1Ab	57.1Ab	57.5Ab	59.5Ab

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		12.8	11.7	9.9	11.8	14.1	14.9	12.8	19.9	20.9	12.7	9.1
0-5 cm	17.0	87.9DEa	104.6CDa	102.4CDEa	106.5Ca	86.8Ea	119.1BCa	108.8BCa	112.9BCa	124.8Ba	145.5Aa	88.6DEa
5-15 cm	5.7	49.0CDb	55.6ABb	55.7ABb	55.6ABb	48.1Db	54.5ABCb	55.3ABb	57.5Ab	57.1Ab	57.0Ab	51.0BCDb
15-30 cm	6.8	47.7Bb	49.3ABb	49.5ABb	53.9ABb	49.0Bb	51.2ABb	53.4ABb	49.8ABb	50.9ABb	50.8ABb	56.0Ab

						2009						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		12.5	21.0	14.7	17.7	14.0	9.3	8.3	15.0	23.3	16.5	8.5
0-5 cm	18.8	99.1EFa	115.4CDEa	120.0CDa	128.5BCDa	113.1DEa	130.7BCDa	133.6BCa	143.9Ba	165.7Aa	147.0Ba	93.9Fa
5-15 cm	8.0	68.0Db	71.5CDb	75.8BCDb	79.0BCb	68.9Db	70.7Db	74.6BCDb	81.4ABb	88.4Ab	82.5ABb	70.4Db
15-30 cm	8.1	59.9Bb	59.7Bb	62.2Bb	62.8ABb	60.1Bb	61.3Bc	60.1Bc	64.3ABc	70.2Ab	67.4ABb	62.5ABb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.24: Results of Haskell Sweet Sorghum Soil Sodium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		64.0	64.0	132.5	85.0	54.9	97.4	121.3	32.9	42.7	57.4	78.3
0-5 cm	114.5	542.7AB§a¶	554.3ABa	492.2Ba	545.4ABa	522.1ABb	518.4ABa	620.3Aa	575.5ABa	533.1ABa	485.5Ba	527.4ABa
5-15 cm	94.5	558.1Aa	552.0Aa	472.2Aa	520.8Aa	562.3Abc	502.7Aa	547.3Aa	552.0Aa	540.6Aa	503.7Aa	503.7Aa
15-30 cm	91.7	537.55ABa	578.2Aa	256.1ABa	548.0ABa	6610.5Aa	552.2ABa	530.0ABa	578.3Aa	544.8ABa	477.3Ba	537.5ABa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.9	9.3	17.8	16.5	11.6	14.6	11.5	7.5	11.1	5.2	15.4
0-5 cm	19.2	85.8ABCa	97.7ABCa	84.8BCa	85.5ABCa	92.7ABCa	82.7Ca	102.7ABa	94.9ABCb	104.1Aa	85.5ABCb	93.4ABCa
5-15 cm	19.4	88.2BCa	100.7ABCa	87.3Ca	92.8ABCa	95.9ABCa	96.7ABCa	108.4Aa	109.4Aa	107.5ABa	93.7ABCa	86.2Ca
15-30 cm	19.0	90.1ABCa	96.4ABCa	83.8Ca	88.2BCa	98.1ABCa	94.6ABCa	108.3Aa	97.1ABCb	103.3ABa	95.0ABCa	95.8ABCa

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		26.5	19.7	13.5	21.2	19.3	18.8	16.6	17.3	27.3	15.1	8.1
0-5 cm	18.3	43.8Aa	48.5Aa	46.3Aa	48.8Aa	59.3Aa	56.8Aa	50.6Aa	56.3Aa	47.2Aa	51.0Aa	47.3Ab
5-15 cm	12.3	50.5BCa	41.0CDa	37.8Da	49.2BCDa	54.6ABa	48.0BCDa	55.4ABa	57.4ABa	64.4Aa	59.0ABa	56.3ABa
15-30 cm	18.7	55.3ABa	42.7Ba	49.0ABa	42.3Ba	49.0ABa	48.4ABa	62.4Aa	56.0ABa	60.9ABa	61.0Aa	56.7ABa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.25: Results of Haskell Sweet Sorghum Soil Phosphorous (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		2.1	3.7	9.0	23.5	2.4	2.3	14.1	16.7	9.5	9.7	4.5
0-5 cm	16.2	11.2CD§a¶	18.8BCDa	34.5ABa	43.9Aa	10.8CDa	10.3CDa	24.4BCa	28.2ABa	30.2ABa	21.6BCDa	6.6Da
5-15 cm	3.0	8.3BCDb	11.3ABb	8.5BCDb	13.4Ab	8.3BCDb	6.2Db	7.8CDb	9.3CBb	9.2BCb	8.9BCDb	7.8CDa
15-30 cm	3.1	7.8Ab	8.4Ab	8.4Ab	8.6Ab	8.9Aab	7.1Ab	6.8Ab	7.9Ab	7.1Ab	8.0Ab	7.8Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		3.3	11.9	11.1	13.0	12.2	8.6	6.5	5.1	16.5	11.8	2.7
0-5 cm	13.0	15.2EFa	31.1CDa	47.4Ba	65.0Aa	15.7EFa	25.3DEa	29.7Da	44.5Ba	44.0BCa	51.5Ba	7.8Fab
5-15 cm	3.8	9.2CDEb	12.6ABCb	12.8ABCb	15.2Ab	7.1Ea	8.2EDb	9.9BCDEb	11.0BCDb	10.5BCDEb	13.2ABb	8.6EDa
15-30 cm	2.6	6.2ABb	5.8ABb	6.4ABb	7.5Ab	6.2ABa	4.7Bb	5.1ABb	5.4ABc	4.4Bb	6.2ABb	5.2ABb

								2009				
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		4.0	12.8	18.5	23.8	11.3	4.6	11.0	33.0	19.1	29.3	1.4
0-5 cm	26.9	24.8EFa	46.2CDEa	76.9ABa	94.0Aa	32.9DEFa	35.7DEFa	57.0BCDa	88.01Aa	70.3ABCa	84.7Aa	11.8Fa
5-15 cm	6.0	10.4 CDEb	15.4 BCDb	20.6 ABb	25.5 Ab	9.7 DEb	11.2 CDEb	15.7 BCb	20.1 ABb	18.7 Bb	18.1 Bb	8.5 Eb
15-30 cm	1.9	8.0 DCb	8.5 ABCb	8.8 ABCb	10.3 Ab	9.6 BAb	7.2 DCb	9.9 Bab	9.3 ABb	9.3 Abb	8.8 ABCb	6.4 Dc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N\text{-}P_2O_5\text{-}K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.26: Results of Haskell Sweet Sorghum Soil Manganese (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		7.0	10.7	18.2	11.9	18.6	18.6	10.9	32.4	13.6	12.2	23.0
0-5 cm	19.4	54.5B§a¶	66.7ABa	75.0Aa	65.7ABb	73.8ABa	69.0ABa	60.4ABa	72.5ABa	73.0ABa	58.5ABa	63.3ABa
5-15 cm	23.1	55.2Ba	67.0ABa	62.3ABa	69.05ABab	64.9ABa	61.6ABa	61.3ABa	79.0Aa	66.2ABab	55.8Ba	52.4Ba
15-30 cm	18.0	58.8Ba	66.5ABa	59.9Ba	78.1Aa	59.4Ba	67.2ABa	58.8Ba	61.1ABa	58.9Bb	53.0Ba	56.7Ba
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		5.6	5.1	16.6	10.0	18.8	8.0	8.2	5.3	13.3	8.6	8.9
0-5 cm	12.2	50.7Ca	57.0ABCa	65.9ABa	58.1ABCa	54.7BCa	62.7ABCa	59.1ABCa	65.7ABa	63.9ABa	68.8Aa	55.5BCa
5-15 cm	11.5	55.0ABa	55.7ABa	63.0Aa	54.3ABa	50.9Ba	58.8ABab	55.6ABab	59.5ABb	60.2ABa	62.3ABa	61.8ABa
15-30 cm	9.9	44.0Ab	46.1Ab	49.3Aa	49.7Aa	50.4Aa	51.2Ab	49.1Ab	49.5Ac	52.3Aa	49.3Ab	53.4Aa

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		5.7	6.0	4.6	4.8	6.9	5.9	10.5	3.0	8.5	4.8	6.0
0-5 cm	6.1	50.9Da	55.5DCa	62.3Aa	58.7ABCa	56.0BCDa	58.8ABCa	63.8Aa	61.6ABa	62.3Aa	58.8ABCa	50.5Da
5-15 cm	7.8	50.3BCa	49.0Cb	58.3Aa	50.9ABCb	51.3ABCa	54.0ABCa	51.9ABCb	53.1ABCb	57.0ABa	53.6ABCb	50.0BCa
15-30 cm	5.2	37.1BCb	37.2BCc	40.7ABa	41.7ABc	39.9ABCb	39.3ABCb	43.2Ab	38.9ABCc	42.9Ab	40.9ABc	35.5Cb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.27: Results of Haskell Sweet Sorghum Soil Iron (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	2007										
		CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		24.2	22.4	29.2	27.5	34.4	38.3	26.1	28.6	15.2	18.7	55.0
0-5 cm	44.1	197.8AB§a¶	207.3ABab	218.3Aa	216.6Aa	207.0ABa	174.3ABa	180.8ABa	188.6ABa	175.9ABa	169.5Bb	187.4ABa
5-15 cm	46.6	186.9Aa	210.2Aa	202.1Aab	199.7Aa	206.5Aa	174.5Aa	184.6Aa	189.4Aa	166.3Aa	188.7Aa	170.2Aa
15-30 cm	42.2	193.0Aa	185.5Ab	179.9Ab	196.1Aa	196.9Aa	193.1Aa	180.5Aa	178.8Aa	170.1Aa	181.1Aab	182.1Aa
		2008										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		17.0	30.9	48.0	35.6	50.7	18.0	19.6	22.5	27.8	40.8	18.6
0-5 cm	40.8	195.4CDEa	228.0ABCDa	261.5Aa	236.3ABa	194.4CDEa	197.3BCDEa	186.3Ea	196.5BCDEa	193.0DEab	234.8ABCa	195.2CDEb
5-15 cm	38.2	195.2Aa	199.9Aa	218.6Aab	191.0Ab	186.0Aa	194.7Aa	187.7Aa	195.9Aa	200.9Aa	211.6Aab	222.2Aa
15-30 cm	29.5	157.3ABb	157.0ABb	172.6ABb	161.2ABb	171.0ABa	174.3ABb	151.0Bb	163.3ABb	169.3ABb	178.4ABb	185.3Ab
		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control

LSD Between Depth Interaction		14.7	23.4	29.5	22.7	9.4	21.9	35.1	32.2	32.1	19.6	12.8
0-5 cm	28.2	194.9EFa	234.7ABCa	251.3ABa	256.2Aa	197.8DEFa	191.7EFa	209.3CDEab	223.4BCDa	216.3CDEa	198.5DEFa	175.7Fb
5-15 cm	37.3	197.2Ba	209.1ABb	235.1Aa	214.8ABb	201.4ABa	194.1Ba	217.4ABa	211.4ABa	222.0ABa	210.6ABa	188.7Ba
15-30 cm	15.2	153.8Db	158.9CDc	168.3ABCDb	158.8CDc	172.1ABCb	162.4BCDb	180.6Ab	166.5ABCDb	174.7ABb	176.7ABb	154.8Dc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.28: Results of Haskell Sweet Sorghum Soil Sulfur (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		11.4	1.2	3.5	2.3	1.8	3.9	3.1	1.8	2.2	3.8	3.0
0-5 cm	3.2	9.0AB§a¶	9.1ABb	8.2ABa	9.3ABb	9.1ABb	7.4ABb	10.2Aa	9.8Ab	8.9ABb	6.2Bb	8.5ABab
5-15 cm	2.4	9.6Aa	9.8Ab	8.1Aa	9.7Aab	9.3Ab	7.4Ab	8.6Aa	9.3Ab	8.6Ab	7.8Aab	7.4Ab
15-30 cm	5.4	17.0Aa	12.3ABa	9.8Ba	11.8ABa	12.5ABa	11.5Ba	10.1Ba	11.8ABa	11.8ABa	11.4Ba	10.4Ba

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.4	3.7	2.0	3.4	2.3	1.9	2.1	3.0	1.6	5.7	1.0
0-5 cm	2.8	15.8BCb	16.6BCa	16.8BCb	15.0Cb	18.2Bb	17.7BCb	18.0Bb	17.6BCb	18.2Bb	21.6Ab	17.7BCb
5-15 cm	3.2	16.8Bab	18.3Ba	18.3Bab	17.1Bab	18.9Bab	18.4Bb	18.9Bab	19.3Bab	19.0Bb	26.3Ab	18.0Bb
15-30 cm	3.4	17.9Ca	18.7BCa	19.3BCa	18.9BCa	20.7BCa	20.5BCa	21.1BCa	21.8Ba	22.0Ba	32.3Aa	20.7BCa

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.4	0.9	2.1	1.2	1.3	1.1	5.8	1.7	2.6	6.6	1.6
0-5 cm	1.7	14.9EFb	15.1DEFb	15.9CDEFab	15.0EFb	16.8BCDb	16.4BCDEb	17.6Ba	17.6Bb	17.5BCb	21.3Aa	14.7Fb
5-15 cm	2.5	15.2Bb	15.8Bb	15.4Bb	15.5Bab	15.9Bb	16.3Bb	17.5Ba	16.7Bb	17.5Bb	24.4Aa	15.4Bb
15-30 cm	3.0	16.8Ea	16.8Ea	17.9CDEa	16.7Ea	18.2CDEa	17.9CDEa	22.9Ba	20.2BCDa	20.6BCa	27.1Aa	17.5DEa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.29: Results of Haskell Sweet Sorghum Soil Copper (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

						2007						
	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.3	0.5	0.5	0.3	0.5	0.5	0.3	0.5	37.0	0.4
0-5 cm	0.5	0.84C§a¶	0.86Ca	0.85Ca	1.10ABCa	0.98BCa	1.05ABCa	1.46ABa	1.43ABa	1.57Aa	0.88Ca	0.83Ca
5-15 cm	0.5	0.87Aa	0.92Aa	0.54Aa	0.89Aa	0.97Aa	0.79Aa	0.87Ab	0.84Ab	1.0Ab	0.54Aab	0.63Aa
15-30 cm	0.4	0.83ABa	0.97ABa	0.78ABCa	1.00ABa	1.15Aa	0.95ABa	0.66BCb	0.99ABb	0.97ABb	0.35Cb	0.78ABCa
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.1	0.1	0.1	0.1	0.3	0.3	0.3	0.1	0.3	0.3	0.1
0-5 cm	0.3	0.62Ea	0.67Eab	0.69DEa	0.63Ea	0.94Da	1.33Ca	1.40BCa	1.76Aa	1.64ABa	1.84Aa	0.69DEa
5-15 cm	0.1	0.63Da	0.68BCDa	0.68CDa	0.67CDa	0.67CDa	0.76ABCb	0.74ABCDb	0.75ABCDb	0.80ABb	0.83Ab	0.70BCDa
15-30 cm	0.1	0.55Ab	0.57Ab	0.63Aa	0.60Aa	0.64Aa	0.63Ab	0.57Ab	0.61Ac	0.63Ab	0.60Ab	0.63Aa

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.1	0.1	0.0	0.1	0.2	0.1	0.2	0.3	0.3	0.3	0.1
0-5 cm	0.3	0.57Dab	0.58Da	0.59Da	0.53Da	1.22Ca	1.20Ca	1.64Ba	2.10Aa	1.74Ba	1.73Ba	0.62Da
5-15 cm	0.1	0.57Da	0.58Da	0.63CDa	0.59CDa	0.69Cb	0.67CDb	0.83Bb	0.93ABb	1.01Ab	0.93ABb	0.62CDa
15-30 cm	0.1	0.51Bb	0.50Bb	0.54Bb	0.51Ba	0.57ABb	0.55Bb	0.52Bc	0.53Bc	0.66Ac	0.57ABc	0.57ABb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.30: Results of Haskell Sweet Sorghum Soil Zinc (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
							2007					
LSD Between Depth Interaction		1.8	3.1	5.0	3.3	4.3	3.6	2.7	2.8	2.2	5.0	2.4
0-5 cm	4.6	3.1A§a¶	2.8Aa	3.6Aa	3.0Aa	3.3Aa	3.9Aa	2.5Aa	2.4Aa	3.7Aa	3.5Aa	3.4Aa
5-15 cm	3.9	3.0Aa	3.8Aa	4.4Aa	0.7Aa	3.5Aa	3.1Aa	2.1Aa	3.4Aa	3.7Aa	3.5Aa	3.6Aa
15-30 cm	2.7	3.8ABa	2.3Ba	3.0ABa	1.4Ba	4.9Aa	2.5ABa	3.9ABa	2.1Ba	3.0ABa	3.3ABa	2.2Ba
							2008					
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.4	0.2	0.2	0.9	0.9	0.6	0.8	7.3	6.3	0.1
0-5 cm	0.5	0.8Da	1.0CDa	1.0CDa	0.9CDa	1.5BCa	2.3Ba	2.2Ba	3.1Aa	2.7ABa	3.0Aa	1.0CDa
5-15 cm	0.6	0.9Ba	1.0ABa	1.1ABa	0.9ABa	1.0ABa	1.3ABb	0.9ABb	1.4Ab	1.1ABa	1.2ABa	0.9ABa
15-30 cm	1.0	0.8Aa	0.7Aa	0.7Ab	0.6Ab	0.8Aa	0.8Ab	0.7Ab	0.8Ab	0.9Aa	0.8Aa	0.6Ab

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.1	0.2	0.1	0.2	0.4	0.4	0.8	0.9	1.0	1.1	0.1
0-5 cm	0.8	1.0Da	1.0Da	1.1Da	1.0Da	2.3Ca	2.5Ca	3.5Ba	4.5Aa	4.0ABa	4.2ABa	1.0Da
5-15 cm	0.2	0.9Db	1.0CDa	0.9Db	0.9Da	1.0CDb	1.1BCb	1.2Bb	1.5Ab	1.5Ab	1.3Bb	0.9Db
15-30 cm	0.4	0.70Bc	0.68Bb	0.67Bc	0.67Bb	0.81Bb	0.84ABb	1.19Ab	0.79Bb	0.91ABb	0.75Bb	0.67Bc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.31: Results of Haskell Sweet Sorghum Soil Nickel (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.2	0.1	0.2	0.2	0.3	0.4	0.9	0.8	0.5	0.5	0.9
0-5 cm	0.7	0.75E§a¶	0.73Eb	0.78Ea	0.84Ea	1.16DEa	1.33CDEa	2.06ABa	1.99ABCa	2.38Aa	1.67BCa	0.87Ea
5-15 cm	0.3	0.78BCa	0.86ABCa	0.74Ca	0.84ABCa	0.84ABCb	0.93ABCa	0.88ABCb	1.04ABb	1.08Ab	0.70Cb	0.70Ca
15-30 cm	0.3	0.77ABa	0.71ABb	0.69ABa	0.80ABa	0.83Ab	0.97Aa	0.65ABb	0.85Ab	0.87Ab	0.49Bb	0.90Aa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.7	0.5	0.3	0.7	0.8	0.6	0.4	0.5	0.4	0.7
0-5 cm	0.5	0.96Aa	1.40Aa	1.31Aa	1.18Aa	1.24Aa	1.01Aa	1.00Aab	1.06Aa	1.28Aa	1.02Aa	1.39Aa
5-15 cm	0.4	0.80Aab	1.09Aa	0.99Aa	0.76Ab	0.73Aa	1.04Aa	1.05Aa	0.77Aab	0.81Aab	1.00Aa	1.05Aa
15-30 cm	0.3	0.60ABCb	0.81ABa	0.82Aa	0.59ABCb	0.63ABCa	0.66ABCa	0.47Cb	0.61ABCb	0.71ABCb	0.56BCb	.80ABa

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.4	0.3	0.3	0.2	0.3	0.4	0.2	0.3	0.4	0.2
0-5 cm	0.4	1.19ABa	1.02Ba	1.47ABa	1.16Ba	1.16ABa	1.15ABa	1.33ABa	1.19ABa	1.12ABa	1.34ABa	0.96Ba
5-15 cm	0.2	0.74ABb	0.75ABa	0.93Ab	0.79ABb	0.76ABb	0.67Bb	0.77ABb	0.73ABb	0.76ABb	0.89ABb	0.76ABb
15-30 cm	0.3	0.76ABb	0.93ABa	0.99Ab	0.83ABb	0.79ABb	0.85ABb	0.85ABb	0.88ABb	0.71Bb	0.91ABb	0.79ABab

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.32: Results of Haskell Sweet Sorghum Soil Water Soluble Phosphorous (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.5	1.7	0.9	2.9	0.9	0.4	1.7	2.4	3.2	0.7	0.7
0-5 cm	1.8	1.6D§a¶	2.8BCDa	4.1ABa	5.5Aa	1.7CDa	1.3Da	2.9BCDa	4.1ABa	3.5BCa	2.0CDa	1.3Da
5-15 cm	1.1	1.6Aa	2.1Aa	1.5Ab	2.0Ab	2.1Aa	1.45Aa	1.8Aa	1.8Aab	2.2Aa	1.7Aa	1.8Aa
15-30 cm	1.5	1.4ABa	1.5ABa	1.3Bb	1.7ABb	1.7ABa	1.3Ba	1.4ABa	1.4ABb	2.8Aa	1.4ABa	1.6ABa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.5	2.8	3.8	3.4	1.5	1.3	2.4	2.4	4.5	1.4	0.6
0-5 cm	2.4	2.1DEa	3.7CDEa	6.4ABa	8.1Aa	2.7DEa	5.5BCa	4.3BCDa	6.3ABa	8.0Aa	5.4BCa	1.8Ea
5-15 cm	1.1	1.9Ba	3.1Aa	2.7ABab	2.2ABb	1.8Ba	1.9Bb	2.1ABab	2.1ABb	2.3ABb	23ABb	1.9Ba
15-30 cm	2.0	2.0ABa	1.4Ba	1.5Bb	1.6Bb	1.5Ba	1.7Bb	1.9ABb	1.8ABb	3.8Aab	1.5Bb	1.4Ba

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.4	1.7	1.9	2.2	1.4	1.1	2.3	2.4	2.5	1.3	0.7
0-5 cm	2.3	4.1FGa	6.6DEa	9.7ABCa	11.9Aa	5.1FGHa	6.4DEFa	8.7BCDa	10.3ABa	11.7Aa	7.7CDa	3.0Ga
5-15 cm	1.2	2.4CDb	2.9BCDb	3.3ABCDb	3.5ABCb	2.4CDb	2.7BCDb	4.2Ab	3.7ABb	3.3ABCDb	2.8BCDb	2.1Db
15-30 cm	0.3	1.8BCc	1.9ABCb	2.0ABb	2.0ABCb	1.9ABCb	1.9ABCb	2.1Ab	2.0ABb	1.9ABCb	1.8BCb	1.7Cb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.33: Results of Haskell Sweet Sorghum Soil NO_3^- (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		3.1	3.1	2.1	1.8	1.3	6.0	1.3	1.6	1.2	2.7	1.7
0-5 cm	3.7	2.9B§b¶	2.6Bb	2.5Bb	2.9Bb	2.6Bc	9.8Aa	2.8Bc	2.8Bc	3.1Bc	2.2Bb	2.6Bb
5-15 cm	2.2	4.4Bb	5.2ABab	3.4Bb	4.1Bb	4.0Bb	7.2Aa	4.5Bb	5.1ABb	5.3ABb	4.9Ba	4.2Bb
15-30 cm	3.1	8.2Aa	8.3Aa	7.3Aa	7.3Aa	6.3Aa	7.4Aa	6.7Aa	7.3Aa	7.7Aa	7.5Aa	6.0Aa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.2	0.9	2.2	2.0	1.5	2.1	1.1	1.8	2.2	2.2	1.8
0-5 cm	0.8	3.3DEa	3.4CDEb	3.2Ea	3.3CDEb	4.0BCDa	4.0BCa	5.2Aa	4.7ABa	4.7ABa	4.7ABa	3.2Ea
5-15 cm	1.0	3.2Ba	4.1Aab	3.3ABa	3.6ABb	3.0Ba	2.9Ba	3.7ABb	4.1Aa	3.3ABa	3.5ABa	3.0Ba
15-30 cm	2.0	3.5Ba	4.5Ba	4.6Ba	7.3Aa	3.0Ba	3.3Ba	3.5Bb	3.8Ba	2.9Ba	2.8Ba	3.0Ba

2009

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.6	5.2	1.4	0.6	0.5	0.5	0.4	1.0	0.8	1.4	1.9
0-5 cm	2.3	3.8ABCa	6.0Aa	4.1ABCa	3.3BCb	4.4ABCa	4.4ABCa	4.7ABCa	5.5ABa	5.2ABCa	4.6ABCa	3.2Ca
5-15 cm	0.7	3.3BCa	3.3BCa	3.7ABa	3.3BCb	3.4BCb	3.3BCb	3.0Cb	4.1Ab	3.7ABb	3.3BCa	2.9Ca
15-30 cm	1.5	3.8ABCa	4.1ABCa	4.3Aa	4.2ABa	3.6ABCb	2.9BCb	3.3ABCb	4.0ABCb	2.7Cc	3.8ABCa	3.4ABCa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.34: Results of Haskell Sweet Sorghum Soil NH_3 (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

						2007						
	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.5	5.4	7.1	1.7	4.9	10.8	0.3	7.5	5.4	0.6	1.3
0-5 cm	7.3	2.6B§a¶	4.6Bb	6.1Ba	4.8Ba	6.5Ba	13.8Aa	2.5Bb	3.4Ba	5.6Ba	2.9Ba	2.9Ba
5-15 cm	5.1	3.2ABa	7.5ABab	8.0Aa	4.5Aa	5.2ABa	6.8ABa	2.9Ba	5.8ABa	2.9ABa	2.8Ba	3.1ABa
15-30 cm	5.3	3.6Ba	10.2Aa	3.5Ba	4.3Ba	5.2ABa	3.5Ba	2.7Bab	7.9ABa	3.0Ba	2.9Ba	2.8Ba
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.3	2.3	2.0	0.9	0.6	0.8	0.9	2.0	0.6	2.5	1.3
0-5 cm	1.0	5.5Ba	6.6Aa	5.5Ba	6.8Aa	5.8Aa	5.5Ba	5.9ABa	6.4ABa	5.4Ba	5.8ABa	5.8ABa
5-15 cm	1.2	5.9ABCa	6.5ABa	6.5ABa	6.7Aa	5.1Cb	5.2Ca	5.7ABCa	5.5BCa	5.2Ca	6.0ABCa	5.4Ca
15-30 cm	1.4	5.2Aa	5.1Aa	5.4Aa	5.6Ab	4.8Ab	4.9Aa	5.4Aa	5.9Aa	5.1Aa	4.9Aa	6.0Aa

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		2.7	5.2	0.5	1.3	3.0	2.3	3.9	2.5	2.1	2.3	1.7
0-5 cm	3.2	11.4ABa	13.5Aa	12.0ABa	11.8ABa	10.3Ba	10.0Ba	11.7ABa	9.7Ba	10.1Ba	10.4ABa	9.5Ba
5-15 cm	1.9	9.3Aab	9.2Aab	8.6Ab	9.1Ab	7.9Aa	8.8Aa	9.3Aa	8.5Aa	8.0Ab	7.7Ab	8.5Aa
15-30 cm	1.5	8.0ABCb	7.5Cb	8.3ABCb	8.0ABCb	8.9ABa	8.2ABCa	8.3ABCa	7.8BCa	8.1ABCab	8.9ABab	9.3Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.35: Results of Haskell Sweet Sorghum Soil Total Nitrogen (TN) (%)) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.02	0.02	0.02
0-5 cm	0.01	0.09A§a¶	0.09Aa	0.09Aa	0.09Aa	0.09Aa	0.09Aa	0.09Aa	0.09Aab	0.09Aa	0.09Aa	0.09Aa
5-15 cm	0.02	0.09Aa	0.09Aa	0.09Aa	0.10Aa	0.09Aa	0.08Aa	0.09Aa	0.10Aa	0.09Aa	0.09Aa	0.09Aa
15-30 cm	0.02	0.09ABCa	0.09ABCa	0.09ABCa	0.09BCa	0.10Aa	0.08Ca	0.10ABCa	0.08Cb	0.08Ca	0.10ABa	0.09ABCa
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.01	0.04	0.02	0.03	0.02	0.09	0.03	0.06	0.12	0.04	0.02
0-5 cm	0.05	0.10Ba	0.11Ba	0.11Ba	0.09Ba	0.11Ba	0.17Aa	0.12ABa	0.09Ba	0.10Ba	0.11Ba	0.13ABa
5-15 cm	0.02	0.10ABa	0.11ABa	0.10ABa	0.09Ba	0.11ABa	0.10ABa	0.10ABa	0.11Aa	0.10ABa	0.10ABa	0.11Aab
15-30 cm	0.03	0.10ABa	0.11Aa	0.10ABCa	0.08BCa	0.11ABa	0.11ABa	0.10ABa	0.08BCa	0.10ABa	0.07Ca	0.12ABb

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.03	0.04	0.03	0.04
0-5 cm	0.03	0.08Aa	0.08Aa	0.09Aa	0.09Aa	0.09Aa	0.10Aa	0.09Aa	0.10Aa	0.09Aa	0.09Aa	0.08Aa
5-15 cm	0.03	0.07Ca	0.08ABCa	0.11Aa	0.08BCa	0.08ABCa	0.08ABCab	0.09ABCa	0.09ABCa	0.10ABa	0.08ABCa	0.07Ca
15-30 cm	0.03	0.07Aa	0.08Aa	0.09Aa	0.09Aa	0.09Aa	0.08Ab	0.01Aa	0.09Aa	0.08Aa	0.08Aa	0.09Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.36: Results of Haskell Sweet Sorghum Soil Total Carbon (TC) (%)) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.08	0.04	0.15	0.07	0.29	0.07	0.08	0.17	0.09	0.05	0.08
0-5 cm	0.08	0.89AB§a¶	0.88Bb	0.90ABa	0.89ABa	0.96Aa	0.93ABa	0.95ABa	0.97Aa	0.95ABa	0.97Aa	0.94ABa
5-15 cm	0.14	0.95ABa	0.97ABa	0.97ABa	0.95Ba	1.06ABa	0.97ABa	0.96ABa	1.10Aab	1.01ABa	1.01ABa	1.00ABa
15-30 cm	0.13	0.96Aa	0.97Aa	1.00Aa	0.95Aa	1.05Aa	0.95Aa	0.97Aa	0.95Ab	0.96Aa	0.97Aa	1.0Aa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.05	0.03	0.07	0.1	0.11	0.06	0.14	0.1	0.13	0.08	0.13
0-5 cm	0.12	0.82Cb	0.85BCb	0.85BCa	0.88BCa	0.89BCa	0.88BCa	0.94ABa	0.91ABCa	0.90ABCa	1.0Aa	0.9ABCa
5-15 cm	0.07	0.88ABa	0.90ABa	0.86ABa	0.83Ba	0.83Ba	0.84ABab	0.86ABa	0.86ABab	0.85ABa	0.90Ab	0.88ABa
15-30 cm	0.07	0.81Ab	0.84Ab	0.81Aa	0.79Aa	0.81Aa	0.79Ab	0.82Aa	0.79Ab	0.80Aa	0.81Ac	0.84Aa

		2009										
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.13	0.16	0.07	0.09	0.07	0.16	0.07	0.13	0.21	0.27	0.12
0-5 cm	0.14	0.96Aa	1.02Aa	1.04Aa	0.95Aa	1.00Aa	0.99Aa	1.06Aa	1.04Aa	0.97Aa	1.03Aa	0.94Aa
5-15 cm	0.07	0.85ABab	0.89ABb	0.88ABb	0.87ABab	0.86ABb	0.86ABa	0.86ABb	0.91Ab	0.90ABa	0.88ABa	0.84Bab
15-30 cm	0.11	0.79Bb	0.87ABb	0.83ABb	0.85Ab	0.82Ab	0.86ABa	0.84ABb	0.81ABb	0.84ABa	0.91Aa	0.81ABb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.37: Results of Woods County Sweet Sorghum pH from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.4	0.4	0.6	0.3	0.4	0.4	0.4	0.3	0.9	0.2	0.2
0-5 cm	0.4	5.5BC§b¶	5.6ABCb	5.3Cb	5.3Cb	5.5ABCb	5.9Ac	5.4BCb	5.8ABc	5.6ABCb	5.5BCc	5.7ABCc
5-15 cm	0.4	5.9ABCDEa	6.0ABCDab	5.9ABCDEa	5.6Eb	5.7DEb	6.3Ab	5.9DEa	6.3ABb	6.1ABCab	5.9BCDEb	6.1ABCDb
15-30 cm	0.6	6.2Ba	6.3ABa	6.4ABa	6.3Ba	6.4ABa	6.8ABa	6.2Ba	6.6ABa	7.0Aa	6.3Ba	6.5ABa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.7	0.5	0.2	0.3	0.1	0.4	0.5	0.4	0.2	0.2
0-5 cm	0.3	5.2CDc	5.1CDb	4.9Db	4.9Db	5.5ABb	5.7Ab	5.6ABb	5.6ABa	5.6ABb	5.4BCb	5.5ABb
5-15 cm	0.3	5.5ABCb	5.5ABab	5.2CDb	5.1Db	5.5ABb	5.8Ab	5.6ABb	5.7ABa	5.5ABb	5.4BCb	5.7ABb
15-30 cm	0.5	6.3ABa	6.1ABa	6.1ABa	5.9Ba	6.3ABa	6.4Aa	6.1ABa	6.0ABa	6.2ABa	5.9ABa	6.3ABa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.39: Results of Woods County Sweet Sorghum Soil Electrical Conductivity (EC) (us cm^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Between Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		78.4	126.8	56.2	82.1	123.5	168.7	32.8	57.9	76.6	81.5	56.2
0-5 cm	75.5	102.9AB§a¶	160.8Aa	109.5ABa	107.9ABa	79.9Ba	89.0ABa	148.1ABa	102.8ABa	89.3ABa	125.3ABa	146.5ABa
5-15 cm	116.6	128.0Aa	95.2Aa	102.1Aa	106.0Aa	181.2Aa	182.1Aa	106.2Ab	100.0Aa	76.6Aa	129.4Aa	110.9Aa
15-30 cm	62.0	178.0Aa	105.4Ba	88.9Ba	146.4ABa	148.8ABa	101.3Ba	109.0Bb	133.7ABa	130.0ABa	123.9ABa	127.2ABa
2008		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		9.0	13.3	13.7	16.4	28.7	18.1	25.2	9.0	16.8	19.4	20.3
0-5 cm	20.6	59.4Ca	60.4BCa	68.0ABCa	75.4ABCa	56.7Ca	65.4BCa	63.1BCa	80.7ABa	66.8BCa	88.0Aa	60.6BCa
5-15 cm	18.9	46.5Bb	46.5Bb	55.7ABab	51.1ABb	60.4ABa	52.7ABab	60.2ABa	61.3ABb	54.9ABab	67.1Ab	47.2Ba
15-30 cm	9.2	38.6Db	39.7Db	51.2ABb	41.1CDb	41.2CDa	41.8CDb	40.3Da	49.8BCc	46.0BCDb	59.3Ab	41.1CDa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.40: Results of Woods County Sweet Sorghum Calcium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		68.7	52.9	118.6	134.0	70.4	96.1	81.1	52.0	249.4	42.0	66.1
0-5 cm	79.7	210.7C§b¶	239.5BCb	241.8BCb	229.3BCb	242.3ABb	326.7Ab	222.5Cb	261.7ABCb	303.1ABa	231.8BCb	269.8ABCb
5-15 cm	85.8	259.7ABb	284.5ABb	301.7ABb	297.1ABab	291.0ABb	332.0Ab	239.7Bb	296.0ABb	295.1ABa	255.1ABb	312.9ABb
15-30 cm	117.5	405.2ABa	408.9ABa	478.2Aa	391.0ABa	430.6ABa	491.9Aa	350.5Ba	390.0ABa	463.7ABa	350.0Ba	432.5ABa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		123.6	48.6	159.1	75.3	102.1	57.9	56.7	40.2	122.1	70.5	77.9
0-5 cm	50.9	215.2EFc	242.5DEFc	213.8EFb	196.4Fc	293.8ABCb	327.2Ab	262.5CDEc	303.1ABCb	328.4Ab	266.5BCDb	315.0ABb
5-15 cm	86.1	352.1ABb	322.9ABb	350.4ABb	288.5Bb	325.7ABb	349.2ABb	324.3ABb	320.7ABb	353.4ABb	305.8ABb	377.6Ab
15-30 cm	115.6	505.7ABa	468.3ABa	529.8Aa	487.6ABa	487.1ABa	490.1ABa	403.0Ba	464.9ABa	490.4ABa	453.6ABa	543.2Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.41: Results of Woods County Sweet Sorghum Soil Magnesium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		14.4	8.6	9.7	23.8	10.9	11.5	15.7	15.2	37.7	6.3	4.8
0-5 cm	18.5	48.3A§b¶	53.9Ab	57.8Ab	57.3Aa	58.2Ab	66.4Aab	57.3Aab	61.0Ab	63.6Aa	58.2Ab	61.5Ab
5-15 cm	26.3	50.8Ab	57.1Ab	63.8Ab	60.8Aa	60.0Ab	60.7Ab	52.3Ab	59.4Ab	69.2Aa	58.2Ab	58.4Ab
15-30 cm	25.2	72.7ABa	74.1ABa	81.9ABa	75.5ABa	77.0ABa	75.4ABa	69.8ABa	87.4Aa	60.0Ba	75.6ABa	71.4ABb
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		16.1	9.2	15.0	13.7	12.4	11.3	10.5	9.6	7.7	11.2	4.4
0-5 cm	11.9	49.7Fb	58.1CDEFb	55.0DEFb	53.0EFb	68.4ABCab	63.9ABCDEab	66.0ABCDa	70.2ABa	75.7Aa	63.8BCDEb	64.6ABCDEb
5-15 cm	15.9	57.3Aab	53.3Ab	62.4Ab	56.6Ab	57.6Ab	59.4Ab	59.2Aa	60.0Ab	65.4Aa	61.2Ab	61.1Ab
15-30 cm	18.7	71.9Aa	71.8Aa	79.7Aa	81.0Aa	76.1Aa	74.1Aa	66.6Aa	79.2Aa	73.3Aa	80.9Aa	80.3Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.42: Results of Woods County Sweet Sorghum Soil Potassium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		8.7	8.8	5.5	5.5	4.8	8.9	14.6	5.7	34.5	6.6	8.3
0-5 cm	15.1	75.2B§a¶	81.2ABa	89.1ABa	96.3Aa	80.5ABa	83.8ABa	86.3ABa	87.9ABa	90.3ABa	88.6ABa	75.5Ba
5-15 cm	20.5	69.9Aa	74.8Aa	82.4Ab	84.0Ab	78.7Aab	81.3Aab	81.5Aa	76.6Ab	89.1Aa	84.9Aa	74.4Aa
15-30 cm	9.7	75.1ABa	74.1ABa	81.0Ab	79.0Ab	74.1ABb	74.0ABb	72.2ABa	76.6Ab	66.2Ba	75.9Ab	75.3ABa

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		12.0	10.7	23.0	29.3	18.7	15.6	27.4	14.6	26.3	13.5	7.7
0-5 cm	30.2	105.15CDa	118.1ABCDa	133.3ABCa	137.1ABa	110.5BCDa	107.1BCDa	114.1ABCDa	124.8ABCa	142.0Aa	123.1ABCa	88.7Da
5-15 cm	17.6	72.4BCb	69.8BCb	85.7ABb	86.8ABb	74.0BCb	70.7BCb	84.9ABCb	77.0ABCb	93.3Ab	86.3ABb	67.4Cb
15-30 cm	8.2	69.1ABb	67.9ABb	71.1ABb	75.1Ab	67.5ABb	70.4ABb	66.6Bb	69.1ABb	73.0ABb	72.6ABc	70.5ABb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.43: Results of Woods County Sweet Sorghum Soil Sodium (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		35.7	56.4	41.3	61.6	35.3	85.0	45.5	42.9	218.2	44.8	37.0
0-5 cm	50.7	489.2AB§a¶	481.3ABa	507.9ABa	489.1ABa	492.6ABa	508.2ABa	487.8ABa	530.0Aa	477.6Ba	503.2ABa	490.8ABa
5-15 cm	129.2	453.5Aa	484.1Aa	512.5Aa	500.1Aa	492.8Aa	476.9Aa	487.3Aa	501.3Aa	467.9Aa	510.8Aa	484.5Aa
15-30 cm	63.3	480.2Aa	497.6Aa	482.0Aa	480.4Aa	488.1Aa	491.6Aa	478.9Aa	499.9Aa	405.6Ba	486.0Aa	485.8Aa
2008		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		8.0	6.8	5.8	7.1	4.8	4.0	31.0	4.0	7.5	5.9	21.9
0-5 cm	11.6	90.1Aab	87.2Aa	86.8Aa	89.5Aa	89.9Aa	90.7Aa	93.1Aa	93.4Aa	95.9Aa	90.9Aa	96.3Aa
5-15 cm	16.8	90.7ABa	85.9Ba	81.3Bab	85.1Bab	84.4Bb	85.4Bb	107.4Aa	90.1Ba	90.3Bab	90.0Ba	83.5Ba
15-30 cm	6.4	82.3ABCb	76.3Cb	76.5Cb	78.7BCb	80.9ABCb	79.1BCc	82.5ABCa	81.3ABCb	84.7ABa	86.0Aa	78.7BCa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.44: Results of Woods County Sweet Sorghum Soil Phosphorous (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.4	5.8	8.9	14.6	3.9	14.3	6.8	9.0	11.7	10.8	2.8
0-5 cm	13.0	17.3CD§a¶	19.7BCDa	30.0ABCa	33.8Aa	17.6CDa	29.9ABCa	31.5ABa	22.4BCDa	34.4Aa	25.8ABCDa	14.9Da
5-15 cm	6.3	12.1CDb	13.3CDb	13.7BCDb	28.1ABb	5.3Db	22.6ABb	21.9ABCb	10.7CDb	28.4Ab	10.9CDb	6.7Db
15-30 cm	3.5	4.2Ab	3.7Ab	3.5Ab	10.0Ab	7.9Ab	9.5Ab	3.5Ac	6.5Ab	7.9Ab	7.0Ab	7.2Ab

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		6.5	2.8	14.2	15.8	5.8	8.1	4.4	8.1	11.4	10.4	5.9
0-5 cm	12.9	46.0DEa	66.9Ba	69.2Ba	83.7Aa	46.9CDa	45.5DEa	59.0BCa	67.3Ba	85.5Aa	68.6Ba	33.7Ea
5-15 cm	7.9	27.0DEFb	33.8CDb	35.4BCb	47.4Ab	21.1FGb	22.1EFGb	31.8CDb	29.5CDEb	41.9ABb	28.0CDEFb	17.0Gb
15-30 cm	3.7	9.9CDc	12.4ABCc	11.1BCDc	15.4Ac	8.3Dc	8.9CDc	11.1BCDc	9.9CDc	14.6ABc	9.4CDc	8.4Dc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.45: Results of Woods County Sweet Sorghum Soil Manganese (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		3.5	5.2	5.4	7.9	6.5	9.8	3.6	10.3	11.9	4.0	6.0
0-5 cm	10.1	18.4A§a¶	21.4Aa	24.1Aa	25.8Aa	19.4Aa	22.5Aa	16.1Aa	22.9Aa	22.1Aa	24.3Aa	19.8Aa
5-15 cm	8.1	10.4Ab	9.6Ab	11.4Ab	12.1Ab	8.7Ab	14.6Aab	9.9Ab	11.8Ab	16.4Aab	11.6Ab	11.3Ab
15-30 cm	4.7	7.1Ab	6.1Ab	7.3Ab	9.7Ab	6.1Ab	8.3Ab	6.4Ab	8.5Ab	7.4Ab	6.9Ac	7.6Ab
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		5.2	4.9	5.2	5.6	5.5	8.0	2.0	5.4	5.1	4.2	5.4
0-5 cm	5.9	21.5Aa	23.0Aa	23.8Aa	21.5Aa	24.6Aa	25.9Aa	21.5Aa	25.7Aa	24.5Aa	24.2Aa	22.6Aa
5-15 cm	6.8	16.0ABb	19.3ABa	22.1Aa	19.3ABa	13.6Bb	16.8ABb	15.2Bb	16.4ABb	20.4ABa	18.2ABb	15.8ABb
15-30 cm	3.5	7.1Bc	8.0ABb	8.4ABb	7.4ABb	7.2ABc	8.0ABc	6.3Bc	7.7ABc	10.6Ab	7.3ABc	8.9ABc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.46: Results of Woods County Sweet Sorghum Soil Iron (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
							2007					
LSD Between Depth Interaction		7.1	18.5	23.4	37.3	18.8	26.1	29.3	11.0	64.4	40.5	18.0
0-5 cm	24.1	167.1BC§a¶	179.5ABCa	190.8ABa	195.8Aa	159.3Ca	171.4BCa	155.5Ca	176.0ABCa	178.7ABCa	175.9ABCa	171.7ABCa
5-15 cm	31.2	148.6Ab	154.4Ab	163.0Ab	157.0Ab	139.0Ab	162.6Aa	153.2Aa	149.6Ab	162.5Aa	158.5Aa	160.3Aa
15-30 cm	27.2	123.68ABc	134.9ABc	133.0ABc	126.9ABb	118.3Bc	148.3Aa	132.8ABa	131.4ABc	119.6Ba	144.2ABa	130.3ABb
							2008					
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		30.8	31.7	19.4	44.0	21.8	29.8	30.0	18.2	23.4	23.1	29.5
0-5 cm	28.3	213.8BCDa	246.8Aa	238.9ABa	252.8Aa	211.4BCDa	203.2CDa	204.0CDa	214.3BCDa	226.0ABCa	193.1Dab	213.8BCDa
5-15 cm	22.5	221.2ABCa	222.0ABa	229.9Aa	22.1ABa	188.1Db	194.2CDab	207.2BDCa	189.7CDb	220.6ABa	199.7BCDa	203.3BCDa
15-30 cm	25.6	159.6Ab	163.2Ab	171.3Ab	160.4Ab	154.2Ac	167.7Ab	157.7Ab	165.8Ac	177.9Ab	175.1Ab	164.5Ab

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.47: Results of Woods County Sweet Sorghum Soil Sulfur (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

						2007						
	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		1.3	1.2	1.4	1.1	2.2	1.7	1.8	3.3	9.2	1.8	1.2
0-5 cm	1.4	0.70D§a¶	0.74CDa	1.18BCDa	2.14ABCa	1.69BCDa	3.19Aa	0.57Da	1.49BCDa	2.49ABa	2.22ABa	1.12BCDa
5-15 cm	3.6	1.47Ba	1.45Ba	1.1Ba	2.59ABa	2.44ABa	1.34Bb	0.88Ba	1.16Ba	5.52Aa	0.84Bb	1.98ABa
15-30 cm	2.1	0.95Ba	0.82Ba	1.37ABa	1.89ABa	1.33ABa	1.97ABab	2.09ABa	3.18Aa	0.87Ba	0.85Bb	1.16ABa
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		3.1	0.9	3.4	2.8	4.7	1.8	1.4	2.4	3.5	3.1	2.2
0-5 cm	2.3	4.38Db	5.40CDc	5.64CDb	5.10CDb	6.81BCa	6.81BCa	6.7BCa	8.02ABa	8.84ABa	9.54Aa	8.4ABb
5-15 cm	3.3	7.56Aa	6.70Ab	7.56Aab	6.95Aab	7.67Aa	6.46Aa	6.87Aa	6.70Aa	8.11Aa	9.40Aa	6.90Ab
15-30 cm	2.4	8.9ABa	8.2ABa	9.3ABa	8.8ABa	8.9ABa	8.1BCa	6.4Ca	8.0BCa	8.8ABa	10.3ABa	10.6Aa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.48: Results of Woods County Sweet Sorghum Soil Copper (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		0.1	0.1	0.1	0.1	0.1	0.5	0.1	0.2	0.3	0.2	0.1
0-5 cm	0.2	0.04B§a¶	0.06Bb	0.06Ba	0.14ABb	0.09ABa	0.27ABa	0.12ABa	0.20ABa	0.30Aab	0.16ABa	0.06Bb
5-15 cm	0.2	0.11BCa	0.08Cb	0.15BCa	0.26ABab	0.06Ca	0.12BCa	0.10BCa	0.11BCa	0.37Aa	0.12BCa	0.10BCab
15-30 cm	0.2	0.09Ba	0.19ABa	0.10Ba	0.16ABa	0.06Ba	0.29Aa	0.04Ba	0.14ABa	0.11Bb	0.10Ba	0.16ABa
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1
0-5 cm	0.1	0.26Gb	0.35EFGc	0.30FGb	0.27FGc	0.46DEa	0.53Da	0.57CDa	0.71Ba	0.92Aa	0.68BCa	0.39EFb
5-15 cm	0.1	0.47ABa	0.42Bb	0.48ABa	0.45Bb	0.44Ba	0.47ABa	0.46ABb	0.48ABb	0.56Ab	0.48ABb	0.43Bb
15-30 cm	0.1	0.64Aa	0.57ABCa	0.56ABCDa	0.64Aa	0.50CDa	0.54BCDa	0.46Db	0.52BCDb	0.56ABCDb	0.54BCDb	0.61ABa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.49: Results of Woods County Sweet Sorghum Soil Zinc (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.1	0.2	0.2	0.2	0.5	0.6	0.6	0.3	0.5	0.6	0.2
0-5 cm	0.5	0.58C§a¶	0.66BCa	0.73BCa	0.76BCa	0.65BCa	1.37Aa	1.11ABa	0.98BCa	1.10ABCa	1.17ABa	0.75BCa
5-15 cm	0.3	0.45Ab	0.45Ab	0.60Aa	0.47Ab	0.42Aa	0.60Ab	0.53Aa	0.57Ab	0.71Aab	0.68Aa	0.68Aa
15-30 cm	0.3	0.41Bb	0.45Bb	0.54ABa	0.39Bb	0.58ABa	0.58ABb	0.54ABa	0.59ABb	0.46Bb	0.79Aa	0.54ABa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.3	0.1	0.1	0.4	0.3	0.4	0.2	0.3	0.4	0.2	0.1
0-5 cm	0.3	0.74Fa	0.72Fa	0.66Fa	0.76EFa	1.25CDa	1.10DEa	1.44BCa	1.63Ba	2.16Aa	1.56BCa	0.87EFa
5-15 cm	0.3	0.63Aa	0.63Aa	0.54Ab	0.56Aa	0.65Ab	0.70Ab	0.76Ab	0.67Ab	0.68Ab	0.58Ab	0.58Ab
15-30 cm	0.2	0.48ABa	0.47ABb	0.44ABc	0.60Aa	0.46ABb	0.42Bb	0.46ABc	0.5ABb	0.45ABb	0.47ABb	0.48ABb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.50: Results of Woods County Sweet Sorghum Soil Nickel (Melich III) (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		1.5	1.6	1.9	1.4	0.9	2.3	1.7	1.3	4.7	1.7	1.5
0-5 cm	1.4	4.0A§a¶	4.8Aa	4.2Aa	4.4Aa	4.8Aa	3.5Aa	4.8Aa	3.6Aa	4.0Aa	4.2Aa	4.6Aa
5-15 cm	2.0	5.4ABa	4.7ABa	4.1ABa	4.5ABa	4.4ABa	4.9ABa	5.0ABa	3.9ABa	5.9Aa	3.7Ba	4.5ABa
15-30 cm	1.5	4.6Aa	4.7Aa	5.1Aa	4.3ABa	4.3ABa	3.0Ba	4.4ABa	4.4ABa	4.7Aa	4.3ABa	4.4ABa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.98	0.52	0.68	0.7	0.47	0.76	0.59	0.42	0.93	0.8	0.88
0-5 cm	0.4	0.53ABa	0.42Ba	0.65ABa	0.68ABa	0.71ABa	0.67ABa	0.43Ba	0.42Ba	0.55ABa	0.56ABa	0.88Aa
5-15 cm	0.4	0.77ABa	0.83ABa	0.55ABa	0.53Ba	0.50Ba	0.90ABa	0.80ABa	0.50Ba	0.91ABa	0.58ABa	0.98Aa
15-30 cm	0.3	1.1Aa	0.77ABCa	0.89ABa	0.89ABa	0.70BCa	0.93ABa	0.56Ca	0.77ABa	0.95ABa	0.77ABCa	0.77ABCa

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.51: Results of Woods County Sweet Sorghum Soil Water Soluble Phosphorous (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		1.1	1.09	1.52	2.15	1.41	3.66	1.46	2.74	2.26	1.27	1.10
0-5 cm	2.8	5.2BC§a¶	5.6BCa	7.0ABCa	7.6ABa	5.9BCa	7.2ABCa	7.8ABa	7.5ABa	9.0Aa	5.8BCa	4.5Ca
5-15 cm	1.1	7.8CDb	3.3BCb	3.2BCDb	4.5Ab	2.2Db	3.6ABCab	4.1ABb	3.3BCb	3.4ABCb	2.5CDb	2.5CDb
15-30 cm	0.9	1.6ABc	1.9ABc	2.0ABb	1.7ABc	1.4ABb	2.2Ab	2.0ABc	1.9ABb	1.9ABb	1.6ABb	1.3Bc
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.71	0.95	2.47	2.35	1.51	2.58	0.91	1.41	1.21	2.47	0.62
0-5 cm	2.4	8.2Ea	10.9Da	12.8BCDa	14.6ABa	8.4Ea	8.3Ea	11.7CDa	13.8ABCa	15.8Aa	10.8Da	5.7Fa
5-15 cm	1.5	4.0DEFb	5.4DCb	5.5CDb	7.9Ab	3.9EFb	4.1DEFb	5.3CDEb	5.9BCb	7.1ABb	4.0DEFb	3.0Fb
15-30 cm	0.6	1.7ABc	1.9ABc	1.7ABc	2.3Ac	1.6Bc	1.7ABb	1.9ABc	1.5Bc	2.1ABc	1.7ABb	1.6Bc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.
¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.52: Results of Woods County Sweet Sorghum Soil NO_3^- (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.2	0.3	34.0	0.3	0.1	1.3	0.2	0.1	1.3	0.2	0.3
0-5 cm	2.3	0.79A§a¶	1.05Aa	1.05Aa	0.97Aa	1.05Aa	2.95Aa	1.10Aa	0.86Aa	3.03Aa	1.09Aa	1.01Aa
5-15 cm	1.6	0.71Aab	0.60Ab	0.59Ab	0.55Ab	0.59Ab	2.1Aa	0.67Ab	0.55Ab	1.6Ab	0.6Ab	0.6Ab
15-30 cm	1.5	0.56Ab	0.52Ab	0.58Ab	0.51Ab	0.50Ab	1.85Aa	0.62Ab	0.57Ab	1.65Ab	0.41Ab	0.46Ab
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.4	0.6	0.4	1.4	0.4	0.2	0.2	0.5	0.4	0.6	0.4
0-5 cm	1.0	1.97BCa	2.12BCa	2.76Ba	3.95Aa	2.07BCa	1.62Cab	2.28BCa	2.57BCa	2.11BCa	2.45BCa	1.87BCa
5-15 cm	0.4	1.59Bb	1.52Ba	2.12Ab	2.09Ab	1.61Bb	1.65Ba	1.71ABb	1.84ABb	1.73ABb	1.75ABb	1.78ABab
15-30 cm	0.3	1.36Cb	1.50BCDa	1.74ABb	1.77Ab	1.46CDb	1.46CDb	1.63ABCDb	1.61ABCDb	1.61ABCDb	1.70ABCb	1.44CDb

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N-P_2O_5-K_2O$ basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.53: Results of Woods County Sweet Sorghum Soil NH_3 (mg kg^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007												
LSD Between Depth Interaction		0.4	0.6	0.1	0.3	0.2	0.6	0.4	0.1	0.5	0.2	0.4
0-5 cm	1.3	0.66B§a¶	0.53Ba	0.51Ba	0.59Ba	0.66ABa	1.91Aa	0.51Ba	0.49Ba	1.56ABa	0.40Ba	0.56Ba
5-15 cm	1.3	0.62Aa	0.61Aa	0.48Aab	0.43Aa	0.46Aab	1.57Aa	0.37Aa	0.43Aa	1.28Aab	0.33Aa	0.52Aa
15-30 cm	1.0	0.39Aa	0.40Aa	0.38Ab	0.33Aa	0.40Ab	1.33Aa	0.52Aa	0.42Aa	0.98Ab	0.34Aa	0.36Aa
2008												
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		3.5	0.9	1.6	0.4	1.4	1.6	0.7	1.0	2.8	1.6	4.5
0-5 cm	2.3	7.0Aa	5.2Aa	5.4Aa	6.2Aa	5.0Aa	5.5Aa	4.8Aa	4.7Aa	6.3Aa	4.9Aa	6.2Aa
5-15 cm	2.6	4.9ABa	4.1Bb	4.8ABab	4.3Bb	4.8ABa	4.9ABa	4.6ABa	4.8ABa	6.2ABa	4.8ABa	6.9Aa
15-30 cm	1.3	3.92ABa	3.67ABb	3.8ABb	4.27ABb	4.13ABa	3.95ABa	3.67ABb	4.18ABa	4.09ABa	4.87Aa	3.29Ba

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.54: Results of Woods County Sweet Sorghum Soil Total Nitrogen (TN) (%)) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
						2007						
LSD Between Depth Interaction		0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.03
0-5 cm	0.01	0.04A§a¶	0.04Aa	0.05Aa	0.05Aa	0.04Aa	0.05Aa	0.05Aa	0.05Aa	0.05Aa	0.05Aa	0.05Aa
5-15 cm	0.01	0.03ABCa	0.03ABCab	0.03ABCb	0.044ABa	0.02Cb	0.04ABb	0.03BCb	0.03ABCb	0.04Aab	0.03ABCa	0.03BCa
15-30 cm	0.02	0.03Aa	0.02Ab	0.03Ab	0.03Aa	0.02Ab	0.04ABb	0.03Ab	0.03Ab	0.03Ab	0.03Aa	0.02Aa
						2008						
		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.05	0.03	0.02	0.02	0.03	0.01	0.05	0.02	0.02	0.02	0.02
0-5 cm	0.03	0.04Ba	0.04Ba	0.05ABa	0.06ABa	0.05ABa	0.04ABa	0.05ABa	0.05ABa	0.04Ba	0.07Aa	0.06ABa
5-15 cm	0.02	0.03ABa	0.05ABa	0.05ABa	0.04ABb	0.02Ba	0.04ABa	0.03ABa	0.04ABab	0.04ABa	0.04ABb	0.04ABb
15-30 cm	0.03	0.03Aa	0.02Aa	0.03Aa	0.04Ab	0.03Aa	0.03Ab	0.04Aa	0.02Ab	0.03Aa	0.03Ab	0.03Ab

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.55: Results of Woods County Sweet Sorghum Soil Total Carbon (TC) (%)) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

2007

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.2	0.14	0.07	0.08	0.16	0.08	0.16	0.06	0.14	0.13	0.18
0-5 cm	0.15	0.58A§a¶	0.68Aa	0.60Aa	0.61Aa	0.64Aa	0.72Aa	0.66Aa	0.62Aa	0.62Aa	0.65Aa	0.67Aa
5-15 cm	0.13	0.47Aab	0.36ABb	0.37ABb	0.40ABb	0.44ABb	0.40ABb	0.42ABb	0.37ABb	0.42ABb	0.35ABb	0.34Bb
15-30 cm	0.04	0.32Ab	0.31Ab	0.32Ab	0.33Ab	0.31Ab	0.32Ab	0.31Ab	031Ab	0.32Ab	0.30Ab	0.32Ab

2008

		CF-A	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
LSD Between Depth Interaction		0.33	0.06	0.08	0.23	0.03	1.13	0.35	0.05	0.21	0.14	0.06
0-5 cm	0.52	0.40Ba	0.50ABa	0.50ABa	0.63ABa	0.49ABa	0.98Aa	0.49ABa	0.56ABa	0.46Ba	0.61ABa	0.49ABa
5-15 cm	0.13	0.50Aa	0.40ABb	0.42ABa	0.39ABb	0.36Bb	0.42ABa	0.34Ba	0.38ABb	0.42ABa	0.36Bb	0.36Bb
15-30 cm	0.08	0.27ABa	0.27ABc	0.29ABb	0.27ABb	0.29ABc	0.27ABa	0.35Aa	0.28ABc	0.32Aa	0.24Bb	0.29ABc

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on $N\text{-}P_2O_5\text{-}K_2O$ basis as A=40-40-30, B=80-80-60, C=120-120-90 D=160-160-120 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

¶Means followed by the same lower case letters are not significantly different at the 0.05 alpha level between depths.

Table A.56: Results of Haskell Bermudagrass Soil Aggregate Stability after 3 Years of Amendment with Commercial Fertilizer or Poultry Litter.

	LSD Between Treatments	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
>4mm	8.3	22.2BC¶	20.8BC	28.2AB	19.6C	22.6ABC	24.0ABC	24.3ABC	17.8C	31.2A	23.4ABC	21.0BC
2-4mm	4.0	19.8AB	20.3AB	21.0AB	19.4AB	21.0AB	19.9AB	21.2AB	17.7B	22.0A	20.4AB	18.6AB
1-2mm	2.7	15.7A	15.3A	14.7A	15.2A	17.0A	15.9A	15.3A	15.4A	14.6A	14.7A	16.3A
0.5-1mm	3.0	12.2A	11.5AB	10.6AB	11.4AB	11.5AB	11.4AB	10.7AB	11.6AB	9.2B	10.5AB	12.2AB
0.25-0.5	3.0	8.3ABC	8.4ABC	6.9BC	9.3AB	7.5BC	7.7BC	9.2AB	10.8A	5.9C	8.4ABC	8.4ABC
<0.25	6.1	21.3ABCD	23.8ABC	18.6CD	25.0AB	19.4BCD	21.5ABCD	19.4BCD	26.7A	17.1D	22.6ABCD	23.5ABC
Sum of First Three	9.0	57.7BCD	56.3BCD	63.9AB	54.3CD	61.6ABC	59.7ABCD	60.8ABC	50.9D	67.8A	58.5BCD	55.9BCD
GMD§	0.3	1.1BC	1.1BC	1.2AB	1.0BC	1.3AB	1.2BC	1.3AB	0.9C	1.6A	1.1BC	1.07BC

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§ Geometric Mean Diameter

¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table A.57: Results of Haskell Sweet Sorghum Soil Aggregate Stability after 3 Years of Amendment with Commercial Fertilizer or Poultry Litter.

	LSD Between Treatments	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
>4mm	8.3	4.49AB	3.69B	3.31B	3.48B	7.85AB	5.85AB	10.28A	6.11AB	6.74AB	5.27AB	5.21AB
2-4mm	4.0	6.33AB	5.24B	5.72AB	6.28AB	7.61AB	6.64AB	7.92A	6.81AB	8.21A	8.03A	6.79AB
1-2mm	2.7	7.48AB	6.88AB	7.32AB	7.77AB	8.03AB	7.72AB	8.52AB	8.21AB	8.79A	6.55B	7.83AB
0.5-1mm	3.0	10.36B	10.01B	10.28B	10.42B	12.06AB	14.29A	12.16AB	12.10AB	13.21AB	11.26AB	12.60AB
0.25-0.5	3.0	18.18A	18.11A	17.74A	17.44A	19.70A	20.53A	18.67A	18.45A	19.43A	19.16A	19.82A
<0.25	6.1	53.15ABC	56.07A	55.63AB	54.61ABC	44.75D	44.98D	42.45D	48.30BCD	43.60D	49.74ABCD	47.77CD
Sum of First Three	9.0	18.31B	15.81B	16.35B	17.54B	23.49AB	20.2AB	26.73A	21.13AB	23.775AB	19.83AB	19.83AB
GMD§	0.3	0.33BC	0.30C	0.30C	0.31C	0.41AB	0.39ABC	0.46A	0.38ABC	0.42AB	0.35BC	0.36ABC

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§ Geometric Mean Diameter

¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table A.58: Results of Haskell Bermudagrass Soil Bulk Density (cm g^{-1}) after 3 Years of Amendment with Commercial Fertilizer or Poultry Litter.

	LSD Between Treatments	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
Bulk Density	0.08	1.20AB	1.20AB	1.23A	1.20AB	1.13B	1.15AB	1.15AB	1.15AB	1.18AB	1.13B	1.15AB

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§ Geometric Mean Diameter

¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table A.59: Results of Haskell Bermudagrass Soil Bulk Density (cm g^{-1}) after 3 Years of Amendment with Commercial Fertilizer or Poultry Litter.

	LSD Between Treatments	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
Bulk Density	0.06	1.33A	1.35A	1.32A	1.30A	1.36A	1.33A	1.32A	1.30A	1.35A	1.37A	1.23A

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§ Geometric Mean Diameter
¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table A.60: Nutrients Added to Haskell Bermudagrass from 2007-2009 with Amendments of Commercial Fertilizer or Poultry Litter.

2007

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF†-A‡	73.8	-	-	-	-	36.2	-	61.0	-	-	-	-	-	-	-	-	-
CF-B	147.6	-	-	-	-	72.5	-	122.0	-	-	-	-	-	-	-	-	-
CF-C	221.3	-	-	-	-	108.7	-	183.1	-	-	-	-	-	-	-	-	-
CF-D	296.3	-	-	-	-	145.6	-	245.1	-	-	-	-	-	-	-	-	-
NL-A	73.8	694.9	11.9	4.2	5.7	36.2	67.5	61.0	14.9	22.4	15.2	0.9	0.9	0.6	1.3	0.0	1011.4
NL-B	147.6	1389.8	23.9	8.3	11.3	72.5	135.1	122.0	29.7	44.9	30.4	1.8	1.7	1.2	2.6	0.1	2022.8
NL-C	221.3	2084.8	35.8	12.5	17.0	108.7	202.6	183.1	44.6	67.3	45.6	2.6	2.6	1.8	3.9	0.1	3034.2
NL-D	296.3	2790.7	47.9	16.7	22.7	145.6	271.2	245.1	59.7	90.1	61.0	3.5	3.5	2.4	5.2	0.2	4061.6
CNL	245.1	2044.2	50.2	2.2	29.3	132.2	290.8	226.8	46.9	60.6	94.0	20.0	3.8	4.0	5.8	0.1	3256.2
CAL	237.0	1955.9	82.1	1.7	11.3	114.8	225.5	203.9	39.4	52.1	178.9	4.2	3.1	3.2	4.1	0.1	3117.4

2008

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	67.1	-	-	-	-	29.0	-	51.2	-	-	-	-	-	-	-	-	-
CF-B	134.3	-	-	-	-	58.0	-	102.3	-	-	-	-	-	-	-	-	-
CF-C	200.3	-	-	-	-	86.6	-	152.6	-	-	-	-	-	-	-	-	-
CF-D	267.5	-	-	-	-	115.6	-	203.8	-	-	-	-	-	-	-	-	-
NL-A	67.1	626.2	12.7	3.0	5.0	29.0	51.9	51.2	11.4	18.3	16.0	0.5	0.8	0.5	1.2	0.0	894.8
NL-B	134.3	1252.4	25.4	6.0	10.1	58.0	103.7	102.3	22.8	36.6	32.0	1.0	1.7	1.0	2.4	0.0	1789.6
NL-C	200.3	1868.3	37.8	9.0	15.1	86.6	154.7	152.6	34.0	54.6	47.7	1.4	2.5	1.5	3.5	0.1	2669.7
NL-D	267.5	2494.6	50.5	12.0	20.1	115.6	206.6	203.8	45.4	72.9	63.7	1.9	3.3	2.0	4.7	0.1	3564.5
CNL	203.8	1930.1	34.2	1.9	21.8	88.7	165.7	186.0	40.2	65.2	58.2	1.6	2.7	1.6	3.7	0.1	2805.4
CAL	231.3	1796.4	65.6	4.6	12.1	88.7	169.6	173.8	38.6	61.6	148.6	2.5	2.8	1.7	3.9	0.1	2801.7

2009

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	62.8	-	-	-	-	24.4	-	48.2	-	-	-	-	-	-	-	-	-
CF-B	126.5	-	-	-	-	49.1	-	97.1	-	-	-	-	-	-	-	-	-
CF-C	189.3	-	-	-	-	73.5	-	145.3	-	-	-	-	-	-	-	-	-
CF-D	253.1	-	-	-	-	98.3	-	194.3	-	-	-	-	-	-	-	-	-
NL-A	62.8	477.9	10.7	1.8	2.5	24.4	42.3	48.2	10.6	14.1	12.9	1.3	0.6	0.4	1.3	0.0	711.8
NL-B	126.5	963.5	21.6	3.7	5.0	49.1	85.2	97.1	21.4	28.4	26.1	2.7	1.2	0.8	2.7	0.0	1435.2
NL-C	189.3	1441.4	32.4	5.5	7.5	73.5	127.5	145.3	32.1	42.5	39.0	4.0	1.9	1.2	4.0	0.1	2147.0
NL-D	253.1	1927.0	43.3	7.3	10.1	98.3	170.4	194.3	42.9	56.9	52.1	5.3	2.5	1.6	5.3	0.1	2870.3
CNL	199.9	1489.7	33.2	0.7	14.5	106.5	180.2	201.1	45.7	59.1	54.0	15.2	2.8	1.9	5.8	0.1	2410.2
CAL	215.5	1348.2	77.1	0.9	6.9	107.0	183.3	229.2	44.9	63.3	177.3	11.6	2.6	1.6	5.2	0.1	2474.8

Total Nutrients Applied 2007-2009

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	203.7	-	-	-	-	89.6	-	160.4	-	-	-	-	-	-	-	-	-
CF-B	408.4	-	-	-	-	179.6	-	321.5	-	-	-	-	-	-	-	-	-
CF-C	611.0	-	-	-	-	268.8	-	481.0	-	-	-	-	-	-	-	-	-
CF-D	816.8	-	-	-	-	359.4	-	643.1	-	-	-	-	-	-	-	-	-
NL-A	203.7	1799.0	35.3	9.0	13.2	89.6	161.6	160.4	36.9	54.8	44.1	2.7	2.3	1.5	3.8	0.08	2618.0
NL-B	408.4	3605.8	70.8	18.0	26.4	179.6	324.0	321.5	74.0	109.9	88.4	5.4	4.6	3.0	7.6	0.16	5247.6
NL-C	611.0	5394.5	106.0	27.0	39.5	268.8	484.8	481.0	110.7	164.4	132.2	8.0	6.9	4.5	11.4	0.23	7850.9
NL-D	816.8	7212.3	141.7	36.1	52.9	359.4	648.2	643.1	148.0	219.8	176.7	10.7	9.3	6.0	15.3	0.31	10496.5
CNL	648.8	5464.0	117.6	4.8	65.6	327.4	636.7	613.8	132.8	184.9	206.1	36.8	9.3	7.5	15.3	0.26	8471.8
CAL	683.8	5100.5	224.8	7.2	30.3	310.5	578.4	606.9	122.9	177.0	504.8	18.2	8.5	6.5	13.2	0.23	8393.8

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

Table A.61: Nutrients Added to Sweet Sorghum Trials from 2007-2009 with Amendments of Commercial Fertilizer or Poultry Litter.

2007

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF†-A‡	49.2	-	-	-	-	24.2	-	40.7	-	-	-	-	-	-	-	-	-
CF-B	98.4	-	-	-	-	48.3	-	81.4	-	-	-	-	-	-	-	-	-
CF-C	147.6	-	-	-	-	72.5	-	122.0	-	-	-	-	-	-	-	-	-
CF-D	196.7	-	-	-	-	96.7	-	162.7	-	-	-	-	-	-	-	-	-
NL-A	49.2	463.3	8.0	2.8	3.8	24.2	45.0	40.7	9.9	15.0	10.1	0.6	0.6	0.4	0.9	0.0	674.3
NL-B	98.4	926.6	15.9	5.5	7.5	48.3	90.0	81.4	19.8	29.9	20.2	1.2	1.1	0.8	1.7	0.1	1348.5
NL-C	147.6	1389.8	23.9	8.3	11.3	72.5	135.1	122.0	29.7	44.9	30.4	1.8	1.7	1.2	2.6	0.1	2022.8
NL-D	196.7	1853.1	31.8	11.1	15.1	96.7	180.1	162.7	39.7	59.8	40.5	2.3	2.3	1.6	3.5	0.1	2697.0
CNL	163.0	1359.7	33.4	1.5	19.5	88.0	193.5	150.8	31.2	40.3	62.5	13.3	2.5	2.7	3.9	0.1	2165.9
CAL	158.7	1310.1	55.0	1.1	7.6	76.9	151.1	136.6	26.4	34.9	119.8	2.8	2.1	2.1	2.7	0.0	2088.0

2008

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	44.6	-	-	-	-	19.3	-	34.0	-	-	-	-	-	-	-	-	-
CF-B	89.2	-	-	-	-	38.5	-	67.9	-	-	-	-	-	-	-	-	-
CF-C	133.8	-	-	-	-	57.8	-	102.0	-	-	-	-	-	-	-	-	-
CF-D	178.5	-	-	-	-	77.1	-	136.0	-	-	-	-	-	-	-	-	-
NL-A	44.6	415.8	8.4	2.0	3.4	19.3	34.4	34.0	7.6	12.1	10.6	0.3	0.6	0.3	0.8	0.0	594.1
NL-B	89.2	831.5	16.8	4.0	6.7	38.5	68.9	67.9	15.1	24.3	21.2	0.6	1.1	0.7	1.6	0.0	1188.2
NL-C	133.8	1248.3	25.3	6.0	10.1	57.8	103.4	102.0	22.7	36.5	31.9	0.9	1.7	1.0	2.4	0.0	1783.7
NL-D	178.5	1665.1	33.7	8.0	13.4	77.1	137.9	136.0	30.3	48.6	42.5	1.3	2.2	1.3	3.2	0.1	2379.3
CNL	135.5	1283.3	22.7	1.3	14.5	59.0	110.2	123.7	26.7	43.4	38.7	1.1	1.8	1.0	2.5	0.0	1865.2
CAL	153.8	1194.5	43.6	3.0	8.0	59.0	112.8	115.6	25.6	40.9	98.8	1.6	1.9	1.1	2.6	0.0	1862.9

2009

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	42.5	-	-	-	-	16.5	-	32.6	-	-	-	-	-	-	-	-	-
CF-B	84.0	-	-	-	-	32.6	-	64.5	-	-	-	-	-	-	-	-	-
CF-C	126.5	-	-	-	-	49.1	-	97.1	-	-	-	-	-	-	-	-	-
CF-D	169.0	-	-	-	-	65.6	-	129.8	-	-	-	-	-	-	-	-	-
NL-A	42.5	323.7	7.3	1.2	1.7	16.5	28.6	32.6	7.2	9.6	8.8	0.9	0.4	0.3	0.9	0.0	482.2
NL-B	84.0	639.8	14.4	2.4	3.3	32.6	56.6	64.5	14.2	18.9	17.3	1.8	0.8	0.5	1.8	0.0	952.9
NL-C	126.5	963.5	21.6	3.7	5.0	49.1	85.2	97.1	21.4	28.4	26.1	2.7	1.2	0.8	2.7	0.0	1435.2
NL-D	169.0	1287.3	28.9	4.9	6.7	65.6	113.8	129.8	28.6	38.0	34.8	3.5	1.7	1.1	3.6	0.1	1917.4
CNL	133.3	993.1	22.1	0.4	9.7	71.0	120.1	134.1	30.4	39.4	36.0	10.1	1.9	1.3	3.9	0.1	1606.8
CAL	143.7	898.8	51.4	0.6	4.6	71.3	122.2	152.8	29.9	42.2	118.2	7.7	1.7	1.1	3.5	0.1	1649.9

Total Nutrients Applied 2007-2009

	TN	TC	NH4	NO3	WSP	P	Ca	K	Mg	Na	S	Fe	Zn	Cu	Mn	Ni	Total Wt.
									kg ha^{-1}								
CF-A	136.3	-	-	-	-	59.9	-	107.3	-	-	-	-	-	-	-	-	-
CF-B	271.5	-	-	-	-	119.5	-	213.8	-	-	-	-	-	-	-	-	-
CF-C	407.9	-	-	-	-	179.5	-	321.2	-	-	-	-	-	-	-	-	-
CF-D	544.3	-	-	-	-	239.4	-	428.5	-	-	-	-	-	-	-	-	-
NL-A	136.3	1202.8	23.6	6.0	8.8	59.9	108.1	107.3	24.7	36.7	29.5	1.8	1.5	1.0	2.5	0.05	1750.6
NL-B	271.5	2397.9	47.1	12.0	17.6	119.5	215.5	213.8	49.2	73.1	58.8	3.6	3.1	2.0	5.1	0.10	3489.7
NL-C	407.9	3601.7	70.8	18.0	26.4	179.5	323.6	321.2	73.9	109.8	88.3	5.4	4.6	3.0	7.6	0.16	5241.7
NL-D	544.3	4805.5	94.4	24.0	35.2	239.4	431.8	428.5	98.6	146.4	117.8	7.1	6.2	4.0	10.2	0.21	6993.7
CNL	431.8	3636.1	78.3	3.2	43.7	217.9	423.8	408.6	88.4	123.0	137.2	24.5	6.2	5.0	10.2	0.18	5637.9
CAL	456.2	3403.3	150.0	4.8	20.2	207.2	386.0	405.0	82.0	118.0	336.9	12.2	5.7	4.4	8.8	0.15	5600.8

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

APPENDIX B

Plant biomass and nutrient removal of sweet sorghum and bermudagrass plots amended with poultry litter and commercial fertilizers over 3 year in Haskell, OK at the Eastern Oklahoma Research Station and 2 years at a private farm in Woods County, OK near Aline, OK (sweet sorghum only). Plant nutrients analyzed by Soil, Water and Forage Analytical Laboratory, Oklahoma State University, OK.

Table B.1: Results of Haskell Bermudagrass Biomass Yield (Mg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	2.6	9.4DE§	11.5BCD	11.6BCD	14.1AB	8.0EF	10.1DE	12.7ABC	14.4A	11.7CD	13.4ABC	6.7F
2008	1.9	8.3CD	10.0BC	12.4A	11.6AB	5.8EF	7.2DE	8.9CD	9.5C	8.7CD	10.0BC	5.0F
2009	1.1	4.7EFG	6.8CD	7.9B	9.1AA	3.6HI	4.3GH	5.6EF	7.4C	5.1EFG	6.0DE	2.7I

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.

‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.

§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.2: Results of Haskell Bermudagrass Nutrient Removal (kg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

Total Nitrogen§

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	30.1	107.73EF¶	139.07CD	150.65BCD	206.05A	92.47FG	122.44DEF	155.14BC	172.04B	123.42DE	154.31BC	76.84G
2008	28.2	112.69E	149.52BC	177.06AB	186.08A	79.49F	112.15E	117.65DE	143.42DC	132.79CDE	130.56CDE	69.22F
2009	22.8	79.32FG	113.75CD	139.32AB	160.94A	62.62GH	78.23FG	95.50DEF	131.31BC	90.26EF	106.73DE	45.90H
Total Removal (3 yr.)		299.7	402.3	467.0	553.1	234.6	312.8	368.3	446.8	346.5	391.6	192.0

Total Carbon

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1173.5	4288.9DE	5264.6CD	5240.6CD	6440.9AB	3595.8EF	4585.1DE	5792.4ABC	6532.2A	5342.6BCD	6109.8ABC	3059.0F
2008	729.3	3671.7CD	4553.7B	566.8A	5312.4A	2626.9E	3390.7D	4058.7BCD	4400.6BC	3882.8BCD	3955.6BCD	2201.5E
2009	504.3	2184.3FGH	3087.7CD	3683.3B	4197.8A	1694.3HI	2011.0GF	2584.2EDF	3452.8BC	2336.8EFG	2770.8DE	1239.1I
Total Removal (3 yr.)		10144.9	12906.0	9490.7	15951.1	7917.0	9986.8	12435.3	14385.6	11562.2	12836.2	6499.6

Phosphorous

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	6.19	19.14EF	24.48CDE	28.61ABC	33.42A	16.82FG	21.91DEF	30.46ABC	32.49A	25.84BCD	31.28AB	12.30G
2008	4.81	22.66DE	26.54CD	35.01A	32.65AB	15.39F	20.86E	24.41CDE	28.30BC	23.13DE	24.68CDE	12.01F
2009	5.75	10.86EFG	16.72CD	23.67AB	28.47A	9.67FG	11.66DEFG	14.18DEF	21.98BC	12.74DEFG	15.68DE	7.62G
Total Removal (3 yr.)		52.7	67.7	87.3	94.5	41.9	54.4	69.1	82.8	61.7	71.6	31.9

Calcium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	14.05	39.56CDE	50.99ABCD	51.16ABC	55.71AB	38.02DE	38.02DE	62.61A	57.78AB	45.64BCDE	53.56ABC	34.86E
2008	11.58	43.57CD	51.59ABC	61.97A	57.27AB	31.67EF	36.78DE	46.08BCD	51.25ABC	46.08BCD	42.05CDE	24.91F
2009	15.21	24.82DEF	45.62AB	40.48BC	57.22A	16.84EF	21.57DEF	32.30BCD	40.99BC	27.20CDEF	31.88BCDE	12.83F
Total Removal (3 yr.)		108.0	148.2	153.6	170.2	86.5	96.4	141.0	150.0	118.9	127.5	72.6

Potassium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	38.85	120.02FG	160.77E	170.10DE	212.70BC	108.43G	156.83EF	203.86BCD	253.04A	192.76CDE	240.20AB	83.96G
2008	32.39	133.14BC	150.18BC	215.20A	201.52A	88.30D	123.61C	140.81BC	165.33B	137.16BC	150.97BC	70.04D
2009	25.39	63.31BCD	82.32B	127.72A	132.59A	52.68CD	66.65BC	67.56BC	120.03A	64.87BC	86.83B	38.78D
Total Removal (3 yr.)		316.5	393.3	513.0	546.8	249.4	347.1	412.2	538.4	394.8	478.0	192.8

Magnesium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	10.46	31.62DEF	38.69ABCDE	35.58BCDE	41.88ABCD	28.89EF	33.33CDEF	45.58ABC	46.75A	34.76CDE	45.38AB	24.18F
2008	5.81	32.71CD	35.89BC	45.76A	40.11AB	21.92EF	27.29DE	31.76CD	33.96C	30.66CD	30.52CD	18.25F
2009	6.14	14.63DEF	23.60BC	25.55AB	30.42A	9.79FG	13.11EFG	18.21CDE	25.59BCD	14.61DEF	19.92BCD	7.94G

Total Removal (3 yr.)	79.0	98.2	106.9	112.4	60.6	73.7	95.6	106.3	80.0	95.8	50.4

Sodium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	2.86	4.55BC	4.1BCD	4.74BC	10.63A	2.62CD	4.04BCD	5.76B	5.66B	3.57BCD	4.79BC	1.57D
2008	2.99	8.86CD	11.39BC	13.96AB	15.28A	5.20E	7.51DE	9.40CD	13.29AB	9.01CD	9.08CD	4.84E
2009	3.74	3.51CD	4.90CD	3.25CD	9.73A	3.35CD	2.90CD	6.63ABC	5.63BD	8.67AB	5.03BCD	2.36D
Total Removal (3 yr.)		16.9	20.4	22.0	35.6	11.2	14.5	21.8	24.6	21.3	18.9	8.8

Sulfur

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	4.6	17.38EF	19.34DE	19.73DE	26.09BC	16.27EF	22.01DC	27.86B	28.72B	27.86B	34.29A	13.16F
2008	5.22	20.32EF	20.82EDF	34.46A	27.09BC	15.94FG	21.63DE	24.09BCDE	29.55AB	22.02CDE	25.69BCD	11.89G

2009	5.02	10.66BCDE	14.71BC	22.65A	22.67A	9.13DE	10.83BCDE	13.24BCD	22.16A	9.91CDE	15.65B	6.76E
Total Removal (3 yr.)		48.4	54.9	76.8	75.9	41.3	54.5	65.2	80.4	59.8	75.6	31.8

<u>Iron</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.01	2.03CD	2.84ABC	1.95CD	3.71A	2.08CD	2.43BCD	2.99ABC	3.17AB	2.34BCD	2.5BCD	1.55D
2008	0.94	1.55ABC	1.94ABC	2.24A	2.04AB	1.00BC	1.2BC	1.67ABC	1.81ABC	2.11AB	1.22ABC	1.00BC
2009	0.75	0.85BCD	2.06A	1.55AB	2.02A	0.54D	0.65D	0.73CD	1.42ABC	0.69D	0.87BCD	0.47D
Total Removal (3 yr.)		4.4	6.8	5.7	7.8	3.6	4.3	5.4	6.4	5.1	4.6	3.0

<u>Zinc</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.08	0.24E	0.33D	0.34CD	0.44A	0.24E	0.32D	0.44AB	0.45A	0.37BCD	0.41ABC	0.18E
2008	0.11	0.29BC	0.28BCD	0.43A	0.33ABC	0.19DE	0.26CDE	0.29BCD	0.33ABC	0.27BCD	0.28BCD	0.16E

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2009	0.13	0.15CD	0.22BCD	0.29AB	0.40A	0.11D	0.14CD	0.17BCD	0.25BC	0.14CD	0.18BCD	0.10D
Total Removal (3 yr.)		0.7	0.8	1.1	1.2	0.5	0.7	0.9	1.0	0.8	0.9	0.4

Copper

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.02	0.07D	0.11BC	0.11BC	0.13ABC	0.07D	0.11C	0.14A	0.14A	0.13AB	0.13ABC	0.05D
2008	0.17	0.40CDE	0.64AB	0.68A	0.56ABC	0.25EF	0.36EDF	0.38EDF	0.48BCD	0.43CD	0.40CDE	0.22F
2009	0.03	0.056CD	0.08B	0.11A	0.09AB	0.04D	0.05CD	0.07BC	0.09A	0.05CD	0.07BC	0.04D
Total Removal (3 yr.)		0.5	0.8	0.9	0.8	0.4	0.5	0.6	0.7	0.6	0.6	0.3

Manganese

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.42	3.63CD	4.58BC	4.41BC	6.45A	2.34DE	3.39CDE	3.32CDE	4.04BC	3.76D	5.27AB	2.04E
2008	1.77	3.01BC	2.86BC	5.83A	5.34A	2.35C	2.77BC	4.49AB	3.20BC	2.54C	3.13BC	1.56C

2009	0.51	1.15D	1.23CD	2.25A	2.36A	0.87DE	1.08DE	1.69BC	1.97AB	0.97DE	1.90AB	0.64E
Total Removal (3 yr.)		7.8	8.7	12.5	14.2	5.6	7.2	9.5	9.2	7.3	10.3	4.2

						Nickel						
	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.043	0.046C	0.052BC	0.063BC	0.091AB	0.057BC	0.061BC	0.081ABC	0.113A	0.042C	0.054BC	0.046BC
2008	0.004	0.006AB	0.004AB	0.008AB	0.007AB	0.005AB	0.003B	0.007AB	0.006AB	0.004AB	0.004AB	0.004AB
2009	0.180	0.12C	0.47A	0.31AB	0.23BC	0.18BC	0.18BC	0.31AB	0.16BC	0.28BC	0.25BC	0.15BC
Total Removal (3 yr.)		0.2	0.5	0.4	0.3	0.2	0.2	0.4	0.3	0.3	0.3	0.2

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§ Total Carbon and Nitrogen (LECO). Other nutrients total acid digestion.
¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.3: Results of Haskell Sweet Sorghum Biomass Yield (Mg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	3.4	10.3AB§	11.7AB	10.9AB	12.3AB	10.9AB	10.1AB	9.1D	12.5AB	13.3A	11.5AB	9.6B
2008	7.2	13.8ED	21.6BC	27.0AB	29.7A	10.3EF	18.0CD	20.8BCD	22.1BC	18.5CD	15.6CDE	5.7F
2009	4.5	11.8BC	10.3BCD	14.5AB	17.1A	11.7BC	9.8CD	14.6AB	13.3ABC	9.9CD	12.1BC	6.3D

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.4: Results of Haskell Sweet Sorghum Nutrient Removal (kg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

Total Nitrogen§

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	30.1	107.73EF¶	139.07CD	150.65BCD	206.05A	92.47FG	122.44DEF	155.14BC	172.04B	123.42DE	154.31BC	76.84G
2008	28.2	112.69E	149.52BC	177.06AB	186.08A	79.49F	112.15E	117.65DE	143.42DC	132.79CDE	130.56CDE	69.22F
2009	22.8	79.32FG	113.75CD	139.32AB	160.94A	62.62GH	78.23FG	95.50DEF	131.31BC	90.26EF	106.73DE	45.90H
Total Removal (3 yr.)		299.7	402.3	467.0	553.1	234.6	312.8	368.3	446.8	346.5	391.6	192.0

Total Carbon

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1173.5	4288.9DE	5264.6CD	5240.6CD	6440.9AB	3595.8EF	4585.1DE	5792.4ABC	6532.2A	5342.6BCD	6109.8ABC	3059.0F
2008	729.3	3671.7CD	4553.7B	566.8A	5312.4A	2626.9E	3390.7D	4058.7BCD	4400.6BC	3882.8BCD	3955.6BCD	2201.5E
2009	504.3	2184.3FGH	3087.7CD	3683.3B	4197.8A	1694.3HI	2011.0GF	2584.2EDF	3452.8BC	2336.8EFG	2770.8DE	1239.1I
Total Removal (3 yr.)		10144.9	12906.0	9490.7	15951.1	7917.0	9986.8	12435.3	14385.6	11562.2	12836.2	6499.6

Phosphorous

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	6.19	19.14EF	24.48CDE	28.61ABC	33.42A	16.82FG	21.91DEF	30.46ABC	32.49A	25.84BCD	31.28AB	12.30G
2008	4.81	22.66DE	26.54CD	35.01A	32.65AB	15.39F	20.86E	24.41CDE	28.30BC	23.13DE	24.68CDE	12.01F
2009	5.75	10.86EFG	16.72CD	23.67AB	28.47A	9.67FG	11.66DEFG	14.18DEF	21.98BC	12.74DEFG	15.68DE	7.62G
Total Removal (3 yr.)		52.7	67.7	87.3	94.5	41.9	54.4	69.1	82.8	61.7	71.6	31.9

Calcium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	14.05	39.56CDE	50.99ABCD	51.16ABC	55.71AB	38.02DE	38.02DE	62.61A	57.78AB	45.64BCDE	53.56ABC	34.86E
2008	11.58	43.57CD	51.59ABC	61.97A	57.27AB	31.67EF	36.78DE	46.08BCD	51.25ABC	46.08BCD	42.05CDE	24.91F
2009	15.21	24.82DEF	45.62AB	40.48BC	57.22A	16.84EF	21.57DEF	32.30BCD	40.99BC	27.20CDEF	31.88BCDE	12.83F
Total Removal (3 yr.)		108.0	148.2	153.6	170.2	86.5	96.4	141.0	150.0	118.9	127.5	72.6

Potassium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	38.85	120.02FG	160.77E	170.10DE	212.70BC	108.43G	156.83EF	203.86BCD	253.04A	192.76CDE	240.20AB	83.96G
2008	32.39	133.14BC	150.18BC	215.20A	201.52A	88.30D	123.61C	140.81BC	165.33B	137.16BC	150.97BC	70.04D
2009	25.39	63.31BCD	82.32B	127.72A	132.59A	52.68CD	66.65BC	67.56BC	120.03A	64.87BC	86.83B	38.78D
Total Removal (3 yr.)		316.5	393.3	513.0	546.8	249.4	347.1	412.2	538.4	394.8	478.0	192.8

Magnesium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	10.46	31.62DEF	38.69ABCDE	35.58BCDE	41.88ABCD	28.89EF	33.33CDEF	45.58ABC	46.75A	34.76CDE	45.38AB	24.18F
2008	5.81	32.71CD	35.89BC	45.76A	40.11AB	21.92EF	27.29DE	31.76CD	33.96C	30.66CD	30.52CD	18.25F
2009	6.14	14.63DEF	23.60BC	25.55AB	30.42A	9.79FG	13.11EFG	18.21CDE	25.59BCD	14.61DEF	19.92BCD	7.94G

Total Removal (3 yr.)	79.0	98.2	106.9	112.4	60.6	73.7	95.6	106.3	80.0	95.8	50.4

<u>Sodium</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	2.86	4.55BC	4.1BCD	4.74BC	10.63A	2.62CD	4.04BCD	5.76B	5.66B	3.57BCD	4.79BC	1.57D
2008	2.99	8.86CD	11.39BC	13.96AB	15.28A	5.20E	7.51DE	9.40CD	13.29AB	9.01CD	9.08CD	4.84E
2009	3.74	3.51CD	4.90CD	3.25CD	9.73A	3.35CD	2.90CD	6.63ABC	5.63BD	8.67AB	5.03BCD	2.36D
Total Removal (3 yr.)		16.9	20.4	22.0	35.6	11.2	14.5	21.8	24.6	21.3	18.9	8.8

<u>Sulfur</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	4.6	17.38EF	19.34DE	19.73DE	26.09BC	16.27EF	22.01DC	27.86B	28.72B	27.86B	34.29A	13.16F
2008	5.22	20.32EF	20.82EDF	34.46A	27.09BC	15.94FG	21.63DE	24.09BCDE	29.55AB	22.02CDE	25.69BCD	11.89G

2009	5.02	10.66BCDE	14.71BC	22.65A	22.67A	9.13DE	10.83BCDE	13.24BCD	22.16A	9.91CDE	15.65B	6.76E
Total Removal (3 yr.)		48.4	54.9	76.8	75.9	41.3	54.5	65.2	80.4	59.8	75.6	31.8

Iron

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.01	2.03CD	2.84ABC	1.95CD	3.71A	2.08CD	2.43BCD	2.99ABC	3.17AB	2.34BCD	2.5BCD	1.55D
2008	0.94	1.55ABC	1.94ABC	2.24A	2.04AB	1.00BC	1.2BC	1.67ABC	1.81ABC	2.11AB	1.22ABC	1.00BC
2009	0.75	0.85BCD	2.06A	1.55AB	2.02A	0.54D	0.65D	0.73CD	1.42ABC	0.69D	0.87BCD	0.47D
Total Removal (3 yr.)		4.4	6.8	5.7	7.8	3.6	4.3	5.4	6.4	5.1	4.6	3.0

Zinc

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.08	0.24E	0.33D	0.34CD	0.44A	0.24E	0.32D	0.44AB	0.45A	0.37BCD	0.41ABC	0.18E
2008	0.11	0.29BC	0.28BCD	0.43A	0.33ABC	0.19DE	0.26CDE	0.29BCD	0.33ABC	0.27BCD	0.28BCD	0.16E

2009	0.13	0.15CD	0.22BCD	0.29AB	0.40A	0.11D	0.14CD	0.17BCD	0.25BC	0.14CD	0.18BCD	0.10D
Total Removal (3 yr.)		0.7	0.8	1.1	1.2	0.5	0.7	0.9	1.0	0.8	0.9	0.4

Copper

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.02	0.07D	0.11BC	0.11BC	0.13ABC	0.07D	0.11C	0.14A	0.14A	0.13AB	0.13ABC	0.05D
2008	0.17	0.40CDE	0.64AB	0.68A	0.56ABC	0.25EF	0.36EDF	0.38EDF	0.48BCD	0.43CD	0.40CDE	0.22F
2009	0.03	0.056CD	0.08B	0.11A	0.09AB	0.04D	0.05CD	0.07BC	0.09A	0.05CD	0.07BC	0.04D
Total Removal (3 yr.)		0.5	0.8	0.9	0.8	0.4	0.5	0.6	0.7	0.6	0.6	0.3

Manganese

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.42	3.63CD	4.58BC	4.41BC	6.45A	2.34DE	3.39CDE	3.32CDE	4.04BC	3.76D	5.27AB	2.04E
2008	1.77	3.01BC	2.86BC	5.83A	5.34A	2.35C	2.77BC	4.49AB	3.20BC	2.54C	3.13BC	1.56C

2009	0.51	1.15D	1.23CD	2.25A	2.36A	0.87DE	1.08DE	1.69BC	1.97AB	0.97DE	1.90AB	0.64E
Total Removal (3 yr.)		7.8	8.7	12.5	14.2	5.6	7.2	9.5	9.2	7.3	10.3	4.2

Nickel

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.043	0.046C	0.052BC	0.063BC	0.091AB	0.057BC	0.061BC	0.081ABC	0.113A	0.042C	0.054BC	0.046BC
2008	0.004	0.006AB	0.004AB	0.008AB	0.007AB	0.005AB	0.003B	0.007AB	0.006AB	0.004AB	0.004AB	0.004AB
2009	0.180	0.12C	0.47A	0.31AB	0.23BC	0.18BC	0.18BC	0.31AB	0.16BC	0.28BC	0.25BC	0.15BC
Total Removal (3 yr.)		0.2	0.5	0.4	0.3	0.2	0.2	0.4	0.3	0.3	0.3	0.2

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§ Total Carbon and Nitrogen (LECO). Other nutrients total acid digestion.
¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.5: Results of Woods County Sweet Sorghum Biomass Yield (Mg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.8	5.5CD§	6.4ABCD	7.4AB	7.9A	4.87D	5.5CD	6.0BCD	6.8ABC	7.1ABC	7.34BC	4.8D

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.6: Results of 2007 Woods County Sweet Sorghum Biomass Nutrient Removal (kg ha^{-1}) Treated with Commercial Fertilizer or Poultry Litter.

		2007									
	LSD Between Treatments	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL
Total Nitrogen§	35.76	52.28BC¶	53.45BC	86.07AB	94.06A	48.66C	47.84C	54.64BC	59.31ABC	50.14C	68.34ABC
Total Carbon	838.89	2538.0CD	2964.7ABCD	3431.5AB	3643.4A	2204.7D	2524.6CD	2756.2BCD	3125.1ABC	3314.5ABC	3377.8AB
Phosphorous	6.63	13.04BC	13.49BC	18.29AB	20.33A	9.93C	12.57BC	15.12ABC	16.87AB	17.53AB	15.36ABC
Calcium	10.68	21.39AB	22.93AB	30.36A	28.77A	17.28B	21.03AB	20.05	29.10A	22.54AB	21.08AB
Potassium	21.32	46.03C	56.05ABC	64.38ABC	73.25AB	45.93C	46.82C	53.40BC	70.52AB	66.81ABC	75.77A
Magnesium	6.61	16.93ABC	18.14ABC	22.78A	23.34A	13.23C	14.80BC	17.56ABC	19.99AB	18.91ABC	15.45BC
Sodium	0.24	0.48AB	0.53AB	0.53AB	0.53AB	0.39B	0.41AB	0.38B	0.65A	0.62AB	0.58AB

Sulfur	2.45	4.64BC	4.66BC	6.06ABC	7.13A	3.69C	4.20BC	4.93ABC	6.20AB	5.93ABC	5.71ABC
Iron	0.39	0.59ABC	0.65ABC	0.93AB	0.84ABC	0.47C	0.62ABC	0.55BC	0.96A	0.72ABC	0.77ABC
Zinc	0.09	0.13B	0.16AB	0.24A	0.20AB	0.12B	0.14B	0.19AB	0.17AB	0.19AB	0.19AB
Copper	0.02	0.05AB	0.05AB	0.06AB	0.07A	0.05AB	0.05AB	0.05AB	0.07A	0.06AB	0.05AB
Magnesium	0.41	0.79BC	0.90ABC	1.05AB	1.28A	0.63C	0.76BC	0.71BC	0.90ABC	0.66BC	0.73BC
Nickel	NA	NA	NA	0.007	0.011	0.002	0.001	0.006	0.002	0.001	0.002

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Composted Natural Litter, CAL-Composted Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§ Total Carbon and Nitrogen (LECO). Other nutrients total acid digestion.
¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.7: Results of Haskell Bermudagrass Nutrient Removal (kg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

Total Nitrogen§

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	30.1	107.73EF¶	139.07CD	150.65BCD	206.05A	92.47FG	122.44DEF	155.14BC	172.04B	123.42DE	154.31BC	76.84G
2008	28.2	112.69E	149.52BC	177.06AB	186.08A	79.49F	112.15E	117.65DE	143.42DC	132.79CDE	130.56CDE	69.22F
2009	22.8	79.32FG	113.75CD	139.32AB	160.94A	62.62GH	78.23FG	95.50DEF	131.31BC	90.26EF	106.73DE	45.90H
Total Removal (3 yr.)		299.7	402.3	467.0	553.1	234.6	312.8	368.3	446.8	346.5	391.6	192.0

Total Carbon

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1173.5	4288.9DE	5264.6CD	5240.6CD	6440.9AB	3595.8EF	4585.1DE	5792.4ABC	6532.2A	5342.6BCD	6109.8ABC	3059.0F
2008	729.3	3671.7CD	4553.7B	566.8A	5312.4A	2626.9E	3390.7D	4058.7BCD	4400.6BC	3882.8BCD	3955.6BCD	2201.5E
2009	504.3	2184.3FGH	3087.7CD	3683.3B	4197.8A	1694.3HI	2011.0GF	2584.2EDF	3452.8BC	2336.8EFG	2770.8DE	1239.1I
Total Removal (3 yr.)		10144.9	12906.0	9490.7	15951.1	7917.0	9986.8	12435.3	14385.6	11562.2	12836.2	6499.6

Phosphorous

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	6.19	19.14EF	24.48CDE	28.61ABC	33.42A	16.82FG	21.91DEF	30.46ABC	32.49A	25.84BCD	31.28AB	12.30G
2008	4.81	22.66DE	26.54CD	35.01A	32.65AB	15.39F	20.86E	24.41CDE	28.30BC	23.13DE	24.68CDE	12.01F
2009	5.75	10.86EFG	16.72CD	23.67AB	28.47A	9.67FG	11.66DEFG	14.18DEF	21.98BC	12.74DEFG	15.68DE	7.62G
Total Removal (3 yr.)		52.7	67.7	87.3	94.5	41.9	54.4	69.1	82.8	61.7	71.6	31.9

Calcium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	14.05	39.56CDE	50.99ABCD	51.16ABC	55.71AB	38.02DE	38.02DE	62.61A	57.78AB	45.64BCDE	53.56ABC	34.86E
2008	11.58	43.57CD	51.59ABC	61.97A	57.27AB	31.67EF	36.78DE	46.08BCD	51.25ABC	46.08BCD	42.05CDE	24.91F
2009	15.21	24.82DEF	45.62AB	40.48BC	57.22A	16.84EF	21.57DEF	32.30BCD	40.99BC	27.20CDEF	31.88BCDE	12.83F
Total Removal (3 yr.)		108.0	148.2	153.6	170.2	86.5	96.4	141.0	150.0	118.9	127.5	72.6

Potassium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	38.85	120.02FG	160.77E	170.10DE	212.70BC	108.43G	156.83EF	203.86BCD	253.04A	192.76CDE	240.20AB	83.96G
2008	32.39	133.14BC	150.18BC	215.20A	201.52A	88.30D	123.61C	140.81BC	165.33B	137.16BC	150.97BC	70.04D
2009	25.39	63.31BCD	82.32B	127.72A	132.59A	52.68CD	66.65BC	67.56BC	120.03A	64.87BC	86.83B	38.78D
Total Removal (3 yr.)		316.5	393.3	513.0	546.8	249.4	347.1	412.2	538.4	394.8	478.0	192.8

Magnesium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	10.46	31.62DEF	38.69ABCDE	35.58BCDE	41.88ABCD	28.89EF	33.33CDEF	45.58ABC	46.75A	34.76CDE	45.38AB	24.18F
2008	5.81	32.71CD	35.89BC	45.76A	40.11AB	21.92EF	27.29DE	31.76CD	33.96C	30.66CD	30.52CD	18.25F
2009	6.14	14.63DEF	23.60BC	25.55AB	30.42A	9.79FG	13.11EFG	18.21CDE	25.59BCD	14.61DEF	19.92BCD	7.94G

Total Removal (3 yr.)		79.0	98.2	106.9	112.4	60.6	73.7	95.6	106.3	80.0	95.8	50.4

<u>Sodium</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	2.86	4.55BC	4.1BCD	4.74BC	10.63A	2.62CD	4.04BCD	5.76B	5.66B	3.57BCD	4.79BC	1.57D
2008	2.99	8.86CD	11.39BC	13.96AB	15.28A	5.20E	7.51DE	9.40CD	13.29AB	9.01CD	9.08CD	4.84E
2009	3.74	3.51CD	4.90CD	3.25CD	9.73A	3.35CD	2.90CD	6.63ABC	5.63BD	8.67AB	5.03BCD	2.36D
Total Removal (3 yr.)		16.9	20.4	22.0	35.6	11.2	14.5	21.8	24.6	21.3	18.9	8.8

<u>Sulfur</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	4.6	17.38EF	19.34DE	19.73DE	26.09BC	16.27EF	22.01DC	27.86B	28.72B	27.86B	34.29A	13.16F
2008	5.22	20.32EF	20.82EDF	34.46A	27.09BC	15.94FG	21.63DE	24.09BCDE	29.55AB	22.02CDE	25.69BCD	11.89G

2009	5.02	10.66BCDE	14.71BC	22.65A	22.67A	9.13DE	10.83BCDE	13.24BCD	22.16A	9.91CDE	15.65B	6.76E
Total Removal (3 yr.)		48.4	54.9	76.8	75.9	41.3	54.5	65.2	80.4	59.8	75.6	31.8

Iron

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.01	2.03CD	2.84ABC	1.95CD	3.71A	2.08CD	2.43BCD	2.99ABC	3.17AB	2.34BCD	2.5BCD	1.55D
2008	0.94	1.55ABC	1.94ABC	2.24A	2.04AB	1.00BC	1.2BC	1.67ABC	1.81ABC	2.11AB	1.22ABC	1.00BC
2009	0.75	0.85BCD	2.06A	1.55AB	2.02A	0.54D	0.65D	0.73CD	1.42ABC	0.69D	0.87BCD	0.47D
Total Removal (3 yr.)		4.4	6.8	5.7	7.8	3.6	4.3	5.4	6.4	5.1	4.6	3.0

Zinc

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.08	0.24E	0.33D	0.34CD	0.44A	0.24E	0.32D	0.44AB	0.45A	0.37BCD	0.41ABC	0.18E
2008	0.11	0.29BC	0.28BCD	0.43A	0.33ABC	0.19DE	0.26CDE	0.29BCD	0.33ABC	0.27BCD	0.28BCD	0.16E

2009	0.13	0.15CD	0.22BCD	0.29AB	0.40A	0.11D	0.14CD	0.17BCD	0.25BC	0.14CD	0.18BCD	0.10D
Total Removal (3 yr.)		0.7	0.8	1.1	1.2	0.5	0.7	0.9	1.0	0.8	0.9	0.4

<u>Copper</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.02	0.07D	0.11BC	0.11BC	0.13ABC	0.07D	0.11C	0.14A	0.14A	0.13AB	0.13ABC	0.05D
2008	0.17	0.40CDE	0.64AB	0.68A	0.56ABC	0.25EF	0.36EDF	0.38EDF	0.48BCD	0.43CD	0.40CDE	0.22F
2009	0.03	0.056CD	0.08B	0.11A	0.09AB	0.04D	0.05CD	0.07BC	0.09A	0.05CD	0.07BC	0.04D
Total Removal (3 yr.)		0.5	0.8	0.9	0.8	0.4	0.5	0.6	0.7	0.6	0.6	0.3

<u>Manganese</u>

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.42	3.63CD	4.58BC	4.41BC	6.45A	2.34DE	3.39CDE	3.32CDE	4.04BC	3.76D	5.27AB	2.04E
2008	1.77	3.01BC	2.86BC	5.83A	5.34A	2.35C	2.77BC	4.49AB	3.20BC	2.54C	3.13BC	1.56C

2009	0.51	1.15D	1.23CD	2.25A	2.36A	0.87DE	1.08DE	1.69BC	1.97AB	0.97DE	1.90AB	0.64E
Total Removal (3 yr.)		7.8	8.7	12.5	14.2	5.6	7.2	9.5	9.2	7.3	10.3	4.2

Nickel

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.043	0.046C	0.052BC	0.063BC	0.091AB	0.057BC	0.061BC	0.081ABC	0.113A	0.042C	0.054BC	0.046BC
2008	0.004	0.006AB	0.004AB	0.008AB	0.007AB	0.005AB	0.003B	0.007AB	0.006AB	0.004AB	0.004AB	0.004AB
2009	0.180	0.12C	0.47A	0.31AB	0.23BC	0.18BC	0.18BC	0.31AB	0.16BC	0.28BC	0.25BC	0.15BC
Total Removal (3 yr.)		0.2	0.5	0.4	0.3	0.2	0.2	0.4	0.3	0.3	0.3	0.2

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL-Degraded Normal Litter, CAL-Degraded Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§ Total Carbon and Nitrogen (LECO). Other nutrients total acid digestion.
¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.8: Results of Haskell Sweet Sorghum Nutrient Removal (kg ha^{-1}) from 2007-2009 Treated with Commercial Fertilizer or Poultry Litter.

Total Nitrogen§

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	30.1	107.73EF¶	139.07CD	150.65BCD	206.05A	92.47FG	122.44DEF	155.14BC	172.04B	123.42DE	154.31BC	76.84G
2008	28.2	112.69E	149.52BC	177.06AB	186.08A	79.49F	112.15E	117.65DE	143.42DC	132.79CDE	130.56CDE	69.22F
2009	22.8	79.32FG	113.75CD	139.32AB	160.94A	62.62GH	78.23FG	95.50DEF	131.31BC	90.26EF	106.73DE	45.90H
Total Removal (3 yr.)		299.7	402.3	467.0	553.1	234.6	312.8	368.3	446.8	346.5	391.6	192.0

Total Carbon

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1173.5	4288.9DE	5264.6CD	5240.6CD	6440.9AB	3595.8EF	4585.1DE	5792.4ABC	6532.2A	5342.6BCD	6109.8ABC	3059.0F
2008	729.3	3671.7CD	4553.7B	566.8A	5312.4A	2626.9E	3390.7D	4058.7BCD	4400.6BC	3882.8BCD	3955.6BCD	2201.5E
2009	504.3	2184.3FGH	3087.7CD	3683.3B	4197.8A	1694.3HI	2011.0GF	2584.2EDF	3452.8BC	2336.8EFG	2770.8DE	1239.1I
Total Removal (3 yr.)		10144.9	12906.0	9490.7	15951.1	7917.0	9986.8	12435.3	14385.6	11562.2	12836.2	6499.6

Phosphorous

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	6.19	19.14EF	24.48CDE	28.61ABC	33.42A	16.82FG	21.91DEF	30.46ABC	32.49A	25.84BCD	31.28AB	12.30G
2008	4.81	22.66DE	26.54CD	35.01A	32.65AB	15.39F	20.86E	24.41CDE	28.30BC	23.13DE	24.68CDE	12.01F
2009	5.75	10.86EFG	16.72CD	23.67AB	28.47A	9.67FG	11.66DEFG	14.18DEF	21.98BC	12.74DEFG	15.68DE	7.62G
Total Removal (3 yr.)		52.7	67.7	87.3	94.5	41.9	54.4	69.1	82.8	61.7	71.6	31.9

Calcium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	14.05	39.56CDE	50.99ABCD	51.16ABC	55.71AB	38.02DE	38.02DE	62.61A	57.78AB	45.64BCDE	53.56ABC	34.86E
2008	11.58	43.57CD	51.59ABC	61.97A	57.27AB	31.67EF	36.78DE	46.08BCD	51.25ABC	46.08BCD	42.05CDE	24.91F
2009	15.21	24.82DEF	45.62AB	40.48BC	57.22A	16.84EF	21.57DEF	32.30BCD	40.99BC	27.20CDEF	31.88BCDE	12.83F
Total Removal (3 yr.)		108.0	148.2	153.6	170.2	86.5	96.4	141.0	150.0	118.9	127.5	72.6

Potassium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	38.85	120.02FG	160.77E	170.10DE	212.70BC	108.43G	156.83EF	203.86BCD	253.04A	192.76CDE	240.20AB	83.96G
2008	32.39	133.14BC	150.18BC	215.20A	201.52A	88.30D	123.61C	140.81BC	165.33B	137.16BC	150.97BC	70.04D
2009	25.39	63.31BCD	82.32B	127.72A	132.59A	52.68CD	66.65BC	67.56BC	120.03A	64.87BC	86.83B	38.78D
Total Removal (3 yr.)		316.5	393.3	513.0	546.8	249.4	347.1	412.2	538.4	394.8	478.0	192.8

Magnesium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	10.46	31.62DEF	38.69ABCDE	35.58BCDE	41.88ABCD	28.89EF	33.33CDEF	45.58ABC	46.75A	34.76CDE	45.38AB	24.18F
2008	5.81	32.71CD	35.89BC	45.76A	40.11AB	21.92EF	27.29DE	31.76CD	33.96C	30.66CD	30.52CD	18.25F
2009	6.14	14.63DEF	23.60BC	25.55AB	30.42A	9.79FG	13.11EFG	18.21CDE	25.59BCD	14.61DEF	19.92BCD	7.94G
Total Removal (3 yr.)		79.0	98.2	106.9	112.4	60.6	73.7	95.6	106.3	80.0	95.8	50.4

Sodium

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	2.86	4.55BC	4.1BCD	4.74BC	10.63A	2.62CD	4.04BCD	5.76B	5.66B	3.57BCD	4.79BC	1.57D
2008	2.99	8.86CD	11.39BC	13.96AB	15.28A	5.20E	7.51DE	9.40CD	13.29AB	9.01CD	9.08CD	4.84E
2009	3.74	3.51CD	4.90CD	3.25CD	9.73A	3.35CD	2.90CD	6.63ABC	5.63BD	8.67AB	5.03BCD	2.36D
Total Removal (3 yr.)		16.9	20.4	22.0	35.6	11.2	14.5	21.8	24.6	21.3	18.9	8.8

Sulfur

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	4.6	17.38EF	19.34DE	19.73DE	26.09BC	16.27EF	22.01DC	27.86B	28.72B	27.86B	34.29A	13.16F
2008	5.22	20.32EF	20.82EDF	34.46A	27.09BC	15.94FG	21.63DE	24.09BCDE	29.55AB	22.02CDE	25.69BCD	11.89G
2009	5.02	10.66BCDE	14.71BC	22.65A	22.67A	9.13DE	10.83BCDE	13.24BCD	22.16A	9.91CDE	15.65B	6.76E
Total Removal (3 yr.)		48.4	54.9	76.8	75.9	41.3	54.5	65.2	80.4	59.8	75.6	31.8

Iron

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.01	2.03CD	2.84ABC	1.95CD	3.71A	2.08CD	2.43BCD	2.99ABC	3.17AB	2.34BCD	2.5BCD	1.55D
2008	0.94	1.55ABC	1.94ABC	2.24A	2.04AB	1.00BC	1.2BC	1.67ABC	1.81ABC	2.11AB	1.22ABC	1.00BC
2009	0.75	0.85BCD	2.06A	1.55AB	2.02A	0.54D	0.65D	0.73CD	1.42ABC	0.69D	0.87BCD	0.47D
Total Removal (3yr.)		4.4	6.8	5.7	7.8	3.6	4.3	5.4	6.4	5.1	4.6	3.0

Zinc

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.08	0.24E	0.33D	0.34CD	0.44A	0.24E	0.32D	0.44AB	0.45A	0.37BCD	0.41ABC	0.18E
2008	0.11	0.29BC	0.28BCD	0.43A	0.33ABC	0.19DE	0.26CDE	0.29BCD	0.33ABC	0.27BCD	0.28BCD	0.16E
2009	0.13	0.15CD	0.22BCD	0.29AB	0.40A	0.11D	0.14CD	0.17BCD	0.25BC	0.14CD	0.18BCD	0.10D
Total Removal (3 yr.)		0.7	0.8	1.1	1.2	0.5	0.7	0.9	1.0	0.8	0.9	0.4

Copper

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.02	0.07D	0.11BC	0.11BC	0.13ABC	0.07D	0.11C	0.14A	0.14A	0.13AB	0.13ABC	0.05D
2008	0.17	0.40CDE	0.64AB	0.68A	0.56ABC	0.25EF	0.36EDF	0.38EDF	0.48BCD	0.43CD	0.40CDE	0.22F
2009	0.03	0.056CD	0.08B	0.11A	0.09AB	0.04D	0.05CD	0.07BC	0.09A	0.05CD	0.07BC	0.04D
Total Removal (3 yr.)		0.5	0.8	0.9	0.8	0.4	0.5	0.6	0.7	0.6	0.6	0.3

Manganese

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	1.42	3.63CD	4.58BC	4.41BC	6.45A	2.34DE	3.39CDE	3.32CDE	4.04BC	3.76D	5.27AB	2.04E
2008	1.77	3.01BC	2.86BC	5.83A	5.34A	2.35C	2.77BC	4.49AB	3.20BC	2.54C	3.13BC	1.56C
2009	0.51	1.15D	1.23CD	2.25A	2.36A	0.87DE	1.08DE	1.69BC	1.97AB	0.97DE	1.90AB	0.64E
Total Removal (3 yr.)		7.8	8.7	12.5	14.2	5.6	7.2	9.5	9.2	7.3	10.3	4.2

Nickel

	LSD Treatment Interaction	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
2007	0.043	0.046C	0.052BC	0.063BC	0.091AB	0.057BC	0.061BC	0.081ABC	0.113A	0.042C	0.054BC	0.046BC
2008	0.004	0.006AB	0.004AB	0.008AB	0.007AB	0.005AB	0.003B	0.007AB	0.006AB	0.004AB	0.004AB	0.004AB
2009	0.180	0.12C	0.47A	0.31AB	0.23BC	0.18BC	0.18BC	0.31AB	0.16BC	0.28BC	0.25BC	0.15BC
Total Removal (3 yr.)		0.2	0.5	0.4	0.3	0.2	0.2	0.4	0.3	0.3	0.3	0.2

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL- Degraded Normal Litter, CAL- Degraded Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§ Total Carbon and Nitrogen (LECO). Other nutrients total acid digestion.
¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

Table B.9: Results of 2007 Woods County Sweet Sorghum Biomass Nutrient Removal (kg ha^{-1}) Treated with Commercial Fertilizer or Poultry Litter.

	2007											
	LSD Between Treatments	CF†-A‡	CF-B	CF-C	CF-D	NL-A	NL-B	NL-C	NL-D	CNL	CAL	Control
Total Nitrogen§	35.76	52.28BC¶	53.45BC	86.07AB	94.06A	48.66C	47.84C	54.64BC	59.31ABC	50.14C	68.34ABC	45.84C
Total Carbon	838.89	2538.0CD	2964.7ABCD	3431.5AB	3643.4A	2204.7D	2524.6CD	2756.2BCD	3125.1ABC	3314.5ABC	3377.8AB	2207.0D
Phosphorous	6.63	13.04BC	13.49BC	18.29AB	20.33A	9.93C	12.57BC	15.12ABC	16.87AB	17.53AB	15.36ABC	12.57BC
Calcium	10.68	21.39AB	22.93AB	30.36A	28.77A	17.28B	21.03AB	20.05	29.10A	22.54AB	21.08AB	20.00AB
Potassium	21.32	46.03C	56.05ABC	64.38ABC	73.25AB	45.93C	46.82C	53.40BC	70.52AB	66.81ABC	75.77A	46.24C
Magnesium	6.61	16.93ABC	18.14ABC	22.78A	23.34A	13.23C	14.80BC	17.56ABC	19.99AB	18.91ABC	15.45BC	15.09BC
Sodium	0.24	0.48AB	0.53AB	0.53AB	0.53AB	0.39B	0.41AB	0.38B	0.65A	0.62AB	0.58AB	0.37B

Sulfur	2.45	4.64BC	4.66BC	6.06ABC	7.13A	3.69C	4.20BC	4.93ABC	6.20AB	5.93ABC	5.71ABC	4.03BC
Iron	0.39	0.59ABC	0.65ABC	0.93AB	0.84ABC	0.47C	0.62ABC	0.55BC	0.96A	0.72ABC	0.77ABC	0.59ABC
Zinc	0.09	0.13B	0.16AB	0.24A	0.20AB	0.12B	0.14B	0.19AB	0.17AB	0.19AB	0.19AB	0.15AB
Copper	0.02	0.05AB	0.05AB	0.06AB	0.07A	0.05AB	0.05AB	0.05AB	0.07A	0.06AB	0.05AB	0.04B
Magnesium	0.41	0.79BC	0.90ABC	1.05AB	1.28A	0.63C	0.76BC	0.71BC	0.90ABC	0.66BC	0.73BC	0.52C
Nickel	NA	NA	NA	0.007	0.011	0.002	0.001	0.006	0.002	0.001	0.002	0.001

†Treatments are CF-Commercial Fertilizer, NL-Natural Poultry Litter, CNL- Degraded Normal Litter, CAL- Degraded Alum-Treated Litter, and Control-no treatment.
‡Fertilizer rates applied on N-P_2O_5-K_2O basis as A=60-60-45, B=120-120-90, C=180-180-135 D=240-240-180 CNL and CAL applied on N basis alone to match rate C.
§ Total Carbon and Nitrogen (LECO). Other nutrients total acid digestion.
¶Means followed by the same upper case letters are not significantly different at the 0.05 alpha level among treatments.

VITA

Scott Thomas Fine

Candidate for the Degree of

Master of Science

Thesis: ECONOMICS AND IMPACT OF MANURE AND COMPOSTED MANURE ON SOIL QUALITY AND YIELD COMPARED TO CHEMICAL FERTILIZER AMONG POTENTIAL BIO-FUEL CROPS

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Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: ECONOMICS AND IMPACT OF POULTRY MANURE AND COMPOSTED MANURE ON SOIL QUALITY AND YIELD COMPARED TO CHEMICAL FERTILIZER AMONG POTENTIAL BIO-FUEL CROPS

Pages in Study: 307 Candidate for the Degree of Master of Science

Major Field: Plant and Soil Science

Scope and Method of Study: The objectives of this study were to determine if poultry litter applications at equal rates as inorganic commercial fertilizers to potential bio-fuel crops in Oklahoma result in differences in biomass yield and soil quality. Field experiments with bermudagrass (*Cynodon dactylon L*.) and sweet sorghum (*Sorghum bicolor (L.) Moench*) were established for 3 years in two different locations. Fresh litter was applied at 4 different rates with inorganic applied to match these rates on an N, P, and K basis. Additionally two degraded litters (alum treated and normal) were applied to match rate C's nitrogen (N) rate.

Findings and Conclusions: Poultry litter and commercial fertilizer application at equal rates produced relatively no difference in soil nutrient concentration applied at equal rates and positive increases in soil physical properties with litter application. Differences in overall biomass yields were present in most years; poultry litter plant available N should be taken into account. Degraded litters possessed higher economic value and alum treatment decreased environment risk of P transport.

ADVISER'S APPROVAL: Dr. Chad J. Penn